Approved VCS Methodology
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Sectoral Scope 14

Methodology for Coastal Wetland Creation

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1 SOURCES

This methodology was developed based on the requirements in the following documents:

- *VCS Standard, v3.3*
- *AFOLU Requirements, v3.3*
- *Program Definitions, v3.4*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Activity Method
Crediting Baseline	Project Method

This methodology quantifies the greenhouse gas benefits of wetland creation activities. The scope of this methodology includes two primary project activities – substrate establishment and vegetation establishment – typically implemented in combination in order to create new wetlands (ie, to restore wetlands that have degraded to open water.) The methodology also allows for implementation of either project activity individually.

The methodology also addresses the potential for the establishment of woody vegetation. As such, this methodology is categorized as a Restoring Wetland Ecosystems (RWE) + Afforestation, Reforestation and Revegetation (ARR) methodology.

This methodology is only applicable to projects located in the United States of America, as set out further in the applicability conditions.

2.1 Project Activities

Wetland creation projects must be designed such that the wetland, over time, will support the ecological processes and functions of a mature wetland habitat. If retention dikes are part of the design, natural degradation and manual breaches must be planned in order to allow for regular tidal exchange or hydrologic connectivity to the surrounding area. The created wetland must support wetland vegetation species capable of contributing to soil carbon accumulation.

The project proponent must include a plan for the establishment and maintenance of a permanent wetland plant community after project construction. The plan must provide evidence that the project area will meet the definition of a wetland upon completion of project activities (but a formal wetland delineation survey is not required). This plan may include natural colonization or manual planting or seeding of the project area. The plan also must demonstrate how the project will be maintained over the project crediting period. Maintenance requirements and activities will vary geographically due to different ecological and physical processes which may influence the project area (eg, elevation deficit vs. shoreline erosion).

Active maintenance may not be required if the created wetland is designed and constructed to offset local processes – including impaired hydrological connectivity – which may have led to the initial deterioration of the historic wetland. For instance, projects created in more protected areas may not be as susceptible to shoreline erosion forces. In addition, other non-related restoration projects near the project area may help alleviate historic issues such as nutrient and sediment source deficits. In Louisiana, for example, future planned diversions of Mississippi River water are designed to supply fresh water, nutrients, and sediment to surrounding wetlands and may influence and sustain the project area depending on proximity to and configuration with the diversion.

The project proponent must demonstrate that the project engineering and design takes into account local water level elevation, tidal range, geotechnical characteristics, sea level rise projections, and the range of plant growth within those constraints.

Monitoring Requirements: Project Activities
The monitoring report must include the following whenever substrate is established: **MRR.1** Plan for establishment of a permanent wetland plant community after project construction. Plan must include long-term monitoring of emergent vegetation and plans for continued maintenance should it become necessary. This documentation must demonstrate that the project activity results in the accumulation or maintenance of soil carbon stock and that, upon completion of the project activities, the project area must meet the definition of a wetland. **MRR.2** Evidence that the project engineering and design takes into account local water level elevation, tidal range, geotechnical characteristics, sea level rise projections, and the range of plant growth within those constraints.

2.1.1 Substrate Establishment

Wetland creation projects are formed with materials including, but not limited to, excavated or dredged sediments from waterways such as rivers, channels, canals, and embayments. Excavated sediments must be placed in open water areas to create tidal wetlands that support emergent plant establishment and growth.

The project activity of creating a wetland from open water first requires the project proponent to select a proper site location that is adjacent to a sediment source which contains a sufficient volume and is within the technical capabilities of delivering the required sediment to the project site to meet design criteria. It is common, but not required, to construct a temporary retention dike around the project area to contain the sediment material and allow for dewatering and compaction in the initial years after project construction. The temporary dike is typically constructed by machinery such as an excavator. Once complete, the project area is filled with sediment via hydraulic or mechanical dredge, pipelines, or other mechanical methods to the proper elevation as determined in the engineering and design documents based on water levels (current and projected), sediment characteristics and geotechnical analyses. The retention dikes may be designed to naturally subside to elevations which will allow for tidal exchange and hydrologic connectivity but may require manual breaches or removal after the project area sediment has consolidated to target levels.

The project proponent must provide documentation of the substrate establishment activities to demonstrate the expected post-construction conditions in the project area.

Monitoring Requirements: Substrate Establishment
The monitoring report must include the following whenever substrate is established: **MRR.3** Post-construction report, including an as-built drawing showing plan view and cross section of the project area along with an estimate of post-construction sediment elevation relative to a geodetic or tidal datum. **MRR.4** Aerial image of the project area within three years prior to construction and an aerial image within one year post-construction.

2.1.2 Vegetation Establishment

The project proponent may use natural colonization, seeding or transplantation to accomplish vegetation coverage. Depending on the time of year when the project construction is complete or the time required for substrate settlement, planting or seeding may need to occur at a future time. When seeding or transplantation occurs, the project proponent may provide a description or design drawing of post-planting or seeding, indicating the species, quantity, and photographs of the operation.

The project proponent must provide documentation of the vegetation establishment activities to demonstrate that the activities result in the accumulation or maintenance of soil carbon stock.

When the activity includes the establishment of woody vegetation, ARR+RWE requirements and methods apply to the project. Such ARR+RWE establishment activities must not include nitrogen fertilization, active peatland drainage, or lowering of the water table depth (eg, draining or construction of channels in order to harvest). Projects with an ARR+RWE component must not include commercial harvest of woody biomass; the extent of ARR requirements is limited to vegetation establishment with no management as reflected by applicability condition 6 in Section 4.

Monitoring Requirements: Vegetation Establishment
The monitoring report must include the following whenever vegetation is established: **MRR.5** A description of the quantity, species, date and location of vegetation establishment, and photographs of the operation. **MRR.6** Aerial image of the project area indicating where species were established.

2.2 Application Overview

If the project meets the applicability conditions of this methodology (see Section 4), the project proponent must follow five steps to ensure that the design of the project activities and monitoring methods meet the requirements of this methodology. Upon completion of the final step, emissions reductions and/or removals are quantified.

2.2.1 Step One: Define the Project

The first step is to identify the boundary of the project area in accordance with Section 5, following the current VCS requirements for RWE project activities. Selecting GHG sources may require an *ex-ante* analysis of expected emissions reductions and/or removals from project activities to determine *de minimis* sources (see Section 8.4.3). The project area is the location where project activities will be implemented, defined in Section 5.3.

2.2.2 Step Two: Characterize Baseline

In this step, the project proponent uses Section 6 to demonstrate that the project area would have remained as open water (see applicability condition 3) and whether dredging would have occurred in the baseline scenario. It is possible that dredging would not have occurred in the baseline scenario, which is allowed by this methodology. In the case where dredging would have occurred in the baseline scenario, emissions from energy consumption must be quantified (see Section 8.1.1).

2.2.3 Step Three: Plan Project and Monitoring Activities

Project activities must adhere to the requirements established in Section 2.1. Monitoring activities must be designed in accordance with Section 9 and are documented in a monitoring plan. Methods for monitoring are described in Appendices A, B, C, D and E. The use of any different methods must be justified by the project proponent as a methodology deviation, in accordance with the VCS rules.

The project proponent determines which sources are *de minimis*, if any, prior to validation (see Sections 8.4.3.1 and 8.4.3.2).

2.2.4 Step Four: Implement Project Activities

The project must be implemented in accordance with the validated project description. If the project is a grouped project, project activities may be implemented as separate project activity instances rather than as a single project activity instance (see Section 9.5).

2.2.5 Step Five: Monitor and Report

During and after the implementation of project activities, the project proponent must use the monitoring plan as the basis for determining emissions reductions and/or removals (see Section 9). For carbon stocks, all plots must be measured prior to the first verification event. The data from monitoring are used in Section 8.

For grouped projects, there are additional monitoring requirements (see Section 9.5). New project activity instances may require modifications to the monitoring plan.

2.3 Notation

The notation used in this methodology is meant to communicate the variables and mathematical processes used to quantify carbon stock, gas fluxes, and greenhouse gas emission reductions over time.

2.3.1 Equations

Equations in this methodology are bracketed (eg, [G.1] in-text) and the full equations are located in Appendix G. Equations in Appendix G contain additional information including citations, literature sources and comments.

At times, similar operations are performed in multiple places on different variables. Rather than repeating nearly identical equations, a single, generic equation with the placeholder x or y is given. To estimate each pool or GHG source, the relevant variable or equation may be substituted for x as indicated within the methodology.

2.3.2 Variables

Variables in this methodology and their units are enumerated in the list of variables in Appendix J. For most of these variables, their units are in tonnes of carbon dioxide equivalents. The variables x and y (with and without subscripts) are sometimes used as placeholder variables — they may stand in for another variable or the results of an equation as indicated by the methodology text.

2.3.2.1 Variable, Subscript and Superscript Designations

Some variables are noted with special designations that allow the reader to immediately identify important information about the variable. The absence of designations also implies information about the variable.

The types of designations are given in Table 1, with examples of the use of these designations given in Section 2.2.3.2. Designations are only provided for variables in Sections 8 and 9.

Table 1: Variable designations and designation descriptions

Designation	Description
Quantity	The type of quantity that the variable represents (see Sections 2.3.6, 2.3.9, 2.3.10, 2.3.11, 2.3.12 and 2.3.15).
Accounting Level	The type of accounting level implies that the variable is part of monitoring.
Change	If the Δ symbol is designated, then the quantity represents a change over a monitoring period rather than cumulative since the project start date. The absence of a change designation implies that the quantity is cumulative since the project start date or that the quantity is part of monitoring which may not be cumulative or over the monitoring period.
Source	The type of source is specified as an acronym in Section 3.1. The absence of source implies that the variable is part of monitoring or that the variable is from multiple sources.
Period	The reference to a monitoring period (see Section 2.3.7).
Index	The reference to a unit.

2.3.2.2 Designation Examples

Tables 2, 3, 4, 5 and 6 provide example variables with designations and designation descriptions.

Table 2: Example variables with designations and designation descriptions

$E_{B\,\Delta\,EC}^{[m]}$		
Component	Designation	Description
E	Quantity	This indicates an emission or an emission reduction and/or removal (see Section 2.3.14). Uppercase means the unit is a total for the project area.
B	Accounting Level	Indicates the emission or an emission reduction and/or removal occurred in the baseline scenario (see definition for P).
Δ	Change	The emission or emission reduction and/or removal is for a period of time.
EC	Source	The emission or emission reduction and/or removal is from energy consumption.
$[m]$	Period	This emission or emission reduction and/or removal is from the monitoring period.

Table 3: Example variables with designations and designation descriptions

$F_{P\,\Delta\,CH4}^{[m-1]}$		
Component	Designation	Description
F	Quantity	This indicates a flux (see Section 2.3.11). Uppercase means the unit is a total for the project area.
P	Accounting Level	Indicates the flux is as a result of the project.
Δ	Change	The flux is for a period of time.
$CH4$	Source	The flux is for methane.
$[m-1]$	Period	This flux is for the prior monitoring period.

Table 4: Example variables with designations and designation descriptions*

$E_{GER\,\Delta}^{[m=1]}$		
Component	Designation	Description
E	Quantity	This indicates an emission or an emission reduction and/or removal (see Section 2.3.14). Uppercase means the unit is a total for the project area.
GER	Accounting Level	The emission or an emission reduction and/or removal constitutes the Gross Emission Reductions (see definition for GERs).
Δ	Change	The emission or emission reduction and/or removal is for a period of time.
$[m=1]$	Period	The emission or emission reduction and/or removal is for the first monitoring period.

*Note that the absence of a P, B or L in the example given in Table 4 above indicates the emission or emission reduction and/or removal is not specific to the project, baseline or leakage.

Table 5: Example variables with designations and designation descriptions*

$E_{NER}^{[m]}$		
Component	Designation	Description
E	Quantity	This indicates an emission or emission reduction and/or removal (see Section 2.3.14). Uppercase means the unit is a total for the project area.
NER	Accounting Level	The emission or emission reduction and/or removal is constitutes the Net Emission Reductions (see definition for NERs).
$[m]$	Period	This emission or emission reduction and/or removal is for the monitoring period.

*Note that the absence of a P, B or L indicates the emission or emission reduction and/or removal is not specific to the project, baseline or leakage. The absence of a Δ indicates the emission or emission reduction and/or removal is not over a period of time, but rather cumulative since the project start date.

Table 6: Example variables with designations and designation descriptions*

$g_{B\,(ty)}^{[m]}$		
Component	Designation	Description
g	Quantity	This indicates a unit of energy (see Section 2.3.12). Lower-case means the unit is per metric tonne of sediment.
B	Accounting Level	Indicates the unit of energy would have resulted in the baseline (see definition for P)
(ty)	Index	The unit of energy is for type ty. The parentheses indicate that ty is an index rather than a designation (such as *P* for project scenario).
$[m]$	Period	This unit of energy is for the monitoring period.

*Note that the absence of a Δ indicates the unit of energy is not over a period of time, but rather cumulative since the project start date.

2.3.3 Summations

Summations use set notation. Sets of variables are indicated using script notation, which reduces the number of variables used as well as the complexity of summations.

2.3.4 Standard Deviations and Variances

Standard deviation is indicated by the σ symbol, with subscripts used to indicate the quantity for which it is estimated. Variance is indicated by the σ^2 symbol and is the square of standard deviation. Standard deviations may not necessarily be in units of tCO_2e.

2.3.5 Standard Errors

Estimated standard error is indicated by the U symbol, with additional subscripts used to indicate the quantity for which the uncertainty is estimated. Standard errors are always in units of tCO_2e.

2.3.6 Theoretical Parameters and Parameterized Models

Parameters to model are denoted by variables, such as the surface friction velocity parameter u_*. When such parameters have a "hat" on them – such as the parameter $\hat{p}_{B\ (ty)}$– they refer to an estimated value rather than a known quantity.

2.3.7 Monitoring Periods

Monitoring periods are notated using bracketed superscripts $[m]$. The first monitoring period is denoted by $[m = 1]$, the second monitoring period $[m = 2]$, and so forth. These superscripts should not be confused with references to equations numbers, as equation numbers are never in superscript. Also see the definition for monitoring period. A verification event is the reporting and verification of NERs claimed for a monitoring period. A monitoring period that is $[m = 0]$ denotes "prior to the project start date."

2.3.8 Baseline, Project and Leakage Estimates

Estimates related to baseline, project and leakage emissions reductions and/or removals and carbon stocks are specifically denoted with B, P and L in the subscripts of variables, respectively.

2.3.9 Averages for Stocks

Average carbon (measured in tCO_2e/ha) to which accounting is applied is denoted by a lower-case c, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $c_{P\ SOC}^{[m]}$ indicates the average carbon stock in soil organic carbon in the project area in monitoring period $[m]$. Subscripts from carbon pools are acronyms listed in Section 3.1.

2.3.10 Totals for Stocks

Total carbon (measured by tCO_2e) to which accounting is applied is denoted by a capital C, with subscripts to differentiate between carbon pools as indicated in the list of variables. Subscripts from carbon pools are acronyms listed in Section 3.1.

2.3.11 Fluxes for Methane and Nitrous Oxide

Fluxes are expressed in units of tCO_2e per day by the variable F with subscripts to differentiate between GHG sources as indicated in the list of variables. Fluxes always contain a Δ in the subscript when the flux emissions are over the monitoring period. For example, $F_{P\,\Delta\,CH4}^{[m]}$ indicates the methane flux in the project area in monitoring period $[m]$. Subscripts from GHG sources are acronyms listed in Section 3.1. Some equations in Appendices B and C use a lower-case f, signifying that the units are tCO_2e per acre per day. It is important to note that although the units for fluxes are in tCO_2e per day, this does not imply that monitored fluxes have a daily resolution. Monitoring may be periodic or seasonal, as per Section 9.2.2.4.1.

2.3.12 Units of Energy or Fuel

Energy or fuel consumption is expressed as a total or per different units as specified in Table 10, denoted by a capital G for a total and a lower-case g per unit (which may be metric tonne of sediment). For example, $G_{P\,\Delta\,FC\,(ty)}^{[m]}$ indicates the total project energy consumption for energy type (ty) during monitoring period $[m]$.

2.3.13 Masses of Sediment

Sediment transport is used to estimate energy consumption in Section 8.1.1, denoted over a monitoring period as a total with an uppercase M. For example, $M_{P\,\Delta}^{[m]}$ indicates the total sediment transport as a result of project activities during monitoring period $[m]$. Masses of sediment are always quantified as metric tonnes.

2.3.14 Emissions Reductions and/or Removals

Total emissions reductions and/or removals (measured as tCO_2e) from accounting are denoted by a capital E, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $E_{P\,\Delta}^{[m]}$ indicates the project emissions reductions and/or removals during monitoring period $[m]$. Subscripts from carbon pools and GHG sources are acronyms listed in Section 3.1.

Emissions are represented by negative E values, while emissions removals are represented by positive E values.

2.3.15 Quantified Uncertainties

Uncertainties in major carbon pools or fluxes are expressed as standard error of a total (measured by tCO_2e or tCO_2e/day, respectively) and are denoted using a capital letter U. For example, $U_{P\,\Delta\,CS}^{[m]}$ is used to indicate the uncertainty in estimated carbon stocks at monitoring period $[m]$. Because this methodology's gas flux measurement methods (described in Appendix B and Appendix C) are inherently conservative, no uncertainty is calculated for methane and nitrous oxide gas fluxes. Thus, uncertainties are calculated for carbon stock estimates only.

2.4 Documentation Requirements

2.4.1 Project Description Requirements

To ensure the project meets the requirements set out in the methodology, this methodology includes Project Description Requirements (PDRs). The project proponent must provide evidence and documentation for each PDR. PDRs are listed in each section of this methodology and in Appendix K.

Project proponents must note that in addition to the PDRs set out in this methodology, the project must adhere to all VCS rules when applying this methodology (ie, the PDRs cover all the requirements of the methodology, but they do not necessarily cover each and every VCS requirement relevant to the project).

2.4.2 Monitoring Report Requirements

To ensure the project's compliance with the methodology, this methodology includes Monitoring Report Requirements (MRRs). The project proponent must provide evidence and documentation for each MRR. MRRs are listed in each section of this methodology and in Appendix L.

2.5 Units versus Resolution of Emissions Reductions and/or Removals Accounting

The methodology accounts for emission reductions and/or removals using daily units in Section 8. Accounting is specified by day to facilitate intra-annual monitoring events and the verification of monitoring periods that may span more or less than exactly a single year.

Although emissions reductions and/or removals are calculated on a daily basis, they may not be measured or monitored on a daily basis. The requirements in Section 9 and in Appendices B, C, D and E specify that measurements are taken periodically throughout the monitoring period, and the duration or interval of those measurements does not need to be daily.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Accretion Depth
Vertical measurement of accumulated soil material from $t^{[m-1]}$ to $t^{[m]}$

Baseline Emissions
For any monitoring period, baseline emissions $E_{B\,\Delta}^{[m]}$ are a sum of estimated emissions over selected carbon pools during the time between two verification events

Baseline Reevaluation
Revision of the baseline scenario which occurs every 10 years

Buffer Release
A periodic release of buffer credits from the AFOLU pooled buffer account

Chamber Sampling Type
A type of temporal sample using static chambers that is either peak, seasonal, or monthly (see Section 9.2.2.4.1)

Coarse Root
A root greater than or equal to 2 mm in diameter

Covariate
A variable possibly predictive of the outcome under study. Synonymous with the term *proxy*, as defined in VCS document *Program Definitions*

de minimis
Considered a negligible source of emissions (<5% of total GHG benefit generated by the project) and therefore not accounted for (see Section 8.4.3)

Degraded Wetland
Area that previously met the definition of a wetland, but now no longer meets that definition due to disruptions in normal hydrological and ecological processes and linkages (ie, the wetland converted to open water, or similar degraded state, in response to impaired sediment supply, sea level rise, impaired water quality, or similar reason). A degraded wetland may include areas of open water.

Direct Measurement
A method used to quantify energy consumption by measuring the volume of fuel consumed (see Section 9.2.4.1)

Dredging
The removal or excavation of bottom sediments from an aquatic environment for the creation or maintenance of waterways

Ebullition
The sudden release to the atmosphere of bubbles of gas (usually methane) from submerged sediment

Eddy Covariance Sampling Type
A type of temporal sample using eddy covariance that is either peak periodic, peak cumulative, seasonal, or monthly (see Section 9.2.2.4.2)

Eddy Covariance
A micrometeorological technique to estimate flux of heat, water, atmospheric trace gases and pollutants that relies on turbulence to calculate fluxes

Energy Type
A type of energy listed in Table 10

Estuarine
A tidal water body or wetland with mixing of fresh and (ocean-derived) salt water, where salinity is greater than or equal to 0.5 ppt (parts per thousand) during the period of average annual low flow

Fixed Soil Sample Depth
At the time of project validation, a fixed depth for soil sampling of the original project soil is defined by the project proponent, which cannot exceed 100 cm. The only time when the fixed sample depth may be exceeded is when accretion depth is measured from $t^{[m-1]}$ to $t^{[m]}$. For any monitoring event, a total sample depth (for carbon stock) cannot exceed the pre-defined fixed soil sample depth and the accretion depth from the current and previous monitoring event.

Flux
A flow of gas into the atmosphere expressed as a rate of mass per unit time and area (accounted for in terms of tCO_2e/ac/day)

Gross GHG Emission Reductions and Removals (GERs)
Tonnes of carbon dioxide equivalent (tCO_2e) emissions that are reduced or removed from the atmosphere due to project activities, given as the difference between baseline and project emissions or emissions reductions and/or removals, minus emissions from leakage (see Sections 8.1, 8.2 and 8.3)

Herbaceous Marsh
Wetland that is periodically flooded and generally characterized by a growth of grasses, sedges, cattails and rushes

Hydrologically Connected Areas
Two or more areas which may share matter, energy, and organisms as a result of water movement

Monitoring Period
An interval of time following the project start date and designated for systematically verifying project claims of GHG emissions reductions and/or removals. Specifically, an interval of time from $t^{[m-1]}$ to $t^{[m]}$ where $t^{[m-1]} \geq 0$ (the project crediting period start date) and $t^{[m-1]} < t^{[m]}$. The length of the monitoring period is $t^{[m]} - t^{[m-1]}$ where m denotes the number of any single monitoring period and t the number of days after the project crediting period start date that is the end of the monitoring period. A monitoring period that is $[m = 0]$ denotes “prior to the project start date.”

Net GHG Emission Reductions and/or Removals (NERs)
Tonnes of carbon dioxide equivalent (tCO_2e) emissions that are reduced or removed from the atmosphere due to project activities, given as GERs adjusted for certain deductions and additions (see Sections 8.4.1, 8.4.2.1 and 8.4.2.3)

Non-Tree
Vegetation such as shrubs, grasses, sedges and other herbaceous plants which does not meet the definition of a tree

Open Water
Water with 90% of its area having a depth that does not support emergent vegetation, and no more than 10% sparse vegetation. Water with dense vegetation is not considered open water.

Original Project Soil
Soil resulting from the emplacement of sediments at the project start date

Permanent Plot
A plot with fixed area and location used to repeatedly measure change in carbon stocks over time

Programmatic Dredging Project
Routine, ongoing dredging often associated with maintaining navigability

Project Area
The geographic area controlled by the project proponent where project activities are implemented

Project Emissions or Emissions Reductions and/or Removals
Project emissions or emissions reductions and/or removals for any monitoring period $[m]$ as estimated by the events of accretion, flux and energy consumption

Project Performance
A comparison of ex-post credit generation to ex-ante estimates over time

Reference Area
An area delineated by the project proponent used to estimate emissions from methane ebullition in the baseline

Sampling Period
The period of months for static chamber or eddy covariance measurement of methane flux corresponding to a sample type (see Section 9.2.2.4.2)

Single Event Dredging Project
A dredging event associated with a discrete planned project

Soil
Unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants

Soil Organic Matter
The organic matter that may be found in soil, not including coarse roots

Substrate Establishment
Adding sediment to an area devoid of sediment, or to add sediment in an open water system to raise the land elevation such that emergent plants can colonize

Tree
A perennial plant containing secondary wood and that is at least three meters tall at maturity

Tidal
A water body or wetland exposed to vertical water level fluctuations corresponding to lunar-solar gravitational cycles. The area may have freshwater or saltwater characteristics (eg, freshwater riverine and lacustrine systems may experience tidal influence without ocean-derived salts).

Vegetation Establishment
The process of seeding or transplanting vegetation to the soil, or providing adequate conditions for natural plant colonization

Verification Event
The reporting and verification of NERs claimed for a monitoring period

Water Impoundment
A body of water created or stored by impoundment structures, such as dams, dikes and levees

Water Table
The surface where water pressure in the soil is equal to the atmospheric pressure

3.1 Acronyms

AG	Above ground
AGNT	Above ground non-tree
AGT	Above ground tree
ARR	Afforestation, reforestation, and revegetation
AS	Activity-shifting
B	Baseline scenario
BA	AFOLU pooled buffer account

BG	Below ground
BGNT	Below ground non-tree
BGT	Below ground tree
BR	Buffer release
CF	Carbon fraction
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CS	Carbon stock
CWA	Clean Water Act
EC	Energy consumption
GERs	Gross GHG Emissions Reductions and/or Removals
GHG	Greenhouse gas
GIS	Geographic Information System
GPS	Global Positioning System
L	Leakage
LQD	Liquid
ME	Market-effects
MRR	Monitoring Report Requirement
NERs	Net GHG Emission Reductions and/or Removals
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
N_2O	Nitrous oxide
P	Project scenario
PAI	Project Activity Instance
PAIA	Project Activity Instance Area
PD	Project Description
PDR	Project Description requirement
PM	Proxy method for energy consumption
SE	Standard error

SLD	Solid
SPC	Species
U	Uncertainty
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VCS	Verified Carbon Standard
VCUs	Verified Carbon Units
VVB	Validation/Verification Body
WR	Wetland restoration

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that create tidal or estuarine wetlands through substrate establishment and/or vegetation establishment.

This methodology is applicable under the following conditions:

1 Project activities must include activities intended to create new wetlands in coastal ecosystems through substrate establishment, vegetation establishment, or both.

2 Project activities must not actively lower the water table depth.

3 The project area must meet the definitions of tidal or estuarine, open water, and degraded wetland before project activities are implemented and would have remained open water in the absence of the project activities (see Section 6.1).

4 The project area must be entirely within tidal or estuarine areas within the coastal zone boundary,[1] and must meet the definition of Waters of the United States,[2] excluding the Great Lakes.[3]

[1] Areas within the coastal zone boundary, as defined by each state of the US. Refer to NOAA's Ocean and Coastal Resource websites or individual coastal zone management maps: http://coastalmanagement.noaa.gov/mystate/welcome.html and http://coastalmanagement.noaa.gov/mystate/docs/StateCZBoundaries.pdf.

[2] For definition of Waters of the United States, refer to: http://www.epa.gov/region6/6en/w/watersus.htm.

[3] Great Lakes: The geographic scope does not include portions of Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania and New York which are hydrologically connected to the Great Lakes.

6 When ARR+RWE project activities are implemented and include the establishment of woody vegetation, there must not be commercial harvest activities, nitrogen fertilization or active peatland drainage (see Section 2.1.2).

7 The project proponent must have obtained the necessary permits to demonstrate that the project will not have a significant negative impact on hydrologically connected areas (see Section 8.3.3). This applicability condition must be satisfied at validation or at the first verification event.

PD Requirements: Applicability Conditions
The project description must include the following: **PDR.1** For each applicability condition, credible evidence in the form of analysis, documentation or third-party reports to satisfy the condition.

5 PROJECT BOUNDARY

5.1 Selecting GHG Sources

The greenhouse gases included in, and excluded from, the project boundary are set out in Table 7 below.

Table 7: GHG sources

	Source	Gas	Included?	Justification/Explanation	Affected by Project?
Baseline	Dredging, transport and re-handling for navigability or maintenance	CO_2	Yes	Emitted by fuel combustion regardless of fuel type.	No
		CH_4	Yes		
		N_2O	Yes		
		Other	None		
	Methane ebullition	CO_2	No	Methane bubbling may occur in open water; the quantity thereof may be included and monitored if desired.	No
		CH_4	Optional		
		N_2O	No		
		Other	None		
Project	Dredging, transport and placement for project activities	CO_2	Yes	Emitted by fuel combustion regardless of fuel type.	Yes
		CH_4	Yes		
		N_2O	Yes		
		Other	None		
	Habitat regeneration	CO_2	Yes	Major pool considered.	Yes
		CH_4	Yes	Wetland creation may result in an increase in CH_4 emissions in comparison to the open water baseline scenario.	
		N_2O	Yes, if significant	Wetland creation may result in an increase in N_2O emissions in comparison to the open water baseline scenario.	
		Other	None		

PD Requirements: GHG Sources
The project description must include the following: **PDR.2** A list of the included and excluded GHG sources.

5.2 Selecting Carbon Pools

The carbon pools included in or excluded from the project boundary are shown in Table 8 below.

Table 8: Carbon pools

Pool	Included?	Relevant to:	Justification/Comments
Above ground tree biomass	Included	Project	Major carbon pool required by VCS *AFOLU Requirements*.
Above ground non tree biomass	Optional	Project	May be conservatively excluded.
Below ground biomass	Optional	Project	May be conservatively excluded, but recommended when applicable root-shoot ratios are available. Only applicable in forested or woody habitats, not herbaceous ones.
Litter	Excluded	-	Conservatively excluded.
Dead wood	Excluded	-	Conservatively excluded.
Soil organic carbon	Included	Project	Major carbon pool expected to increase due to project activities.
Wood products	Excluded	-	Conservatively excluded. Not expected to be a significant pool.

Optional pools may always be conservatively excluded. The baseline scenario allows for up to 10% vegetation cover (see definition of open water in Section 3), but it is conservative to exclude the CO_2 emissions that occur from the likely loss of wetlands, CH_4 emissions from ongoing biogeochemical activity in the remaining vegetation or methane ebullition that would be expected to occur in the baseline scenario. The set of selected carbon pools is denoted by C.

PD Requirements: Carbon Pools
The project description must include the following: **PDR.3** A list of the selected and excluded carbon pools.

5.2.1 Allochthonous Carbon in Soil Organic Carbon Pool

Autochthonous carbon sequestration, resulting from the growth of vegetation in the project area, must be estimated separately from allochthonous carbon, where there is reasonable evidence that the mass of carbon that is imported to the site exceeds that which is exported. The fate of transported organic matter must be conservatively assessed, where relevant. The opposite condition also may exist, where the mass of exported carbon from the growth of vegetation as a result of project activities is greater than the mass of carbon that would be washed out to sea under baseline conditions.

5.2.1.1 Criteria for Projects Located Within Louisiana

For projects located within Louisiana, and not within the direct influence of a river diversion or river mouth, project proponents are not required to account for allochthonous carbon import because such import has been demonstrated to be negligible (see Appendix I).

Where river diversions are implemented to enhance growth and maintenance of created wetlands, and where such river diversions are designed to import substantial quantities of mineral-associated carbon, the project proponent must justify the exclusion of allochthonous carbon using the criteria listed in Section 5.2.1.2, or must quantify the carbon import per the procedures described in Section 9.2.6.

Where there exists an artificial water impoundment which affects the hydrological regime of the project area, the project proponent must justify the exclusion of allochthonous carbon using the criteria listed in Section 5.2.1.2, or must quantify the carbon import per the procedures described in Section 9.2.6.

5.2.1.2 Criteria for Projects Located Outside Louisiana

For projects located outside Louisiana, the project proponent may conservatively exclude allochthonous carbon by using publicly available regional case studies, peer-reviewed literature or regional models to justify that the import of organic matter will not cause carbon accretion estimates to be significantly overestimated. The justification and evidence must be commensurate with the justification provided in Appendix I for projects located within Louisiana. The justification must include the following evidence which must be applicable to the geomorphology of the project area:

- Description of the dominant sources of sediments with respect to external (ie, fluvial) inputs or internal (within estuary or tidal freshwater wetland) recycling.
- Proximity of the project area with respect to direct fluvial inputs or near-shore sediment sources.
- An annual mass estimate of the total carbon imported or exported from the estuary or tidal freshwater wetland where the project area is located.
- Description of the project area/region with respect to tidal energy (such as flood- or ebb-dominated) or tidal dispersive flux. Under ebb-dominated conditions, ‘outwelling’ or transfer of carbon from the tidal wetland to the ocean would be reasonably expected.

If the project proponent cannot demonstrate that allochthonous carbon sedimentation in the project area can be conservatively excluded, monitoring of allochthonous carbon must follow the methods in Section 9.2.6, where marker horizons are used to differentiate between carbon accreted in the project area as a result of project activities and allochthonous carbon imported into the project area.

PD Requirements: Allochthonous Carbon in Soil Organic Carbon Pool
For projects located outside Louisiana, the project description must include the following in order to demonstrate that allochthonous carbon import can be conservatively ignored: **PDR.4** Narrative justification that the import of organic matter will not cause carbon accretion estimates to be significantly overestimated including citations to case studies, literature or models. **PDR.5** Description of the dominant sources of sediments with respect to external (ie, fluvial) inputs or internal (within estuary or tidal freshwater wetland) recycling. **PDR.6** Proximity of the project area with respect to direct fluvial inputs or near-shore sediment sources. **PDR.7** An annual mass estimate of the total carbon imported or exported from the estuary or tidal freshwater wetland where the project is located. **PDR.8** Description of the project area with respect to tidal energy (such as flood- or ebb-dominated) or tidal dispersive flux.

5.3 Delineating Spatial Boundaries of Project Area

The spatial boundaries of the project must be delineated using GIS techniques. The project area may consist of multiple project activity instances. That is, the project area need not be spatially contiguous and may comprise one parcel or multiple adjacent or non-adjacent parcels. The project proponent must demonstrate control of the project area as described in the most recent version of the VCS *AFOLU Requirements*.

At the project start date, the entire project area must meet the definition of open water (see Section 3 for definition). The project proponent also must demonstrate that the project area meets the definition of tidal or estuarine open water wetlands which once supported emergent wetland vegetation – such as freshwater or saltwater herbaceous marsh, scrub-shrub or forest (eg, mangrove, cypress-tupelo swamp) – but which are degraded (prior to the implementation of project activities) to a flooded or subtidal condition. In order to demonstrate that the project area is located in a tidal or estuarine system, the project proponent must provide one of the following:

- Federal or state agency supporting documentation describing the project's tidal or salinity designation. For example, the National Wetland Inventory *Wetlands Mapper* provides both tidal and salinity descriptors or modifiers for the coastal areas of the United States, or

- Peer-reviewed literature showing the proximity of the project area to study areas and the evidence of tidal influence or presence of salinity greater than 0.5 ppt (parts per thousand), or
- The location of the tide gage adjacent to the project area and data which show either a discernible diurnal, semi-diurnal or mixed-tide signal; salinity greater than 0.5 ppt (parts per thousand) during the year; or evidence of a tidal datum designation (MLLW, MSL, MHHW, etc.).

Further, the project proponent must demonstrate compliance with the most current version of the VCS *AFOLU Requirements* regarding the clearing of native ecosystems.

Additionally, the project proponent must assess the hydrological connectivity of the project area to surrounding areas using the procedures described in Section 8.3.1 and demonstrate that there are no negative impacts to hydrologically connected areas and that any adjacent hydrologically connected areas are not likely to affect the GHG emissions of the project area.

Sea level rise may affect the project area by converting wetlands into shallow open water if the rate of sea level rise exceeds the rate of soil elevation gain. Because the project boundaries are fixed throughout the lifetime of the project, any lateral movement of wetlands in the project area caused by sea level rise is inherently captured by monitoring activities (see Section 9). However, given the significant potential impact of sea level rise on constructed wetlands in the coastal zone, the proponent must demonstrate that the project's spatial boundaries and wetland establishment activities have taken into account projections of future sea level rise. In particular, the project proponent must review current technical scientific literature relevant to the area (considering sources such as the most recent IPCC assessment report and peer-reviewed literature), document expected sea level rise in the vicinity of the project area, and demonstrate that wetland construction activities have been designed to withstand expected sea level rise.

In addition, the project description must include the following:

- A description of the existing natural or constructed measures for ensuring resilience to sea level rise (eg, how existing landforms or constructed features offer physical protection of the project area).
- A description of the post-construction soil surface elevation relative to mean sea level, taking into account estimated accretion, subsidence and sea level rise parameters within the project area.

After project activities commence, it is possible that one or more tidal channels will develop within the project area. Such areas must remain part of the project area and must not be excluded.

PD Requirements: Delineating Spatial Boundaries	
The project description must include the following:	
PDR.9	GIS-based maps of the project area with, at a minimum, the features listed in Section 5.3 above.
PDR.10	Documentation that the entire project area is/was open water at the project start date.
PDR.11	Evidence that the project area meets the definition of tidal or estuarine open water wetlands which once supported emergent wetland vegetation.
PDR.12	Evidence that the project area is compliant with the most current version of the VCS *AFOLU Requirements* regarding the clearing of native ecosystems.
PDR.13	If methane emissions are included in the baseline scenario, an estimate of the average water depth in the project area prior to the implementation of project activities (see Section 6.3).
PDR.14	Documentation that the project proponent has control over the project area, in accordance with the most recent version of the VCS *AFOLU Requirements*.
PDR.15	Documentation of the assessment of effects to hydrologically connected areas as further described in Section 8.3.1.
PDR.16	Documentation of projected sea level rise in the vicinity of the project area, evidence that existing landforms or constructed features are expected to withstand project sea level rise, and a description of the post-construction soil surface elevation relative to mean sea level.

5.4 Defining Temporal Project Boundaries

Temporal project boundaries define the period of time when the project area was under the control of the project proponent and are used to determine the dates at which project activities, monitoring activities, and baseline reevaluation must occur. The following temporal project boundaries must be defined:

- The project start date.
- The length of the project crediting period.
- The dates and periodicity of baseline reevaluation and monitoring periods. A baseline reevaluation after the project start date and monitoring must conform to the VCS rules.

Within six months of the project crediting period start date and prior to the first verification event, the monitoring equipment must be installed per Sections 9.2.1.1 and 9.2.2.4. Upon the project start date, records of energy consumption must be maintained per the requirements of Section 9.2.4.

For the project duration, the project proponent must reevaluate the baseline in accordance with the VCS rules (see Section 6.4).

The project proponent must document the planned duration of monitoring periods and corresponding frequency of verification events.

PD Requirements: Temporal Project Boundaries
The project description must include the following: **PDR.17** The project start date. **PDR.18** The project crediting period start date and length. **PDR.19** The date by which mandatory baseline reassessment must occur after the project start date. **PDR.20** A timeline including the first anticipated monitoring period showing when project activities will be implemented. **PDR.21** A timeline for anticipated subsequent monitoring periods.

Monitoring Requirements: Temporal Project Boundaries
The monitoring report must include the following: **MRR.7** The project start date. **MRR.8** The project crediting period start date and length. **MRR.9** Evidence of the start of monitoring per the frequency requirements described in Sections 5.4, 9.2.1.1, 9.2.2.4, and 9.2.3.4.

5.5 Grouped Projects

In addition to the requirements for grouped projects set out in the *VCS Standard*, the project proponent must establish criteria at the time of project validation that include the following:

- Landscape configuration: All project activity instances must be similar with respect to biogeochemical processes, which are affected principally by such factors as vegetation type, salinity, and presence or absence of external nitrate loading.
- Monitoring methods: In order to facilitate the consistent accounting of all project activity instances within a single project, all project activity instances must employ the same methods to monitor emissions reductions and removals (eg, direct measurement, models from literature, or proxy model) for each included GHG source. Similarly, all project activity instances must employ the same modeling assumptions and sampling protocols for the selected monitoring methods.

Additional monitoring requirements must also be followed for grouped projects, per Section 9.5.

The set of all project activity instances is denoted by $\mathcal{G}$.

PD Requirements: Grouped Projects
If grouped projects are developed, the project description must include the following, as per the requirements set out in the *VCS Standard*: **PDR.22** A list and descriptions of all enrolled project activity instances in the group at the time of validation. **PDR.23** A map of the designated geographic area within which all project activity instances in the group may be located, indicating that all instances are in the same region. **PDR.24** A list of eligibility criteria for project activity instances.

Monitoring Requirements: Grouped Projects
If grouped projects are developed, the monitoring report must include the following, as per the requirements set out in the *VCS Standard*: **MRR.10** A list and description of all project activity instances in the project. **MRR.11** A map of the boundaries of all project activity instances in the project demonstrating that all instances are in the designated geographic region.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

6.1 Demonstrating the Most Plausible Baseline Scenario

The project proponent must consider a range of alternative land uses when determining the baseline scenario for both RWE and ARR+RWE projects. Possible baseline scenarios may include a continuation of open water, additional wetland loss in accordance with long-term trends, natural reestablishment of the wetland or alternative wetland reestablishment activities not associated with carbon finance. The project description must include a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives.

As per the applicability conditions, this methodology is only applicable where the following baseline scenario is identified:

> The project area must meet the definitions of tidal or estuarine, open water, and degraded wetland before project activities are implemented and would have remained open water in the absence of the project activities.

The project proponent must use one of the analysis methods described in Section 6.1.1 or 6.1.2 to demonstrate the baseline scenario.

To demonstrate that this applicability condition has been met, it is recommended that the project proponent acquire data from USGS data sets (ie, Couvillion 2012) or the U.S. Fish & Wildlife Service's National Wetlands Inventory to show that the project area historically met the definition of a wetland and thus the definition of degraded wetland. If the applicability condition is met as required under the methodology, the only possible baseline scenario is open water. To support the chosen analysis method, the project proponent also must provide evidence of long-term water level changes in the project area with minimum record length of 20 years of hydrological data (eg, water table, water level, sea level). The evidence must demonstrate the long-term nature of the documented pattern of wetland loss.

The project proponent must also demonstrate that wetland creation is unlikely to occur in the project area based upon historical evidence of land accretion and loss.

PD Requirements: Baseline Scenario
The project description must include the following: **PDR.25** Results of a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives, and justification for the most plausible baseline scenario. **PDR.26** Documentation to demonstrate that the project area previously met the definition of a wetland before converting to open water. Documentation must include hydrological data to show evidence of long-term patterns of wetland loss. **PDR.27** The selected method for demonstrating the baseline scenario in the project area (regional land use change or spatial analysis).

6.1.1 Using a Published Regional Land Use Change Analysis

The baseline scenario may be demonstrated through documentation regarding land loss rates in the hydrologic basin in which the project area is located. Documentation must be based on Landsat or other satellite or aerial imagery that shows a trend of continued land loss or static condition in the basin for a period of at least 10 years prior to the project start date or the date of baseline reevaluation (see Section 6.4). Examples include the US Geologic Survey publication 'Land Area Change in Coastal Louisiana from 1932 to 2010', or the US Fish & Wildlife Service, National Wetlands Inventory, 'Wetlands Status and Trends' report series. The documentation must be from peer-reviewed literature, government publication or third party publication and must be publicly available.

The project proponent must also identify the boundary of the project area and its proximity to any existing and/or future water management activities (eg, river diversions) which could influence the project area. If water management activities are identified (either existing or planned over the next 10 years), the project proponent must address the potential for land-building based on significant deposition of sediment in the project area in the absence of project activities. An updated figure of water management activities must also be identified in the baseline reassessment.

PD Requirements: Regional Land Use Change for Baseline Scenario
The project description must include the following: **PDR.28** A reference to the document providing evidence of continued land loss or static condition in the basin for a period of 10 years prior to the project start date. **PDR.29** A summary of the referenced document indicating where in the document the evidence is provided. **PDR.30** Documentation of water management activities (eg, river diversions) that could influence the baseline scenario.

6.1.2 Conducting a Spatial Analysis

The baseline scenario may be demonstrated using high-resolution satellite or aerial imagery that demonstrates that the area of open water (ie, non-wetland) has not decreased over time in the region surrounding the project area. Sections 6.1.2.1 and 6.1.2.2 provide guidance on conducting the analysis. For such analysis, the following requirements must be met:

- The analysis must be conducted using data from two points in time (image dates) at least ten years apart, one of which is within two years prior to the project start date or date of baseline reevaluation (see Section 6.4).
- The two image dates must be within the same three-month period of their respective years to prevent seasonal variability.
- The study region must be at least three times the size of the project area.
- The study region must be located in an area near the project area, with similar climatic and edaphic conditions.
- Cloud cover must not exceed 20% of the study region for either image date.
- Accuracy determined by error checking or ground-truthing must be at least 90%.
- The analysis must infer that the area of open water in the study region has not decreased over time via natural processes.

The region of analysis may or may not include the project area.

PD Requirements: Spatial Analysis for Baseline Scenario	
The project description must include the following:	
PDR.31	A report describing how the analysis was conducted, including data sources and dates, demonstration of conformance with the requirements listed in Section 6.1.2, and justification for the selection of the region in which the analysis was conducted.
PDR.32	A map of the region in which the analysis was conducted.
PDR.33	The quantified change in water area.

6.1.2.1 Selecting Image Type

Aerial or satellite imagery must be high-resolution or multispectral in order to accurately delineate wetland vs. open water. Multiple images from each image date may be used to increase cloud-free coverage of the study region. The analysis must consider varying water levels on land areas at the time of the imagery, and the potential impact on interpretation of imagery. Proper pre-processing techniques must be observed, such as geometric and radiometric corrections, cloud and shadow removal and reduction of haze, as needed.

6.1.2.2 Classifying and Post-Processing

Change detection analysis may be used to determine the change in water area over time. Post-processing must include error checking and ground-truthing as needed to ensure accurate land cover assessment. For further information, see the detailed maps included with the US Geologic Survey publication ‘Land Area Change in Coastal Louisiana from 1932 to 2010,’ as well as Klemas (2011) for a detailed description regarding remote sensing techniques to monitor changes in wetlands.

6.2 Determining Dredging in Baseline Scenario

In the baseline scenario, dredging may or may not occur for navigation or maintenance purposes. Dredging may include hydraulic and mechanical machinery and the methods of sediment removal and disposal may be classified as permanent or temporary (see dredging activities described in Table 9). If dredging is included in the baseline scenario, this must be clearly identified in the project description.

In large rivers or near-shore coastal environments, navigation dredging may include a combination of temporary displacement (thalweg or current disposal) and temporary open water disposal that occurs within the banks of the river or within an embayment. In the case of temporary displacement/disposal, sediments may be re-handled multiple times before permanent removal occurs. The project proponent may account for sediment re-handling. Permanent sediment removal also may occur with dredging, transportation, and disposal at open water sites or confined disposal areas (facilities).

For the baseline scenario, the process of dredging must be described based on a single event (planned project) or routine programmatic dredging. The baseline dredging must contain a description of equipment types, method of dredging/transport/disposal/re-handling, sediment volume, and energy type and energy quantity used. The documentation of dredging activities also must include a description of the likely fate of dredged sediments in the baseline, thus indicating that the sediments would not be used for wetland creation activities in the baseline scenario.

Acceptable documents for describing single event dredging projects or programmatic dredging projects may include but are not limited to a Section 10 permit (River and Harbors Act 1899), Dredge Material Management Plan (USACE) and interagency project documents that provide descriptions or authorization for project-specific or routine operations (eg, Beneficial Use of Dredge Material, BUDMAT).

Table 9: Types of dredging activities and alternative sediment fates (permanent or temporary)

	Sediment Fate	Typical Equipment	Description
Baseline	Temporary displacement	Dustpan dredge; cutterhead suction dredge; mechanical excavator	Sediments are dredged and displaced in the river/nearshore current, subject to subsequent downstream removal from the waterway. The process of temporary sediment displacement is also described as *agitation* or *thalweg disposal*.
	Temporary removal and disposal	Hopper dredge; barge; mechanical excavator	Sediments are dredged, then transported in a confined vessel and disposed of in a temporary area, subject to subsequent downstream removal from the waterway.
	Permanent disposal	Cutterhead suction dredge; hopper dredge; mechanical excavator	Permanent sediment disposal may include confined upland disposal, non-wetland beneficial use, ocean dredge material dump site.

PD Requirements: Determination of Dredging
The project description must include the following: **PDR.34** Statement regarding whether dredging is included in the baseline scenario. **PDR.35** If dredging is included in the baseline scenario, a description of the single event or programmatic dredging projects, including the likely fate of dredged sediments in the baseline scenario.

6.2.1 Determining Navigability of Dredge Site Waterway

The project proponent must demonstrate whether navigation or maintenance dredging would have occurred in the baseline. Acceptable documents for demonstrating dredging would have occurred may include but are not limited to a Section 10 permit (River and Harbors Act 1899) or Dredge Material Management Plan (USACE) or interagency project documents that provide descriptions or authorization for project-specific or routine operations (eg, Beneficial Use of Dredge Material, BUDMAT).

If navigation or maintenance dredging in the baseline cannot be demonstrated, then baseline emissions from energy consumption must be zero per Section 8.1.1.

PD Requirements: Demonstration of Navigability
The project description must include the following if navigation or maintenance dredging can be demonstrated in the baseline scenario: **PDR.36** Map of dredging activities, including justification for planned dredging locations. **PDR.37** Documents that demonstrate dredging would have occurred.

6.2.2 Determining Energy Consumption for Dredging

When dredging occurs in the baseline scenario for navigation or maintenance, the project proponent must estimate the energy types and quantities used for dredging. For each energy type in Table 10, the project proponent must estimate the unit of energy consumed per metric tonne of sediment removed from the sediment source in the baseline scenario. These estimates must be based on private industry or federal cost-engineering procedures or data. These estimates may include energy consumption from dredging, transport, disposal and re-handling of sediment. The assumptions of equipment type(s), sediment production rates, duration of operations, and conveyance distances must be used to justify these estimates.

The project proponent must use conservative assumptions when determining these estimates. In the baseline scenario, low estimates of energy consumption for dredging are more conservative than high estimates.

The set of all energy types in the baseline scenario is denoted $\mathcal{T}_{B\ EC}$ and the unit of energy consumed per metric tonne of sediment removed from the sediment source for energy type (ty) is denoted by $g_{B\ EC\ (ty)}$ (see Section 8.1.1).

PD Requirements: Determination of Baseline Energy Consumption
The project description must include the following: **PDR.38** For each energy type in Table 10, the estimate of the unit of energy consumed per metric tonne of sediment dredged. **PDR.39** Description of equipment types and method or process of sediment dredging, transport, disposal, re-handling, sediment production rates, duration of operations and conveyance distances. **PDR.40** Estimates of cumulative sediment quantity excavated and re-handled, including temporary disposal and displacement activities, if applicable. **PDR.41** Source of procedures or data on which these estimates are based.

6.3 Determining Methane Emissions in Baseline Scenario

Methane ebullition, or bubbling from sediments, sometimes occurs in open water and may increase the GHG emissions associated with the baseline scenario in which the project area remains open water. It is optional to include emissions from methane ebullition in the baseline scenario. If baseline emissions from methane ebullition are included, the project proponent must monitor such emissions in an area of open water – referred to as a reference area – located near the project area and with environmental conditions similar to those found in the project area prior to the start of wetland creation activities (see Section 6.3.1). Methane emissions must then be monitored in the reference area (see Section 9.2.7).

6.3.1 Delineating Reference Area Boundaries

If emissions from methane ebullition are included in the baseline scenario, the project proponent must define a reference area in which emissions flux from ebullition is measured and demonstrate that the reference area is similar to the project area with respect to the following criteria:

a. Hydrologically and biogeochemically similar to the project area:
    i. Must meet the definition of open water, with no soil exposed during normal tidal cycle,

ii. Must be devoid or mostly devoid of vegetation,

iii. Must exhibit similar salinity and presence or absence of tidal influence, and

iv. Must be similar with respect to presence or absence of external nitrate loading (see Section 9.2.3.1).

b. Similar landscape configuration with respect to proximity to river delta(s), specifically if the project area is not within a delta, the reference area must not be located within a delta.

c. Soil type of similar substrate to the project area as of the project start date, specifically the soils must be classified as the same *Soil Series* as reported by the USDA NRCS Soil Survey; or if the *Soil Series* is different, then the percent organic matter of the upper 30cm of soil must occur within a common range.

d. Constrained to a minimum water depth no less than the minimum depth in the project area.

Furthermore, water depth must be recorded at each sample point. The average depth of these measurements must be at least as deep as the average depth measured in the project area as of the project start date.

Measurements in the reference area are described in Section 9.2.7.

PD Requirements: Determination of Baseline Methane Emissions
The project description must include the following: **PDR.42** Description and justification for the selected reference area.

6.4 Reevaluating the Baseline Scenario

The baseline scenario must be reevaluated every ten years in accordance with the VCS rules. The baseline reevaluation must meet the requirements in Section 6.1. If new project activity instances have been added in the case of a grouped project, the reevaluation must meet the requirements in Section 6.2.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality. Project activities that meet the applicability conditions of this methodology (see Section 4) and demonstrate regulatory surplus are deemed as additional.

7.1 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 *VCS Standard*.

PD Requirements: Demonstration of Project Additionality
The project description must include the following: **PDR.43** Demonstration that pertinent laws and regulations have been reviewed and that none mandate the project activities.

7.2 Positive List

The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed as complying with the positive list.

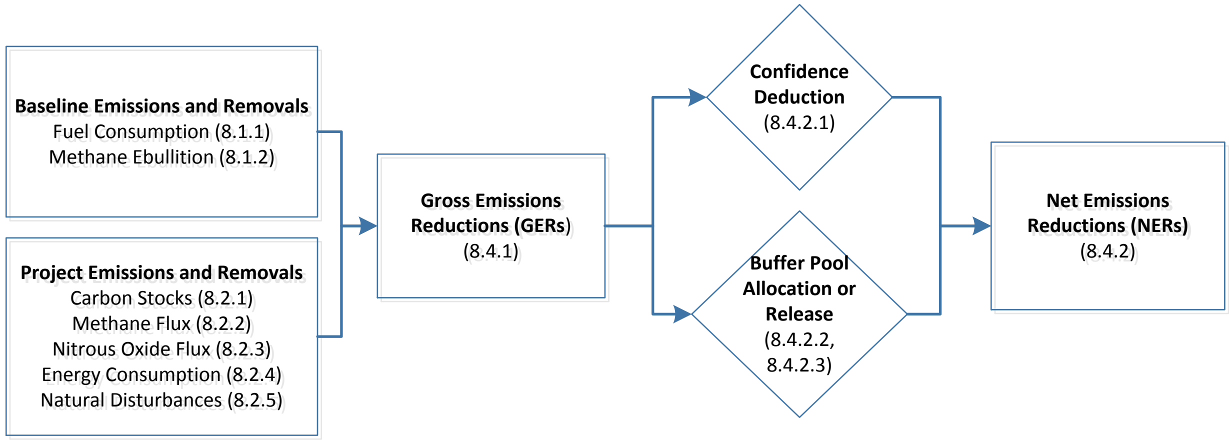
The positive list was established using the activity penetration option (Option A in the *VCS Standard*). Demonstration of additionality following this approach is set out in Appendix H – Supporting Information on Development of Positive List.

PD Requirements: Demonstration of Project Additionality
The project description must include the following: **PDR.44** Evidence that project activities comply with all applicability conditions set out under Section 4 above.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

The project proponent must calculate gross emissions reductions and/or removals (GERs) in each monitoring period. GERs are calculated by subtracting project emissions or emissions reductions and/or removals from baseline emissions. The project proponent must then calculate net emissions reductions and/or removals (NERs) by taking into account a confidence deduction (if any) and buffer pool allocation.

Cumulative GERs and NERs are quantified as those since the project crediting period start date up to the end of the monitoring period. Current GERs and NERs are quantified as those since the end of the previous monitoring period to the end of the monitoring period.



When quantifying GHG emissions reductions and removals, the project proponent must note the difference between units and resolution of monitoring data described in Section 2.5.

8.1 Baseline Emissions

Baseline emissions $E_{B\,\Delta}^{[m]}$ for the monitoring period are given by equation [G.6], equal to the sum of baseline emissions from energy consumption and emissions from methane ebullition for the monitoring period. Note that $E_{B\,\Delta}^{[m]}$ is always less than or equal to zero.

Monitoring Requirements: Baseline Emissions	
The monitoring report must include the following:	
MRR.12	Calculations of current baseline emissions $E_{\mathrm{B}\,\Delta}^{[m]}$ for the (current) monitoring period.
MRR.13	Calculations of baseline emissions $E_{\mathrm{B}\,\Delta}^{[m-1]}$ for prior monitoring periods.

8.1.1 Calculating Emissions from Energy Consumption

Baseline emissions from energy consumption are given by equation [G.3] where $g_{B\,(ty)}^{[m]}$ is the energy consumed per metric tonne of sediment dredged in the baseline using energy type (ty), and $M_{P\,\Delta}^{[m]}$ is the mass of sediment dredged from the sediment source as a result of project activities during the monitoring period. Note that, since $E_{B\,\Delta\,EC}^{[m]}$ is an emission, its value is always less than or equal to zero.

The energy consumed per metric tonne of sediment dredged in the baseline is determined in Section 6.2.2. The mass of sediment dredged from the sediment source is determined each monitoring period using Section 9.2.5.

The emissions coefficients $e_{(ty)}$ for each energy type are given in Table 10. Energy emissions coefficients for fuels are defined by the EPA Final Mandatory Reporting of Greenhouse Gases Rule, while electricity emissions are determined using the most recent U.S. EPA eGRID database. For both, it is important to note that these factors are updated periodically and that the factor which is applicable for the year in which the emissions occurred must be used. Refer to Appendix M for documentation and sources of the emission coefficients listed in Table 10.

Table 10: Emissions coefficients (including CO_2, CH_4, N_2O) for energy types

Energy Type (ty)	Project Proponent Reports As:	Emission Coefficient $\boldsymbol{e_{(ty)}}$
Diesel	Gal	0.010241 tCO_2e / gal
Motor gasoline	Gal	0.008809 tCO_2e / gal
Biodiesel	Gal	0.009459 tCO_2e / gal
Compressed natural gas	Scf	0.000055 tCO_2e / scf
Electric grid	kWh	eGRID regional emission factor (tCO_2e/kWh)

Monitoring Requirements: Emissions Coefficients
The monitoring report must include the following if an emission coefficient is used for the electric grid: **MRR.14** Source and date of the emission coefficient. **MRR.15** Reference to the exact page number or worksheet cell in the source.

8.1.2 Calculating Emissions from Methane Ebullition

If baseline emissions from open water methane ebullition are included in the project accounting, these emissions $\boldsymbol{E_{B\,\Delta\,CH4}^{[m]}}$ are calculated using equation [G.5] and are expressed in units of tCO_2e. These emissions are the product of the daily flux and the number of days in the monitoring period. Note that, since $E_{B\,\Delta\,CH4}^{[m]}$ is an emission, its value is always less than or equal to zero.

8.2 Project Emissions or Emission Reductions and/or Removals

Project emissions or emission reductions and/or removals $E_{P\,\Delta}^{[m]}$ for the monitoring period are given by equation [G.15], equal to emissions or emission reductions and/or removals from change in carbon stocks, nitrous oxide, methane and energy consumption resulting from the implementation of project activities.

Project emissions will occur if the flux emissions and emissions from energy consumption are greater than carbon accretion for the monitoring period, in which case $E_{P\,\Delta}^{[m]}$ will be negative. Likewise, project emission removals will occur if carbon accretion is greater than flux emissions and emissions from energy consumption, in which case $E_{P\,\Delta}^{[m]}$ will be positive.

Monitoring Requirements: Project Emissions or Emission Reductions and/or Removals
The monitoring report must include the following: **MRR.16** Calculations of current project emissions or emissions reductions and/or removals $E_{P\,\Delta}^{[m]}$ as of the monitoring period. **MRR.17** Calculations of project emissions or emissions reductions and/or removals $E_{P\,\Delta}^{[m-1]}$ from prior monitoring periods.

8.2.1 Calculating Emission Removals in Carbon Stocks

Carbon stocks must be monitored during the project crediting period to calculate the GHG emissions or removals that occur as a result of project activities. Current emissions or emissions reductions and/or removals from carbon stocks $E_{P\,\Delta\,CS}^{[m]}$ are defined as the difference between carbon stocks from the prior monitoring period and carbon stocks from the monitoring period as given in equation [G.8] for a project that is not grouped and equation [G.9] for a grouped project; carbon stock estimates are derived from methods described in Section 9.2.1. Note that $E_{P\,\Delta\,CS}^{[m]}$ is positive if vegetation growth has occurred and carbon stocks have not been reduced by disturbances.

8.2.2 Calculating Emissions from Methane

Project emissions from methane $E_{P\,\Delta\,CH4}^{[m]}$ are calculated using equation [G.11] and are expressed in units tCO_2e. These emissions are the product of the daily flux and the number of days in the monitoring period. Note that, since $E_{P\,\Delta\,CH4}^{[m]}$ is an emission, its value is less than or equal to zero.

8.2.3 Calculating Emissions from Nitrous Oxide

Project emissions from nitrous oxide $E_{P\,\Delta\,N2O}^{[m]}$ are calculated using equation [G.13] and are expressed in units tCO_2e. These emissions are the product of the daily flux and the number of days in the monitoring period, as described in Section 9.2.2. Note that, since $E_{P\,\Delta\,N2O}^{[m]}$ is an emission, its value is less than or equal to zero.

8.2.4 Calculating Emissions from Energy Consumption

Project emissions from energy consumption are given by equation [G.14], the total energy consumed as a result of project activities. Energy use and type must be monitored per Section 9.2.4. The emissions coefficients $e_{(ty)}$ for each energy type are given in Table 10 found in Section 8.1.1. Note that, since $E_{P\,\Delta\,EC}^{[m]}$ is an emission, its value is less than or equal to zero.

8.2.5 Calculating Emissions from Disturbances

Emissions from natural disturbances and other events within the project area are inherently captured by the monitoring of carbon stocks (see Section 9.2.1). The project area must be monitored regularly for evidence of significant disturbance. The following disturbance events may be significant:

- Hurricanes
- Fires
- Marsh dieback

For guidance on how to define a significant disturbance, project proponents should refer to the definition of *loss event* in the current version of the *VCS Program Definitions.*

In the event that a significant disturbance is apparent, the project proponent must document the nature and extent of the disturbance and, if necessary, re-measure existing plots or install new plots in the disturbed area. In order to estimate these carbon stocks, the project area may need to be re-stratified per Appendix A as part of monitoring (see Section 9). If the disturbance is likely to qualify as a loss event, the loss event must be reported in accordance with VCS rules.

If re-stratification is necessary, the new strata must be effective as of the date of the disturbance, thus ensuring that the stratification accurately represents conditions in the project area.

PD Requirements: Emissions or Emissions Reductions and/or Removals Events in Project Area
The project description must include the following: **PDR.45** The selected definition of a significant disturbance.

Monitoring Requirements: Emissions or Emissions Reductions and/or Removals Events in Project Area
The monitoring report must include the following: **MRR.18** The selected definition of a significant disturbance. **MRR.19** A map of the boundaries of any significant disturbance in the project area during the monitoring period. **MRR.20** Evidence that plots were installed into these disturbed areas and were measured per Section 9.2.1.

8.3 Leakage

8.3.1 Determining Activity-Shifting Leakage

Activity-shifting leakage is zero because the project area continues to be open water in the baseline scenario, and wetland creation does not materially change the land use activities outside of the project area. Thus, leakage from shifting livestock, agricultural activities or communities cannot occur. Further, dredging emissions occur in both the baseline and project scenarios and as such are not considered as leakage emissions from machinery.

8.3.2 Determining Market-Effects Leakage

Market-effects leakage is zero as there is no commercial value to the baseline scenario of open water. As a result, no change in supply and demand can exist, nor can shift in production exist elsewhere outside of the project area.

8.3.3 Demonstrating No Ecological Leakage

As a result of adding sediment to the project area during wetland creation, the watershed-scale hydrology could be affected. These effects could cause displacement of water (either standing or flowing) to areas not inundated prior to the project start date. The project proponent must demonstrate that the project will not have a significant negative impact on hydrologically connected areas, and therefore, that there will be no ecological leakage.

In order to demonstrate that the project will not have a significant negative impact on hydrologically connected areas, the project proponent must demonstrate compliance with Section 404 of the Clean Water Act by providing an individual or general permit issued by the USACE, prior to the completion of the first verification event. Where applicable, compliance with Section 10 of the Clean Water Act (River and Harbors Act) must also be demonstrated. Likewise, any NEPA analyses and decision documents must be provided (ie, a Finding of No Significant Impact [FONSI] for an Environmental Assessment or a Record of Decision [ROD] for an Environmental Impact Statement), where applicable.

Where the project proponent demonstrates that the project will not have a significant negative impact on hydrologically connected areas in accordance with the requirements above, ecological leakage is considered to be zero.

PD Requirements: Hydrologic Effects
The project description must include the following: **PDR.46** Where possible at validation, demonstration that the project will not have a significant negative impact on hydrologically connected areas, in accordance with the requirements of Section 8.3.3.

Monitoring Requirements: Hydrologic Effects
The monitoring report must include the following: **MRR.21** Demonstration that the project will not have a significant negative impact on hydrologically connected areas, in accordance with the requirements of Section 8.3.3, where same has not already been demonstrated at validation.

8.4 Summary of GHG Emission Reduction and/or Removals

The GHG emissions reductions resulting from the project activities are quantified in two steps: Gross Emissions Reductions (GERs) and Net Emissions Reductions (NERs), Sections 8.4.1 and 8.4.2, respectively. The quantity of NERs are those that are available for retirement or sale, and are GERs minus a confidence deduction (Section 8.4.2.1) and allocation to the AFOLU pooled buffer account (Section 8.4.2.2), plus a buffer release (Section 8.4.2.3). The quantity of GERs is the difference between baseline and project emissions or emissions reductions and/or removals.

8.4.1 Quantifying Gross Emission Reductions and/or Removals

Gross Emissions Reductions (GERs) for a monitoring period $[m]$ are quantified using equation [G.16] and are equal to the total baseline emissions over the monitoring period minus the total project emissions or emissions reductions and/or removals over the monitoring period.

Monitoring Requirements: Quantification of GERs
The monitoring report must include the following: **MRR.22** Quantified GERs for the monitoring period including references to calculations. **MRR.23** Quantified GERs for the prior monitoring period. **MRR.24** A graph of GERs by monitoring period for all monitoring periods to date.

8.4.1.1 Handling Reversals Resulting from Energy Consumption

In the event that quantified GERs are negative – indicating that project emissions or emissions reductions and/or removals are greater than baseline emissions – and that the cause of this event is the consumption of energy by project activities, the project must not generate NERs until cumulative GERs $E_{GER}^{[m]}$ are greater than zero per equation [G.17]. Note that although cumulative GERs may be greater than zero, a reversal may still occur.

8.4.2 Quantifying Net Emissions Reduction and/or Removals

Net Emissions Reductions (NERs) are equivalent to quantified GERs less a confidence deduction (if any) and AFOLU pooled buffer account allocation. NERs generated during a monitoring period $[m]$ are determined using equation [G.21]. Quantified NERs should be rounded down to the nearest whole number.

Monitoring Requirements: Quantification of NERs
The monitoring report must include the following: **MRR.25** Quantified NERs for the monitoring period including references to calculations. **MRR.26** Quantified NERs for the prior monitoring period. **MRR.27** A graph of NERs by monitoring period for all monitoring periods to date.

8.4.2.1 Calculating the Confidence Deduction

The confidence deduction $E_{U\,\Delta}^{[m]}$ is given by equation [G.19] where uncertainty in the estimate of the total carbon stock is given by equation [G.18], the sum of squared-uncertainty in all selected carbon pools $\mathcal{C}$. If the monitoring plan specifies a different sampling design, equations for uncertainty will differ for biomass and soil (see Section 9).

Uncertainty is calculated solely on the basis of the carbon stock estimate and does not include uncertainty in the measurements of methane and nitrous oxide. Although estimates of methane and nitrous oxide flux are uncertain, the flux measurement methods set out in in this methodology (Sections 9.2.2 and 9.2.3) are designed to provide conservative (ie, high) estimates of project emissions or emissions reductions and/or removals from these GHG sources. Thus, the uncertainty associated with an unbiased estimate of these fluxes is expected to be negligible when compared to the intentional difference between these estimates and the true (but unknown) fluxes. Therefore, the confidence deduction does not include uncertainty from methane or nitrous oxide estimates.

The confidence deduction must be greater than or equal to zero. If the result from equation [G.19] is less than zero, the confidence deduction must be set to zero.

Monitoring Requirements: Confidence Deduction
The monitoring report must include the following: **MRR.28** The calculated confidence deduction and supporting calculations. **MRR.29** Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

8.4.2.2 Determining Allocation to AFOLU pooled buffer account

The project proponent must undertake an assessment of non-permanence risks that apply to the project. This assessment must conform to current VCS requirements and must be used to determine the allocation of GERs to the AFOLU pooled buffer account. GERs allocated to the AFOLU pooled buffer account are denoted by $E_{BA\,\Delta}^{[m]}$ as given in equation [G.20] and must be based on the change in carbon stocks for the monitoring period as described in Section 8.2.1. GERs allocated to the AFOLU pooled buffer account must be rounded up to the nearest whole number.

Monitoring Requirements: AFOLU pooled buffer account	
The monitoring report must include the following:	
MRR.30	Reference to the VCS requirements used to determine the AFOLU pooled buffer account allocation.
MRR.31	Reference to calculations used to determine the AFOLU pooled buffer account allocation.

8.4.2.3 Determining Release from AFOLU pooled buffer account

Periodically, the project may be eligible for a release of credits from the AFOLU pooled buffer account. The buffer release $E_{BR\,\Delta}^{[m]}$ must be determined in accordance with VCS requirements.

Monitoring Requirements: Buffer Release	
The monitoring report must include the following:	
MRR.32	Reference to the VCS requirements used to determine the release from the AFOLU pooled buffer account.
MRR.33	Reference to calculations used to determine the buffer release.

8.4.2.4 Quantifying Vintages over a Monitoring Period

When the monitoring period spans more than one calendar year, NERs must be allocated by year, proportional to the number of calendar days in each year relative to the total number of days in the monitoring period. Quantified NERs should be rounded to the nearest whole number for each vintage year such that the sum of vintages in each monitoring period is equal to the NERs for that monitoring period.

Monitoring Requirements: Vintages	
The monitoring report must include the following:	
MRR.34	Quantified NERs by vintage year for the monitoring period including references to calculations.

8.4.3 Estimating Ex-Ante GHG Emission Reductions and/or Removals

To calculate ex-ante estimates of greenhouse gas reductions and removals, use the steps outlined in Section 8, substituting estimates of parameters that require monitoring with conservative estimates of those parameters derived from scientific literature or preliminary sampling as applicable. The following table lists the parameters required and provides guidance for estimating ex-ante project benefits in a conservative fashion. Note that derived quantities are not shown in this table.

Data / Parameter	Unit	Description	Ex-Ante Source of Data	Guidance for Conservative Estimation
$b^{[m]}$	Unit-less	Buffer withholding percentage calculated as required by the VCS AFOLU Non-Permanence Risk Tool	VCS AFOLU Non-Permanence Risk Tool	The non-permanence risk tool is to be applied at validation, therefore the value of $b^{[m]}$ should be known.
$C_{P\ CS}^{[m]}$	tCO_2e	Cumulative carbon stocks in project area for monitoring period	Scientific literature or preliminary sampling in areas of past wetland creation	It is conservative to underestimate carbon stocks.
$E_{P\ \Delta\ N2O}^{[m]}$	tCO_2e	Total emissions for nitrous oxide in project area over monitoring period	Select appropriate estimates from the tables given in Section 8.4.3.2	NA
$E_{P\ \Delta\ CH4}^{[m]}$, $E_{B\ \Delta\ CH4}^{[m]}$	tCO_2e	Total methane emissions in project area over monitoring period	Scientific literature or preliminary sampling	It is conservative to overestimate methane emissions in the project scenario.
$E_{BR\ \Delta}^{[m]}$	tCO_2e	Buffer release	See current VCS requirements	
$e_{(ty)}$	tCO_2e/gal	Emissions coefficient from Table 10 in Section 8.1.1 for energy type ty	Apply coefficients as given in Table 10	NA
$p_{B\ (ty)}$	unitless	Proportion of energy for energy type ty consumed in the baseline scenario	Records of past energy use for similar activities	It is conservative to assume that energy types with lower emission factors would have been used predominantly in the baseline scenario.
$p_{P\ (ty)}$	unitless	Proportion of energy for energy type ty consumed in the project scenario	Records of past energy use for similar activities	It is conservative to assume that energy types with higher emission factors would have been used predominantly in the project scenario.

Data / Parameter	Unit	Description	Ex-Ante Source of Data	Guidance for Conservative Estimation
U_s	tCO_2e	Standard error for a set of strata	Guidance from Appendix A may be used to plan sampling that is likely to meet a targeted precision level	See Appendix A

8.4.3.1 Determining Whether Emissions from Methane are *de minimis*

In systems with high salinity (>18 ppt), methane emissions may be *de minimis*. Such emissions are considered *de minimis* if, together with any other sources which may be *de minimis*, they account for less than 5% of the total GHG benefit generated by the project. The project proponent may choose one of the following methods to demonstrate that methane emissions are *de minimis*:

1. Models from literature (see Section 9.2.2.1)
2. Proxy models (see Section 9.2.2.2)
3. Direct measurements (see Section 9.2.2.3)

8.4.3.2 Determining Whether Emissions from Nitrous Oxide are *de minimis*

In systems without nitrate loading, nitrous oxide emissions may be *de minimis*. Such emissions are considered *de minimis* if, together with any other sources which may be *de minimis*, they account for less than 5% of the total GHG benefit generated by the project. The project proponent may choose one of the following methods to demonstrate that nitrous oxide emissions are *de minimis*:

1. Default factors (see Section 9.2.3.1)
2. Proxy models (see Section 9.2.3.2)
3. Direct measurements (see Section 9.2.3.3)

8.4.4 Evaluating Project Performance

Project performance must be evaluated each verification event and deviations from *ex-ante* NERs must be described. Differences in credit generation from *ex-ante* estimates may result from changes in the quality of data (literature estimates versus carbon stock estimates), changes in measurement approaches, occurrences of disturbance events or baseline re-evaluation.

Monitoring Requirements: Project Performance
The monitoring report must include the following: **MRR.35** Comparison of NERs presented for verification relative to those from *ex-ante* estimates. **MRR.36** Description of the cause and effect of differences from *ex-ante* estimates.

9 MONITORING

Project proponents must monitor the applicable GHG sources and selected carbon pools identified for the project (see Section 5.1 and Section

5.2). Table 11 provides a step-by-step summary of the monitoring program. Given that multiple GHG sources must be monitored across multiple carbon pools, it is likely that stratification of the project area will improve sampling efficiency and overall monitoring costs (see Section 9.1). Thus, stratification is performed prior to any field measurements.

The project proponent must then develop a monitoring plan to guide monitoring activities. The methods for measuring and estimating carbon stocks and gas fluxes described in the monitoring plan must adhere to the requirements provided in Section 9.2. The monitoring plan must be implemented in the first monitoring period and must guide ongoing monitoring for the duration of the project crediting period.

Using the monitoring plan as a guide, the values of data and parameters identified in Sections 9.3 and 9.4 must be reported in the project description (PD) or monitoring report (MR). When monitoring carbon stocks and fluxes, the project proponent must note the difference between accounting units (typically tCO_2e/day) and the frequency and interval monitoring activities (see Section 2.5).

Finally, grouped projects must report additional information in the Monitoring Report per Section 9.5.

Table 11: Stages of the monitoring program

Development Task	Selection of GHG sources and carbon pools →	Stratification →	Monitoring plan →	Monitoring activities
Key Activities	Identify applicable GHG sources. Select carbon pools for measurement and accounting. Determine which sources are *de minimis*, if any	Stratify project area to focus monitoring effort and reduce costs.	Develop sampling methods and procedures. Schedule dates and locations of monitoring events. Develop methods for storing, auditing and reporting monitoring data.	Perform monitoring activities. Synthesize and report monitoring data. In the event of a significant disturbance, re-stratify per Section 8.2.5 as described in Sections 9.1 and 9.2.1.2.
Section of Methodology	5.1 and 5.2	9.1 and 9.2.1.2	9.2	9.2, 9.3 and 9.4

In the case of a methodology deviation, alternative criteria and procedures relating to monitoring and measurement must still meet the requirements of Section 9.2.

9.1 Stratification

Stratification is recommended for the direct measurement of carbon stocks, and is required for the direct measurement of methane and nitrous oxide fluxes. Appendix A provides general guidelines for stratifying the project area, including guidance on allocating sampling and measurement units within strata. Different stratification systems may be used for estimating different emissions or emissions reductions and/or removals from different GHG sources.

In the case of direct measurement of carbon stocks, stratification may be used to improve sampling efficiency and thereby reduce the effort and costs associated with monitoring. In particular, stratification is likely to reduce the uncertainty of population estimates within each stratum, which often will reduce the number of plot measurements needed to meet VCS precision requirements.

For methane and nitrous oxide fluxes, stratification is used to identify the stratum that is likely to yield the greatest flux of each gas on an annual basis. The project proponent must measure the identified stratum for each gas. If desired, other strata may be measured as well.

In order to further streamline monitoring activities, in cases where the project proponent encounters a very small stratum (eg, a tidal channel that becomes established naturally within the project area), it is permissible to combine the stratum with another stratum with higher estimated emissions flux per unit of area. In the event that the very small stratum is combined with another stratum with lower estimated emissions flux per unit area, the project proponent must show that the difference in emissions is expected to be *de minimis*.

9.1.1 Multiple Flux Monitoring Methods in Strata

The project proponent may select one method for monitoring methane or nitrous oxide emissions fluxes across all strata (as described in Sections 9.2.2 and 9.2.3). Alternatively, the project proponent may choose to apply different methods to different strata.

For example, the project proponent may choose to use a well-accepted model to predict methane flux in a stratum that is well-vegetated (provided the project proponent can demonstrate the requirements of Section 9.2.2.1) and chamber measurements to directly measure methane flux elsewhere. Per Sections 9.2.1.2 and 9.2.1.3, the project proponent then allocates the chambers to the stratum and locations within the stratum that will likely yield the greatest methane flux over the course of the year.

The project proponent must clearly indicate in the monitoring plan the methods that are to be used and to which stratum each is to be applied (see Section 9.2).

The project proponent must use a stratum-area weighted average to calculate emissions fluxes for the purpose of accounting in Section 8.

9.2 Description of the Monitoring Plan

The project proponent must develop a monitoring plan to guide monitoring activities. The monitoring plan must include a description of measurement methods and procedures and an approximate schedule indicating when the project proponent will perform each monitoring activity throughout the entire project crediting period. The monitoring plan must include the following:

1. The purpose of monitoring;
2. Sampling procedures for carbon stocks and fluxes;
3. Anticipated dates and locations for sampling over a five-year period;
4. Organizational structure, responsibilities and competencies of individuals and organizations responsible for monitoring;
5. Methods for generating, recording, storing, aggregating, collating and reporting data per Sections 9.2.1, 9.2.2 and 9.2.3; and
6. Methods for internal auditing and handling of any identified non-conformities to the monitoring plan.

The schedule for monitoring activities must be based upon the guidance provided in this methodology for the frequency of measurement for the applicable GHG sources.

Table 12: Approximate schedule of monitoring activities by GHG source

<table>
<tr><th colspan="2"></th><th>First verification</th><th>Years 1-10 after first verification</th><th>Years 11 + after first verification</th></tr>
<tr><td colspan="2">Carbon stocks (9.2.1.4)</td><td>All plots measured.</td><td>All plots measured at least once. May ‘cycle’ through a portion of plots each year.</td><td>All plots measured at least once every 5 years. May ‘cycle’ through a portion of plots each year.</td></tr>
<tr><td rowspan="2">Methane</td><td>Project (9.2.2.4)</td><td>Flux measured regardless of monitoring method.</td><td colspan="2">Model from literature: No direct measurements. Assess applicability of methods at each verification event.
Proxy model: Direct measurement of covariates every monitoring period.
Direct measurement: Flux measured every year. (Chamber method: at least 2 measurement events per year; eddy covariance method: at least 21 days of measurements per year)</td></tr>
<tr><td>Baseline (9.2.7)</td><td>Flux measured regardless of monitoring method.</td><td colspan="2">(same as above)</td></tr>
<tr><td colspan="2">Nitrous oxide (9.2.3.4)</td><td>Flux measured regardless of monitoring method.</td><td colspan="2">Model from literature: No direct measurements. Assess applicability of methods at each verification event.
Proxy model: Direct measurement of covariates every monitoring period.
Direct measurement: Flux measured every year. (at least 12 measurement events; see Section 9.2.3.4)</td></tr>
</table>

PD Requirements: Monitoring Plan
The project description must include the following: **PDR.47** A summary of carbon stock sampling procedures for the project area, with a copy of a sampling protocol used by field personnel to carry out measurements. **PDR.48** A summary of flux measurement procedures for the project area, with a copy of a flux measurement protocol used by field personnel to carry out measurements. **PDR.49** A reference to the monitoring plan. **PDR.50** Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

Monitoring Requirements: Monitoring Plan
The monitoring report must include the following: **MRR.37** Documentation of training for field measurement crews. **MRR.38** Documentation of data quality assessment. **MRR.39** References to plot allocation for carbon stock measurement. **MRR.40** List of plot geodetic coordinates for plots and flux measurement devices. **MRR.41** Description and diagram of flux measurements devices for methane and/or nitrous oxide. **MRR.42** The estimated carbon stock, standard error of the total for each stock, and the sample size for each stratum in the project area. **MRR.43** Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language. **MRR.44** Frequency of monitoring for each plot and flux measurement location – all carbon stock plots must be measured for the first verification.

9.2.1 Monitoring Project Carbon Stocks

Carbon stocks must be monitored prior to the first verification, at least once within 10 years after the first verification, and at least once every 5 years thereafter, and not necessarily at every verification event. Total carbon stock for the selected carbon pools is calculated using equation [G.7].

9.2.1.1 Requirements for First Verification

At the first verification, carbon stocks prior to the project start date must be estimated, denoted as $C_P^{[m=0]}$, using equation [G.7]. If plots were not installed prior to the project start date, stratification from aerial imagery may be required to estimate $C_P^{[m=0]}$ (see Section 9.2.1.2).

All plots must be measured at the first verification.

9.2.1.2 Requirements for Stratification

Stratification may be used to improve sampling efficiency, and may be required to estimate carbon stocks prior to the first monitoring period (see Section 9.2.1.1). Appendix A provides general guidelines for stratifying the project area, including guidance on allocating measurement units within strata. For measurements of carbon stocks, some strata may not be measured if these areas can conservatively be assumed not to accumulate soil or biomass carbon stock. For example, an aerial photo may be used to delineate unproductive areas in which minimal above ground biomass has accumulated in a given monitoring period. Rather than allocating sample units to these strata, the project proponent may conservatively assume that these areas have a stock of zero, focusing sampling efforts on areas that have more substantial biomass accumulation.

Strata boundaries may change over time to improve carbon stock estimates.

PD Requirements: Stratification
The project description must include the following if stratification is not elected for either biomass or SOC: **PDR.51** Justification for not stratifying carbon stocks.

9.2.1.2.1 Stratification for SOC

When estimating soil carbon stocks, the project proponent may stratify the project area according to factors such as water depth, elevation or relative terrain position, soil type maps, or vegetation cover. A map of all identified strata and their areas must be reported as well as the allocation of plots within each stratum.

PD Requirements: Stratification for SOC
The project description must include the following if the project area is stratified: **PDR.52** Description for how the strata were delineated. **PDR.53** Map(s) of the initial strata boundaries.

Monitoring Requirements: Stratification for SOC
The monitoring report must include the following if the project area is stratified: **MRR.45** Map(s) of the current strata boundaries. **MRR.46** A description of changes to the strata boundaries (if applicable).

9.2.1.2.2 Stratification for Biomass

When estimating biomass carbon stocks, the project proponent may stratify the project area according to factors such as vegetation type; age, stocking, or vegetation density; site quality; elevation or relative terrain position. A map of all identified strata and their areas must be reported as well as the allocation of plots within each stratum.

PD Requirements: Stratification for Biomass	
The project description must include the following if the project area is stratified:	
PDR.54	Description for how the strata were delineated.
PDR.55	Map(s) of the initial strata boundaries.

Monitoring Requirements: Stratification for Biomass	
The monitoring report must include the following if the project area is stratified:	
MRR.47	Map(s) of the current strata boundaries.
MRR.48	A description of changes to the strata boundaries (if applicable)

9.2.1.3 Direct Measurement for Stock Change

The project proponent must take direct measurements of biomass and SOC. The project proponent must use the protocols prescribed in Appendix D and Appendix E as the basis for carbon stock measurement in the monitoring plan.

The project proponent must describe the methods for allocating plots to strata and within strata.

PD Requirements: Measuring Carbon Stocks	
The project description must include the following:	
PDR.56	Method for allocating plots to stratum.
PDR.57	Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.

Monitoring Requirements: Measuring Carbon Stocks
The monitoring report must include the following: **MRR.49** Method for allocating plots to stratum. **MRR.50** Map of the location of plots within strata. **MRR.51** Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.

9.2.1.3.1 Soil Plot Design

Permanent plots must be randomly allocated in the project area. Artificial marker horizons (feldspar or other technique) may be used to define the original project soil surface after the implementation of project activities. The project proponent must specify the maximum soil sample depth, which will be fixed for the life of the project.

PD Requirements: Soil Plot Design
The project description must include the following: **PDR.58** Diagram of a soil plot showing the locations of artificial marker horizons and core samples within the plot over time. **PDR.59** Description of the fixed soil sample depth.

Monitoring Requirements: Soil Plot Design
The monitoring report must include the following: **MRR.52** For each measured soil plot, a diagram showing the location of installed artificial marker horizons and sampled cores. **MRR.53** Field report describing soil sample depths (accretion depth and fixed soil sample depth) and coring devices used to collect samples. The report must also include number of soil samples and their identification in a chain of custody form submitted to the laboratory.

9.2.1.4 Frequency of Measurement

All plots must be measured at the first verification. For the remainder of the project crediting period, carbon stocks must be monitored at least once within the next 10 years and at least once every five years thereafter, and not necessarily at every verification event. The project proponent may choose to 'cycle' through a portion of measurement plots over the five-year period.

PD Requirements: Frequency of Carbon Stock Measurements
The project description must include the following: **PDR.60** The anticipated frequency of monitoring for each plot and flux measurement location – all carbon stock plots should be measured for the first verification.

Monitoring Requirements: Frequency of Carbon Stock Measurements
The monitoring report must include the following: **MRR.54** List of plots measured during the monitoring period – all carbon stock plots should be measured for the first verification.

9.2.2 Monitoring Project Methane Flux

In the project case, methane flux $F_{P\,\Delta\,CH4}^{[m]}$ must be monitored using one of three approaches: models taken from peer reviewed scientific literature (Section 9.2.2.1), proxy methods developed by the project proponent (Section 9.2.2.2) or direct measurement of flux from the project area (Section 9.2.2.3). All three approaches result in an estimate of flux in units of tCO_2e/day, which is then used in equation [G.11] to predict emissions as a result of project activities (see Section 8.2.2). Specific field methods for measuring methane flux are described in Appendices B and C.

In deciding which monitoring approach to use, keep in mind that direct measurement is usually the most demanding in terms of time and cost. If the project proponent is able to identify a model that meets the requirements herein, it will likely be the most efficient method.

Once an approach is selected, it cannot be changed after the first verification event unless it is being changed to direct measurement.

PD Requirements: Monitoring Methane
The project description must include the following: **PDR.61** The selected approach for monitoring methane.

9.2.2.1 Models from Literature

Methane flux may be predicted using a process model or proxy model selected from peer-reviewed scientific literature but only after the model has been demonstrated to be applicable to the project area. In selecting a model and demonstrating that it is applicable to the project area, the project proponent must do the following:

1. Provide a description of the model that includes references to key technical papers and justifies why the selected model is appropriate for predicting methane flux in the project area.

2. Enumerate the assumptions (or applicability conditions) of the model, explain how each of those assumptions is satisfied in the application of the model to the project area.

3. List all parameters of the model, providing the values applied, the source of those parameters, and providing a justification for why the selected value is appropriate to the project area. If parameters are selected by the user to calibrate the model, the project proponent must justify the values selected for these parameters conservatively predicts emissions. Modeling conducted in support of credit generation activities must use parameter values that are specific to the project area where it is possible to do so (ie, the model must be calibrated based on measurements made at the project site, not applied with default settings).

4. List any forcing variables or covariates (for example, meteorological or hydrological measureable variables available at each time step for which the model is run) that drive the model and provide a plan to obtain project area-specific values for those parameters.

At the initial project verification and at baseline reevaluation, the model's applicability must be assessed by comparison to direct field measurements of methane flux. The project proponent must do all of the following to determine if the model is applicable to the project area:

1. Directly measure methane flux for one season as described in Appendix B. The measurements must meet all assumptions outlined in Appendix B. Appendix B is designed to provide conservative (high) estimates of methane flux.

2. Use the selected and calibrated model to predict the measured methane flux independent of any data used to calibrate the model.

3. Estimate the model error as the sum of the differences between predicted and measured fluxes, divided by the number of measurements.

4. The mean error must demonstrate that the model conservatively over-predicts emissions fluxes compared to direct measurement of methane flux.

Predicted emissions fluxes by the selected model from literature must be converted to units of tCO_2e/day, such that they can be used directly in equation [G.11] as described in Section 8.2.2 (for the distinction between units and resolution, see Section 2.5).

If a model(s) from literature is selected, it must be justified at the time of validation and its applicability determined at the first verification event and subsequent baseline reevaluations.

PD Requirements: Methane Models from Literature
The project description must include the following if a model from literature is used to estimate methane flux: **PDR.62** Justification of methane flux model from the literature, per the requirements of Section 9.2.2.1.

Monitoring Requirements: Methane Models from Literature
The monitoring report must include the following if a model from literature is used to estimate methane flux: **MRR.55** Demonstration that the selected model is applicable to the project area per the requirements of Section 9.2.2.1. **MRR.56** Description of how model predictions are converted to tCO_2e/day.

9.2.2.2 Proxy Modeling

Project proponents may develop new proxy models to predict methane flux from wetland ecosystems. In building such a predictive model, the project proponent must measure or collect published data on response variables (methane flux) using the guidance in Appendix B as well as possible covariates, consider a range of alternative models and select a model using statistically sound procedures, and apply the model at each verification event to predict methane flux. Use Sections 9.2.2.2.1, 9.2.2.2.2, 9.2.2.2.3 and 9.2.2.2.4 to develop new proxy models.

Although the possible covariates to methane flux must be reported at the time of validation, the selected model and data used to fit the model must be reported at the time of the first verification event.

Such models must comply with requirements for models set out in the *VCS Standard*.

9.2.2.2.1 Considering Covariates

In developing a statistical model, project proponents should first develop a list of possible covariates and list sources of potential data for those covariates, which may include direct field measurement, remote sensing, peer-reviewed scientific literature, and technical reports completed by government agencies. Covariates to be considered may include but are not limited to soil salinity, water salinity, soil temperature, water temperature, air temperature, flooding, spectral reflectance, elevation, flooding frequency, flooding depth, soil organic carbon, and sulfate concentrations. From the initially considered covariates, identify those whose data availability and expected relationship with methane flux are most relevant to the project needs.

Possible and selected covariates and sources for covariates must be validated.

PD Requirements: Covariates for Proxy Methane Models
The project description must include the following if a proxy model is used to estimate methane flux: **PDR.63** A list of possible covariates and the sources of data available for each. **PDR.64** A list of selected covariates to be used for model fitting.

9.2.2.2.2 Collecting Data for Model Fitting and Response Variables

Data for model fitting may be collected from a combination of direct field measurements (see Appendix B), peer-reviewed scientific literature and/or technical reports issued by government agencies. Field data must be collected to cover the entire range of methane emissions flux potentially expected by the project, as well as the values of covariates that correspond to that range. Additional guidance is provided in Section 4.1.7 of the *VCS Standard v3.3*.

When data are collected directly by the project proponent in the field, a data collection plan (or protocol) must be prepared, detailing the data collection methods and referencing appropriate technical source documents.

Monitoring Requirements: Data Collection for Proxy Methane Model
The first monitoring report must include the following if an proxy model is used to estimate methane flux: **MRR.57** Complete references to the source of any data collected from literature or reports. **MRR.58** Data collection procedures, plans or protocols for any data collected directly from the project area.

9.2.2.2.3 Model Fitting, Selection, and Goodness of Fit

This methodology is not prescriptive with regard to model form and fitting procedures, as various types of models may be appropriate depending on the observed relationship between covariates and response variables. However, the model must be fit using sound and well documented statistical methods. The model must predict methane flux in tCO_2e/day (or units that can be converted appropriately) from some combination of measurable covariates. The project proponents must consider a variety of model forms and data transformations as appropriate to the data collected. During model fitting, attention should be paid to outliers and overly influential data points. Residual plots should be analyzed to confirm that model fitting assumptions have been met. Model selection and goodness of fit must be evaluated as described in Appendix F.

Monitoring Requirements: Model Fit for Methane
The first monitoring report must include the following if a proxy model is used to estimate methane flux: **MRR.59** The form of the selected model. **MRR.60** Summary statistics of the model fit as appropriate to the fitting of the model. **MRR.61** The estimated model parameters. **MRR.62** A description of the range of covariate data with which the model was fit.

9.2.2.2.4 Predicting Methane Flux

When a proxy model is used, measurement of the selected covariates replaces direct measurement of methane flux at each verification event. Covariates must be measured according to the procedures outlined by the project proponent in Section 9.2.2.2.1 and their actual values reported. Use the measured values as inputs to the statistical model. In the case that there is uncertainty about the value of a covariate model input, choose the value that results in the most conservative (ie, largest) estimate of methane emissions flux. Models must not be extrapolated more than 10% (that is, no independent variables that exceed the range from which the model was fit by more than 10% must be input into the model).

Monitoring Requirements: Model Prediction for Methane
The first monitoring report must include the following if an proxy model is used to estimate methane flux: **MRR.63** The values of any measured covariates. **MRR.64** The predicted methane flux.

9.2.2.3 Direct Measurement

Either chamber measurements (Section 9.2.2.3.2), eddy covariance measurements (Section 9.2.2.3.3), or other substantive equivalent techniques must be used. The project proponent must select the measurement method at the time of validation.

Monitoring of gas fluxes is inherently uncertain when aggregated over space and time. This methodology addresses this uncertainty by providing requirements that ensure the fluxes are overestimated, rather than underestimated, using conservativeness as a mediator to accuracy. These requirements include guidelines for stratification, a requirement for making measurements in the stratum expected to have the highest emissions, and guidelines for the points in time during which measurements are made.

To convert monitoring data from flux per acre per day to flux per day as required in Section 8.2.2, use equation [G.10].

Monitoring Requirements: Processed Chamber and Eddy Covariance Flux Data
The monitoring report must include the following: **MRR.65** A table of chamber flux or eddy covariance emission summary statistics of the mean (±1SEM) and number of samples for each mean in tCO_2e/ac/day for each sample location within a stratum.

9.2.2.3.1 Stratification

Stratification must be used to determine the stratum that is likely to yield the greatest methane emissions flux over the course of a year. Appendix A, Section A.1, provides general guidelines for stratifying the project area. Direct measurements must be conducted in the stratum that is likely to yield the greatest methane emissions flux, and may optionally be conducted in other strata as well, using appropriate area weighted stratification estimators as provided in appendix A.

The following factors predominantly affect methane emissions flux:

1. Carbon source: Methane emissions are associated with productive emergent plants that supply labile organic matter for methane producing bacteria. Areas with stressed plants or low plant productivity may have limited emissions over an annual period.

2. Soil saturation or reduction-oxidation potential: Persistent soil saturation or inundation above the wetland surface indicates reduced conditions and a likelihood of enhanced methane emissions. Methane production occurs when the reduction-oxidation potential is less than < 200mV. Optimal methane production occurs when redox is below -200mV.

3. Sulfate (salinity): The absence of sulfate favors methane production. The regular replenishment of sulfate with seawater from tidal action can suppress methane production. Methane production can occur when sulfate is less than 4mM umol (or typically when salinity < 18ppt).

4. Plant traits: 'Shunt' plant species are capable of conducting methane from the soil to atmosphere. A comprehensive list of species is not known, however, candidate genera that contain substantial aerenhymatous roots and shoots includes: *Typha*, *Sagittaria*, *Peltandra*, *Nuphar*, *Nymphaea*, *Phragmites*, and *Cladium* (see Couwenberg 2009).

5. Electron acceptors: In the absence of sulfate and other electron acceptors, such as nitrate and iron, methane production may be enhanced.

These factors must be considered when determining the stratum that is likely to yield the greatest methane emissions flux. The project proponent must justify the selected strata for direct measurement, including time considerations related to cyclical changes in the tidal frame.

Strata boundaries may change over time. If this occurs, the project proponent must ensure that the stratum likely to yield the greatest methane flux is always measured.

PD Requirements: Stratification for Methane Emissions
The project description must include the following if direct measurement is used to estimate methane flux: **PDR.65** Description for how the strata were delineated. **PDR.66** Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest methane emissions flux. **PDR.67** Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest methane emissions flux.

Monitoring Requirements: Stratification for Methane Emissions
The monitoring report must include the following if direct measurement is used to estimate methane flux: **MRR.66** Map(s) of the current strata boundaries. **MRR.67** A description of changes to the strata boundaries (if applicable).

9.2.2.3.2 Chamber Measurements

If the chamber measurement method is selected, the project proponent must take direct measurements of methane flux using chambers. The project proponent may use the protocols prescribed in Appendix B as the basis for flux measurement in the monitoring plan.

Within stratum, chambers must be located in areas that are likely to yield the greatest methane emissions flux over the course of a year (see factors in Section 9.2.2.3.1).

PD Requirements: Instrumentation for Chambers
The project description must include the following: **PDR.68** Diagram of chamber design.

Monitoring Requirements: Instrumentation for Chambers
The monitoring report must include the following: **MRR.68** Diagram of chamber design. **MRR.69** Map showing the location of chambers in the project area.

9.2.2.3.3 Eddy Covariance Measurements

The project proponent may take direct measurements of methane flux using eddy covariance. The project proponent may use the protocols prescribed in Appendix C as the basis for flux measurement in the monitoring plan.

The footprint of the eddy covariance tower must be more than half in the stratum determined to yield the greatest methane emissions flux over the course of a year (see factors in Section 9.2.2.3.1). The tower must be located in the stratum determined to yield the greatest methane emissions flux over the course of a year. The footprint of the tower must be defined using a published model (eg, Kljun et al. 2004, Kormann and Meixner 2001).

Monitoring Requirements: Instrumentation for Eddy Covariance
The monitoring report must include the following: **MRR.70** Diagram or map of eddy covariance tower delineating the selected footprint area where flux was integrated from and the computed mean 80% footprint distance (including the footprint model used) from the tower during the period of analysis. A table of computed estimates for each of the following parameters: σ_w = standard deviation of the vertical velocity fluctuations (m/s) u^*= surface friction velocity (m/sec) z_m= measurement height (m) z_0= roughness length (m) (or canopy height and density to be used to estimate roughness length) **MRR.71** Description of the published model used to define the footprint. **MRR.72** Map showing the location of eddy covariance towers in the project area. **MRR.73** Documentation of adherence to manufacturer-recommended procedures for calibration of the methane analyzer.

The project proponent must use one of the software packages for eddy covariance data processing listed below. An inter-comparison of some of these software packages for eddy covariance data quality control was reviewed by Mauder et al. (2008), and any of these packages must be considered equally acceptable for computing GHG fluxes. Eddy covariance algorithms may be used in other commercial software, such as MatLab, but will require justification from the project proponent.

- EddyPro 4.0 (fully documented, maintained, and supported by LI-COR®, Inc.)
- ECO_2S (IMECC-EU)
- EdiRe (Rob Clement, University of Edinburgh)
- TK3 (Matthias Mauder and Thomas Foken, University of Bayreuth)
- ECPack (GNU Public License; Wageningen University);
- EddySoft (Olaf Kolle and Corinna Rebmann, Max-Planck Institute for Biogeochemistry)
- Alteddy (Jan Elbers, Alterra Institute in Wageningen)

The project proponent must plot a time series of 30 min data including methane concentration, surface friction velocity and temperature. Data points must be omitted based on the following thresholds:

- Methane concentration must not be less than ambient (< 1.7 ppm) or the regional average, which is available from the nearest NOAA ERSL laboratory field station.

- Surface friction velocities less than 0.10 m/s or greater than 1.2 m/s.

Upper and lower limits of daily temperature should be within norms of the nearest meteorological station.

Monitoring Requirements: Eddy Covariance Data Processing and Flux Computation
The monitoring report must include the following: **MRR.74** Frequency diagram of wind direction (0-359° with 30° intervals) and velocity (m/s) for the period of analysis. **MRR.75** Summary of the dates of data collection, the selected approach for averaging over each period, explicit formulas used for computing flux, number of 0.5-hr samples used in calculations. **MRR.76** Graphical plot of 0.5-hr GHG concentration (ppmv), wind velocity and direction, and temperature used for the flux calculations **MRR.77** Summary statistics (number of samples, mean, median, variance) of GHG flux for each averaging period.

9.2.2.4 Frequency of Measurement

The project proponent must monitor methane flux periodically during a sampling period. The frequency of measurement is dependent upon the measurement method selection (ie, chamber or eddy covariance).

9.2.2.4.1 Chamber Measurements

The sampling period must be defined by a chamber sampling type selected from Table 13; guidance on the appropriate seasons for sampling activities is given for the northern hemisphere. The chamber sampling type may change from monitoring period to monitoring period, but must never change within a monitoring period. The project proponent must justify their selection of the chamber sampling type every monitoring period.

Table 13: Measurement requirements for chambers

Chamber Sampling Type	Sampling Period	Frequency	Period Flux Calculation ($tCO_2e/ac/d$)	Annual Flux Calculation ($tCO_2e/ac/yr$)
Peak	June - August	Minimum of two sampling events. If only two, no less than 30 days between events.	Mean of all measurements during the sampling period.	Mean period flux * 365 days.
Seasonal	October – February (winter) March – May (spring) June – September (summer)	Minimum of four sampling events. Each season must have at least one event and the summer season must have at least two, with no less than 30 days between events.	Mean of all measurements per each sampling season.	SUM of the mean winter season flux * 151 days and the mean spring season flux * 92 days and the mean summer season flux * 122 days.
Monthly	January - December	Minimum of 12 sampling events with no less than seven days between events. Minimum of one event per each calendar month.	Mean of all monthly measurements during the sampling period.	Mean period flux * 365 days.

Methane production from wetland soils predominantly occurs when mean soil and water temperatures exceeds 20°C (Whalen 2005). Because the peak chamber sampling type is during the hottest months in the northern hemisphere, this sampling type is most conservative; it also requires the least amount of sampling. Seasonal and Monthly chamber sampling types may provide a more accurate estimate of seasonal and inter-annual fluxes.

Sampling must occur when water levels are within mean low and mean high water (ie, not during extended low water events).

Monitoring Requirements: Chamber Sampling for Methane	
The monitoring report must include the following:	
MRR.78	Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature.
MRR.79	Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.

9.2.2.4.2 Eddy Covariance Measurements

The sampling period must be defined by the eddy covariance sampling type and the eddy covariance sampling type must be selected from Table 14; sampling periods are given for the northern hemisphere. The eddy covariance sampling type may change from monitoring period to monitoring period, but must never change within a monitoring period. The project proponent must justify their selection of the eddy covariance sampling type every monitoring period.

Flux measurements must not be verified during the sampling period if the selected eddy covariance sampling type is peak or seasonal.

Table 14: Measurement requirements for Eddy Covariance

Eddy Covariance Sampling Type	Sampling Period	Frequency	Period Flux Calculation ($tCO_2e/ac/d$)	Annual Flux Calculation ($tCO_2e/ac/yr$)
Peak	July 1 – September 30	Minimum of 21 days.	Mean of all measurements during the 21 cumulative days (or more).	Mean period flux * 365 days.
Seasonal	March 1 – May 30 (spring) July 15 – September 15 (summer)	Minimum of 21 days sampled in the spring and minimum of 21 days sampled in the summer.	Mean of all measurements during the 21 cumulative days (or more) per each season.	SUM of the mean spring season flux * 243 days and the mean summer season flux * 122 days.
Monthly	January - December	Minimum of 3 days sampled per calendar month. No less than 7 days between sampling events.	Mean of all measurements during the 36 days (or more).	Mean period flux * 365 days.

The following criteria establish the frequency of measurements within each day:

1) A sample interval is 0.5 hr.

2) A minimum of 12 samples must comprise a daily flux mean.

3) One missing sample between two samples may be linearly interpolated. No interpolation is allowed for time periods greater than 1 hr.

4) A list of interpolated samples must be recorded and provided to the verifier.

PD Requirements: Eddy Covariance Measurement	
The project description must include the following:	
PDR.69	The type of analyzer selected for direct measurements of methane, including a description of the resolution of measurements (in ppb) and the frequency at which measurements are to be taken (in Hz).
PDR.70	A table of meteorological variables selected for measurement. For each variable in the table, justification for its selection, the unit of measurement, resolution of measurement and frequency of measurement.
PDR.71	A description the eddy covariance tower configuration including the distances between sensors (vertical, northward and eastward separation).
PDR.72	A scale diagram of the eddy covariance tower configuration showing the relative location and distance of the anemometer relative to the methane sensor.
PDR.73	Plan view diagram or map of the eddy covariance tower delineating strata and the area of highest anticipated emissions within a 100m radius of the tower. Delineation of any patch vegetation (twice the dominant canopy height and occupying >100m^2 in area) occurring within the estimated 80% footprint area.
PDR.74	Description of dominant plant canopy height (in m) over an annual cycle. An estimate of the 80% flux footprint distance (in m) and parameter estimates, as follows: σ_w= standard deviation of the vertical velocity fluctuations (m/s) u_*= surface friction velocity (m/sec) z_m= measurement height (m) h_m= planetary boundary layer height (m) or 1000m z_m= roughness length (m) or 1/10th of the average canopy height

Monitoring Requirements: Eddy Covariance Measurement
The monitoring report must include the following: **MRR.80** A table of meteorological variables selected for measurement. For each variable in the table, an indication of whether the variable was measured, the make and model of the instrument used for measurement. **MRR.81** For each measured variable, a graphical plot or table of the data with respect to time during the monitoring period. A data table or plot must include at minimum: air temperature, methane concentration, methane flux. A list of interpolated/missing samples. **MRR.82** Documentation of calibration dates and zero checks for methane analyzer. Provide the date of last full calibration (0-10 ppm methane standard). Provide dates of carbon-free air gas checks for methane analyzer.

9.2.3 Monitoring Project Nitrous Oxide Flux

Nitrous oxide may be *de minimis* as determined per Section 8.4.3.2 and current VCS requirements. If it is not *de minimis*, the project proponent must monitor nitrous oxide flux $F_{P\,\Delta\,N20}^{[m]}$ using one of three approaches: applying default values (Section 9.2.3.1), proxy methods developed by the project proponent (Section 9.2.3.2) or direct measurement of flux from the project area (Section 9.2.3.3). All three approaches result in an estimate of flux in units of tCO_2e/day, which is then used in equation [G.13] to predict emissions as a result of project activities (see Section 8.2.3). Specific field methods for measuring nitrous oxide flux are described in Appendix B.

In deciding which monitoring approach to use, it should be kept in mind that direct measurement is usually the most demanding in terms of time and cost. If the project proponent is able to identify a default value or model that meets the requirements herein, these will likely be the most efficient methods.

Once an approach is selected, it cannot be changed after the first verification event.

PD Requirements: Monitoring Nitrous Oxide
The project description must include the following: **PDR.75** The selected approach for monitoring nitrous oxide.

9.2.3.1 Default Values

This section provides peer-reviewed estimates for nitrous oxide emissions flux in a variety of wetland ecosystems in several regions of North America (primarily Louisiana). The values provided in Table 16 may be used to determine a default value for nitrous oxide emissions.

If the project proponent demonstrates that the project area is not located within a direct ‘outfall’ of a NPDES major discharger (as described in this section) and is not located within a CWA Section 303d designated impaired water, the project proponent may use an applicable default value provided in Table 16 of Section 9.2.3.1.1, taking into consideration the issues described in this section in order to determine if the values in Table 16 are applicable to the project. If the project area is determined to be within the ‘outfall’ of a NPDES major discharger (ie, affected by external nitrate loading) or is located within a CWA Section 303d designated impaired water, the project proponent must either apply a proxy model (see Section 9.2.3.2) or conduct direct monitoring (see Section 9.2.3.3).

Prior to selecting a default value from Table 16, the project proponent must determine whether there exists an external nitrogen loading that is likely to influence gas fluxes in the project area. The project proponent must provide supporting evidence to show where major point sources of nitrogen are located relative to the project area and to define the hydrologic connections that lead to direct discharge into the project area. Major point sources of nitrogen may include state-authorized NPDES permits (industrial or municipal wastewater effluent) or public works projects resulting in the alteration of surface water flow into wetlands and estuaries (eg wetland restoration projects with freshwater/sediment river diversions). Major non-point nitrogen sources from surface runoff or wastewater – including agricultural, urban and suburban areas, leach fields, and leaking sewer pipes – also must be considered.

Specifically, the project proponent must demonstrate:

1. The project area is not located within a direct ‘outfall,’ nor is it downstream and in close proximity of a NPDES major discharger (>1 mgd) or public works project (river diversion) discharging elevated nitrogen effluent (>3 mg TN/L);

2. The project area is not located within a CWA Section 303d designated impaired water, where nitrogen (or ‘nutrients’) is the suspected causal factor of impairment; and

3. The project area does not receive direct surface runoff from agricultural, urban or suburban areas, and is not immediately adjacent to areas with sewer lines or leach fields.

Acceptable sources of supporting documentation to demonstrate the presence or absence of external nitrogen loading may include: state-authorized National Pollutant Discharge Elimination System (NPDES) documentation; Clean Water Act 303d Impaired Waters documentation; watershed-based Total Maximum Daily Load (TMDL) regulations; project-specific monitoring reports; first order, area-based water quality models; and ambient water quality monitoring data.

PD Requirements: Determining Project Area Exposure to Nitrogen Loading
The project description must include the following: **PDR.76** Location of the project area within a minimum definable watershed, using a USGS, EPA or state delineated watershed. **PDR.77** Locations of all NPDES major dischargers and public works projects producing > 1 MGD of elevated nitrogen effluent (>3 mg TN/L) discharging into the project area and located within the minimum definable watershed. **PDR.78** List of EPA CWA Section 303d designated impaired waters for the state.

Alternatively, other peer-reviewed estimates may be used, in which case the project proponent must demonstrate and justify the selected default value. Where default factors are used, they must be consistent with the current version of the VCS Standard's requirements for default factors (currently located in Section 4.5.6 of the VCS Standard version 3.3). The project proponent must calculate the selected default value in terms of tCO_2e/year and apply this calculated default to determine emissions in equation [G.13]. Models must be publicly available, though not necessarily free of charge, from a reputable and recognized source (eg, the model developer's website, IPCC or government agency).

PD Requirements: Default Values for Nitrous Oxide Monitoring
The project description must include the following if a default value is used to estimate nitrous oxide flux: **PDR. 79** Justification for the selected default value.

9.2.3.1.1 Default Factors in Absence of External Nitrate Loading

Under background wetland conditions, defined as those wetland areas not exposed to external nitrate loading sources (eg, a river diversion or wastewater treatment outflows, or other significant point sources), in the Mississippi River delta plain, nitrous oxide emissions flux to the atmosphere is ≤0.1 t CO2e/ac/yr (Smith et al. 1983). Under these conditions, the project proponent may use a value from Table 16, making sure to justify its applicability to the project area.

Table 15 shows annual estimates of nitrous oxide emissions fluxes from vegetated wetland and open water habitats across a salinity gradient in Louisiana (Smith et al. 1983),. The study was done over 2 years with samples taken on ~6 week intervals (17 sampling events) using static flux chambers at sites representative of background conditions for Louisiana wetlands (in the absence of external nitrate loading). The emissions fluxes are presented relative to an anticipated annual sequestration rate of 3 tCO_2e/ac/yr.

Table 15: Background annual nitrous oxide flux values from vegetated wetland and open water habitats across a salinity gradient in Louisiana (Smith et al. 1983)

Wetland Type	Annual mg N20-N/m2/yr	Annual $tCO_2e/ac/yr$	% of Benefit @ 3 $tCO_2e/ac/yr$
Salt marsh	31	0.06	2.0%
open water	10	0.02	
Brackish marsh	48	0.09	3.2%
open water	21	0.04	
Fresh marsh	55	0.11	3.6%
open water	34	0.07	

For projects in Louisiana, the values provided in Table 15 may be used to estimate nitrous oxide flux. For projects outside Louisiana, the project proponent must identify appropriate flux estimates from peer-reviewed literature and must demonstrate that they are applicable to the project.

The effects of river diversions on nitrous emissions flux to the atmosphere are less predictable than background conditions. Nitrous oxide emissions flux from freshwater wetlands near the outfall of river diversions may depend on whether the diversion is operating (positive flux to the atmosphere ~0.4 t CO2e/ac/yr; Yu et al. 2006) or not operating (flux from the atmosphere to the wetland -0.17 t CO2e/ac/yr; Table 15, Yu et al. 2006). The study of Lundberg (2012) conducted along a salinity gradient from the outfall of one river diversion showed that wetland nitrous emissions flux to the atmosphere are relatively low (< 0.07 t CO2e/ac/yr).

9.2.3.1.2 Projects in Presence of External Nitrate Loading

Exposure to high external nitrate loads may result in increased nitrous oxide emissions flux compared to background conditions. For project areas in the presence of external nitrate loading, the project proponent must either apply a proxy model (see Section 9.2.3.2) or conduct direct monitoring (see Section 9.2.3.3).

9.2.3.2 Proxy Modeling

Project proponents may develop new proxy models to predict nitrous oxide flux from wetland ecosystems. In building such a predictive model, the project proponent must measure or collect published data on response variables (nitrous oxide flux) using the guidance in Appendix B as well as possible covariates, consider a range of alternative models and select a model using statistically sound procedures, and apply the model at each verification event to predict nitrous oxide flux. Use Sections 9.2.3.2.1, 9.2.3.2.2, 9.2.3.2.3 and 9.2.3.2.4 to develop new proxy models.

Although the possible covariates to nitrous oxide flux must be reported at the time of validation, the selected model and data used to fit the model must be reported at the time of the first verification event.

9.2.3.2.1 Considering Covariates

In developing a statistical model, project proponents must first develop a list of possible covariates and list sources of potential data for those covariates, which may include direct field measurement, remote sensing, peer-reviewed scientific literature, and technical reports completed by government agencies. From the initially considered covariates, identify those whose data availability and expected relationship with methane flux are most relevant to the project needs.

Possible and selected covariates and sources for covariates must be validated.

PD Requirements: Covariates for Proxy Nitrous Oxide Models
The project description must include the following if an proxy model is used to estimate nitrous oxide flux: **PDR.80** A list of possible covariates and the sources of data available for each. **PDR.81** A list of selected covariates to be used for model fitting.

9.2.3.2.2 Collecting Data for Model Fitting and Response Variables

Data for model fitting may be collected from a combination of direct field measurements (see Appendix B), peer reviewed scientific literature and/or technical reports issued by government agencies. Field data must be collected to cover the entire range of nitrous oxide emissions flux potentially expected by the project, as well as the values of covariates that correspond to that range.

When data are collected directly by the project proponent in the field, a data collection plan (or protocol) must be prepared, detailing the data collection methods and referencing appropriate technical source documents.

Monitoring Requirements: Data Collection for Proxy Nitrous Oxide Model
The first monitoring report must include the following if an proxy model is used to estimate nitrous oxide flux: **MRR.83** Complete references to the source of any data collected from literature or reports. **MRR.84** Data collection procedures, plans or protocols for any data collected directly from the project area.

9.2.3.2.3 Model Fitting, Selection, and Goodness of Fit

This methodology is not prescriptive with regard to model form and fitting procedures, as various types of models may be appropriate depending on the observed relationship between covariates and response variables. However, the model must be fit using sound and well-documented statistical methods. The model must predict nitrous oxide flux in tCO_2e/day (or units that can be converted appropriately) from some combination of measureable covariates. The project proponents must consider a variety of model forms and data transformations as appropriate to the data collected. During model fitting, attention should be paid to outliers and overly influential data points. Residual plots should be analyzed to confirm that model fitting assumptions have been met. Model selection and goodness of fit must be evaluated as described in Appendix F.

PD Requirements: Model Fit for Nitrous Oxide
The project description must include the following if an proxy model is used to estimate nitrous oxide flux: **PDR.82** Justification that the proxy is an equivalent or better method (in terms of reliability, consistency or practicality) to determine the value of interest than direct measurement.

Monitoring Requirements: Model Fit for Nitrous Oxide
The first monitoring report must include the following if an proxy model is used to estimate nitrous oxide flux: **MRR.85** The form of the selected model. **MRR.86** Summary statistics of the model fit as appropriate to the fitting of the model. **MRR.87** The estimated model parameters. **MRR.88** A description of the range of covariate data with which the model was fit.

9.2.3.2.4 Predicting Nitrous Oxide Flux

When a proxy model is used, measurement of the selected covariates replaces direct measurement of nitrous oxide flux at each verification event. Covariates must be measured according to the procedures outlined by the project proponent in Section 9.2.2.2.1 and their actual values reported. Use the measured values as inputs to the statistical model. In the case that there is uncertainty about the value of a covariate model input, choose the value that results in the most conservative (ie, largest) estimate of nitrous oxide emissions flux. Models must not be extrapolated more than 10% (that is, no independent variables that exceed the range from which the model was fit by more than 10% must be input into the model).

Monitoring Requirements: Model Prediction for Nitrous Oxide
The first monitoring report must include the following if an proxy model is used to estimate nitrous oxide flux: **MRR.89** The values of any measured covariates. **MRR.90** The predicted nitrous oxide flux.

9.2.3.3 Direct Measurement

If using direct measurements, the project proponent must measure nitrous oxide flux using chambers. The project proponent may use the protocols prescribed in Appendix B as the basis for flux measurement in the monitoring plan.

Monitoring of gas fluxes is inherently uncertain when aggregated over space and time. This methodology addresses this uncertainty by providing requirements that ensure the fluxes are overestimated, rather than underestimated, using conservativeness as a mediator to accuracy. These requirements include guidelines for stratification, a requirement for making measurements in the stratum expected to have the highest emissions, and guidelines for the points in time during which measurements are made.

To convert monitoring data from flux per acre per day to flux per day as required in Section 8.2.3, use equation [G.12].

9.2.3.3.1 Stratification

Stratification must be used to determine the stratum that is likely to yield the greatest nitrous oxide emissions flux over the course of a year. Appendix A, Section A.1, provides general guidelines for stratifying the project area. Direct measurements must occur in the stratum that is likely to yield the greatest nitrous oxide emissions flux, and may optionally be made in other strata as well, using appropriate area-weighted stratification estimators as provided in Appendix A to determine a weighted-average estimate of flux for the project area. Strata boundaries may change over time. If this occurs, the project proponent must ensure that the stratum likely to yield the greatest nitrous oxide flux is always measured.

PD Requirements: Stratification for Nitrous Oxide Emissions
The project description must include the following if direct measurement is used to estimate nitrous oxide flux: **PDR.83** Description for how the strata were delineated. **PDR.84** Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest nitrous oxide emissions flux. **PDR.85** Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest nitrous oxide emissions flux.

Monitoring Requirements: Stratification for Nitrous Oxide Emissions
The monitoring report must include the following if direct measurement is used to estimate nitrous oxide flux: **MRR.91** Map(s) of the current strata boundaries. **MRR.92** A description of changes to the strata boundaries (if applicable).

9.2.3.3.2 Chamber Measurements

In most cases, chamber measurements for nitrous oxide flux will be collocated with methane flux. In the event that they are not collocated, the requirements of Section 9.2.2.4.1 must be used to identify the location of chambers for nitrous oxide.

9.2.3.4 Frequency of Measurement

There are two options for the frequency of nitrous oxide flux measurements:

1. In conjunction with chamber samples of methane flux per Section 9.2.2.4.1 (if applicable); or
2. Approximately once per calendar month, a minimum of 12 samples that are no less than seven days apart.

For either option, nitrous oxide flux must be calculated as the mean of all measurements.

Monitoring Requirements: Chamber Sampling for Nitrous Oxide
The monitoring report must include the following: **MRR.93** Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature. **MRR.94** Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.

9.2.4 Monitoring Project Energy Consumption

Units of energy that are consumed as a result of project activities and monitoring activities must be monitored using the direct measurement approach or the cost approach (see Sections 9.2.4.1 and 9.2.4.2).

Monitoring Requirements: Energy Consumption Measurement Method
The monitoring report must include the following: **MRR.95** The selected approach to monitoring energy consumption.

9.2.4.1 Direct Measurement of Energy Consumption

If direct measurement is used, the project proponent must maintain separate records of energy consumption for each energy type listed in Table 10 (see Section 8.1.1). The total units of energy consumed during the monitoring period for each energy type is recorded as $G_{P\,\Delta\,(ty)}^{[m]}$.

Monitoring Requirements: Direct Measurement of Energy Consumption
The monitoring report must include the following: **MRR.96** Energy consumption for each energy type listed in Section 8.1.1. **MRR.97** References to records of energy consumption.

9.2.4.2 Cost Approach to Energy Consumption

The cost approach to estimating energy consumption assumes that the project proponent does not possess definitive, itemized records of energy expenditures, given that energy and fuel costs often are paid directly by dredging subcontractors and actual energy consumption is not often reported. If the cost approach is used, the project proponent must extrapolate energy consumption based on the project budget and historic energy costs. The project proponent must adhere to the following procedure:

1. Determine the proportion of the dredging budget estimated for fuel (or electricity) purchases,
2. Identify the energy type(s) likely to have been used in the course of dredging, and
3. Calculate the estimated energy consumption by energy type using published historic energy prices (eg, U.S. Energy Information Administration) at the time of dredging activities. The estimate of total units of energy consumed during the monitoring period for each energy type is recorded as $G_{P\,\Delta\,(ty)}^{[m]}$.

The project proponent must justify how the energy prices and proportion allocated to energy type is conservative; the most conservative scenario will always be to assume the lowest energy prices and allocate the highest emission factor for each type.

Monitoring Requirements: Cost Approach to Energy Consumption	
The monitoring report must include the following:	
MRR.98	Justification for the proportion of dredging budget allocated for fuel (or electricity) purchases.
MRR.99	Justification for choice of energy type(s).
MRR.100	Documentation of historic energy costs at the time of dredging activities.
MRR.101	Justification of estimate of energy consumption.

9.2.5 Monitoring Project Sediment Transport

Emissions from energy consumption are based upon the mass of sediment transported as a result of project activities. The mass of sediment transported is given by equation [G.2] where $M_{P\,\Delta}^{[m]}$ is the mass of sediment dredged from the sediment source as a result of project activities during the monitoring period, $V_{P\,\Delta}^{[m]}$ is the volume of transported sediment, and $d_{P\,\Delta}^{[m]}$ is the density of the transported sediment. The estimated volume of transported sediment must be based upon the volume of the catchment area to which dredged sediment is transported. Given that dredged sediment is likely to be a solid-liquid mixture, the density must be measured as equation [G.1].

Monitoring Requirements: Monitoring Sediment Transport
The monitoring report must include the following: **MRR. 102** Justification for the estimate of volume of dredged sediment transported. **MRR. 103** Justification for the estimate of the density of dredged sediment. **MRR.104** Estimated mass of sediment transported.

9.2.6 Monitoring Allochthonous Carbon

For projects that do not meet the criteria for the conservative exclusion of allochthonous carbon import (per Section 5.2.1), the project proponent must monitor allochthonous carbon sedimentation. Accretion measurements (ie, with a marker horizon technique) must be used to estimate the fraction of allochthonous mineral-associated carbon with sedimentation.

Based on literature values for the project area, a conservative deduction must be assessed according to the procedures described in Appendix E.6.4 and using equation [E.4]. Using regionally appropriate literature, the project proponent must use a peer-accepted correction factor (typically ≤3% of the mineral content is bound by organic matter, see Andrews et al. 2011) for the type of wetland system (eg, fluvial, non-fluvial) in order to compute the mass of the mineral-associated carbon that must be subtracted from total soil carbon accumulation during the monitoring period.

Monitoring Requirements: Monitoring Allochthonous Carbon
The monitoring report must include the following: **MRR.105** Reference(s) to the regionally appropriate literature used to determine the correct factor for mineral-associated carbon.

9.2.7 Monitoring Baseline Methane Flux

Baseline monitoring for methane must be conducted in a suitable reference area (as defined in Section 6.3.1). Methane monitoring (chamber or eddy covariance) must conform to the requirements in Sections 9.2.2 and must use the sampling designs and specifications outlined in Appendices B and C.

9.2.8 Procedures for Quality Control and Assurance

The monitoring plan must specify specific measures for quality control and assurance. These measures must conform to the requirements in Sections 9.2.8.1, 9.2.8.2 and 9.2.8.3.

9.2.8.1 Field Measurements

The project proponent must develop a monitoring plan that includes a detailed field sampling protocol. Field data must be spot-checked for errors in sampling, transcription, and analysis (see Section 9). The project description must describe the type and frequency of training for field personnel responsible for sampling carbon stocks, fluxes, and covariates. The monitoring report must document the type and training field personnel received during the monitoring period.

PD Requirements: Field Training for Field Sampling	
The project description must include the following:	
PDR.86	A description of the type and frequency of training of field personnel responsible for sampling carbon stocks, fluxes, and covariates.

Monitoring Requirements: Field Training for Field Sampling	
The monitoring report must include the following:	
MRR.106	The type and frequency of training of field personnel during the monitoring period.

9.2.8.2 Data Transcription and Analysis

Project proponents must document a procedure for ensuring high quality data is used in determining emissions reductions and removals. This procedure must include methods for recording and archiving data, checking data for errors, and analyzing data in a transparent manner. To the extent possible, analysis methods should be maintained throughout the lifetime of the project (eg, using the same spreadsheets, software, and computer code for all calculations made during the project lifetime). A percentage of any data entered manually should be randomly checked for transcription errors, preferably by a person not involved in the initial entry.

9.2.8.3 Carbon Stock Measurements

All carbon stock data from individual plots must be provided to the validation/verification body, along with all spreadsheets or computer code used to calculate project-level carbon stocks and associated uncertainties. Data analysis should be carefully checked for transcription or calculation errors. The distribution of biomass estimates by plot should be examined and compared to available literature to confirm that reasonable results have been achieved; a similar procedure must be followed for SOC. Any plots with unusually high or low biomass or SOC (ie, outliers) should be examined closely. It is good practice to re-measure a subset of biomass plots to verify the accuracy of field measurements when non-destructive sampling techniques are used. When destructive sampling is used, evidence of calibration of instruments (such as scales) must be provided.

Monitoring Requirements: Carbon Stock Measurements	
The monitoring report must include the following:	
MRR.107	Biomass and SOC carbon stock data for all plots, along with any ancillary spreadsheets or computer code used to generate these predictions.
MRR.108	List of outliers with unusually high or low biomass or SOC, including justification for their continued inclusion.
MRR.109	Results of accuracy assessment if non-destructive sampling techniques are used. Otherwise, justification for why accuracy need not be formally addressed.

9.2.8.4 Eddy Covariance Data

The project proponent must take direct measurements of methane flux using eddy covariance. The project proponent may use the protocols prescribed in Appendix C as the basis for flux measurement in the monitoring plan.. Refer to Section 9.2.2.4.2 for eddy covariance sampling requirements. Requirements for calibration are found in Section C.2.5.

PD Requirements: Quality Control and Assurance of Eddy Covariance Data	
The project description must include the following:	
PDR.87	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

Monitoring Requirements: Quality Control and Assurance of Eddy Covariance Data
The monitoring report must include the following: **MRR.110** Description of processing software used, assumptions, and data quality control measures, which must include the selected method of coordinate rotation, detrending, and density fluctuation correction.

9.2.8.5 Laboratory Analyses

The analysis of methane and/or nitrous oxide from chamber samples (see Sections 9.2.2.3.2 and 9.2.3.3, Appendix B) must meet or exceed USEPA QA/QC requirements. The selected laboratory must provide written pre-analysis sample processing procedures, specific chemistry test methods and detection limits for the analysis.

Sample analyses must follow the EPA Method 3C (Determination of Carbon Dioxide, Methane, Nitrogen, and Oxygen from Stationary Sources). Instrument calibration must comply with EPA Protocol Gaseous Calibration Standards.

Soil samples must be analyzed for bulk density and SOC by a qualified laboratory following the methods of Nelson and Sommers 1996 and Ball 1964, respectively, or comparable methods. The chosen laboratory must have a rigorous Quality Assurance program that meets or exceeds the USEPA QA/QC requirements or similar international standards for laboratory procedures, analysis reproducibility, and chain of custody. The laboratory must also provide a document that defines the pre-analysis sample processing procedures, and the specific chemistry test methods they use at the laboratory, including the minimum detection limits for each constituent analyzed.

Monitoring Requirements: Laboratory Analyses
The monitoring report must include the following if samples are sent to a laboratory: **MRR.111** Documentation of the laboratory QA/QC protocols, the methods of sample analysis, and general calibration procedures used the laboratories conducting the analysis.

9.3 Data and Parameters Available at Validation

Data Unit / Parameter	A_{PA}
Data unit	acre
Description	Size of project area
Equations	[G.10], [G.12]
Source of data	GIS analysis prior to sampling
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of data	
Comments	

Data Unit / Parameter	$e_{(ty)}$
Data unit	tCO_2e/gal, tCO_2e/scf, tCO_2e/kWh
Description	Emissions coefficient for energy type *ty*
Equations	[G.3], [G.14]
Source of data	Emission factors in Section 8.1.1, Table 10
Justification of choice of data or description of measurement methods and procedures applied	Selected from published values
Purpose of data	
Comments	

Data Unit / Parameter	$g_{B\,(ty)}$
Data unit	gal/tonne, scf/tonne, kWh/tonne
Description	Energy consumed per metric tonne of sediment dredged in the baseline
Equations	[G.3]
Source of data	Documentation provided by project proponent
Justification of choice of data or description of measurement methods and procedures applied	Direct measurement

Purpose of data	
Comments	

Data Unit / Parameter	$p_{B\ (ty)}$
Data unit	proportion (unitless)
Description	Proportion of energy for energy type *ty* consumed in the baseline scenario
Equations	[G.3]
Source of data	Documentation provided by project proponent
Justification of choice of data or description of measurement methods and procedures applied	Calculated from direct measurement
Purpose of data	
Comments	

PD Requirements: Data and Parameters Available at Validation
The project description must include the following: **PDR.88** The value of each variable, data and parameter. **PDR.89** The units, descriptions, source, purpose and comments for each variable reported in the PD.

9.4 Data and Parameters Monitored

Data Unit / Parameter	$C_{P\ CS\ (c)}^{[m]}$
Data unit	tCO_2e
Description	Cumulative project carbon stock in pool *c* at end of monitoring period
Equations	[G.7]
Source of data	Sampling of carbon stocks
Description of measurement methods and procedures to be applied	See Appendix D
Frequency of	At least every five years

monitoring/recording	
QA/QC procedures to be applied	Independent review of equations and check against literature estimates. See Section 9.2.8.3
Purpose of data	
Calculation method	
Comments	

Data Unit / Parameter	$d_{LQD}^{[m]}$
Data unit	kg/m3
Description	Density of liquid in dredged sediment
Equations	[G.1]
Source of data	Direct measurement
Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Where sediment is transported, Every monitoring period.
QA/QC procedures to be applied	Compare data from multiple samples. See Section 9.2.8.1
Purpose of data	
Comments	

Data Unit / Parameter	$d_{SLD}^{[m]}$
Data unit	kg/m^3
Description	Density of solids in dredged sediment
Equations	[G.1]
Source of data	Direct measurement
Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Where sediment is transported, Every monitoring period
QA/QC procedures to be applied	Compare data from multiple samples. See Section 9.2.8.1
Purpose of data	

Comments	

Data Unit / Parameter	$f_{B\,\Delta\,CH4}^{[m]}$
Data unit	tCO_2e/ac/day
Description	Baseline methane emissions flux per unit area
Equations	[G.5]
Source of data	Static chamber or eddy covariance measurement
Description of measurement methods and procedures to be applied	See Section 9.2.7
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
Purpose of data	
Comments	

Data Unit / Parameter	$f_{P\,\Delta\,CH4}^{[m]}$
Data unit	tCO_2e/ac/day
Description	Methane emissions flux per unit area within project area
Equations	[G.10]
Source of data	Static chamber or eddy covariance measurement
Description of measurement methods and procedures to be applied	See Section 9.2.2.3
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
Purpose of data	
Comments	

Data Unit / Parameter	$f_{P\,\Delta\,N2O}^{[m]}$

Data unit	tCO_2e/ac/day
Description	Nitrous oxide emissions flux per unit area within project area
Equations	[G.12]
Source of data	Static chamber or eddy covariance measurement
Description of measurement methods and procedures to be applied	See Section 9.2.3.3
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
Purpose of data	
Comments	

Data Unit / Parameter	$G_{P\,\Delta\,(ty)}^{[m]}$
Data unit	gal, scf, kW
Description	Energy consumed in project area for energy type *ty* over monitoring period
Equations	[G.14]
Source of data	Direct measurement approach or cost approach
Description of measurement methods and procedures to be applied	See Sections 9.2.4.1 and 9.2.4.2
Frequency of monitoring/recording	Every monitoring period when sediment is transported
QA/QC procedures to be applied	Independent review of calculations and monitoring records. See Sections 9.2.8.1 and 9.2.8.2
Purpose of data	
Comments	

Data Unit / Parameter	$p_{SLD}{}^{[m]}$
Data unit	proportion (unitless)
Description	Proportion of solids by weight in the dredged sediment
Equations	[G.1]
Source of data	Direct measurement of dredged sediment

Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Every monitoring period when sediment is transported
QA/QC procedures to be applied	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1 and 9.2.8.2
Purpose of data	
Comments	

Data Unit / Parameter	$t^{[m]}$
Data unit	days
Description	Elapsed time from project start at the end of the monitoring period
Equations	[G.11], [G.13]
Source of data	Monitoring records
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	
Comments	

Data Unit / Parameter	$t^{[m-1]}$
Data unit	days
Description	Elapsed time from project start at the beginning of the monitoring period
Equations	[G.11], [G.13]
Source of data	Monitoring records
Description of measurement methods and procedures to be applied	N/A
Frequency of	Every monitoring period

monitoring/recording	
QA/QC procedures to be applied	N/A
Purpose of data	
Comments	

Data Unit / Parameter	$V_{P\,\Delta}^{[m]}$
Data unit	m^3
Description	Volume of sediment dredged from the sediment source over monitoring period
Equations	[G.2]
Source of data	Direct measurement
Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Every monitoring period when sediment is transported
QA/QC procedures to be applied	Independent review of calculations and monitoring records. See Section 9.2.8.2
Purpose of data	
Comments	

Monitoring Requirements: Data and Parameters Monitored	
The monitoring report must include the following:	
MRR.112	The value of each variable, data and parameter.
MRR.113	The units, descriptions, source, purpose, references to calculations and comments for each variable reported in the Monitoring Report.
MRR.114	For those variables obtained from direct measurement, a description of measurement methods and procedures. These may simply be references to components of the monitoring plan.
MRR.115	For those variables obtained from direct measurement, a description of monitoring equipment including type, accuracy class and serial number (if applicable). These may simply be references to components of the monitoring plan.
MRR.116	Procedures for quality assurance and control, including calibration of equipment (if applicable).

9.5 Grouped Projects

Grouped projects are allowable in order to permit the expansion of project activities after initial validation. For such projects, project documentation may differ by project activity instance with respect to carbon stock estimation, as stratification and plot location will vary. Otherwise, the same monitoring requirements set out in Section 9 apply.

As per Section 9.2.1.1, during the first verification including new project activity instances, all new plots must be measured.

If the original project area is stratified for SOC or biomass, then subsequent project activity instances must be similarly stratified as well, per Section 9.2.1.2.

Monitoring Requirements: Monitoring Grouped Projects	
The monitoring report must include the following when new project activity instances are added to the project:	
MRR.117	List and descriptions of all project activity instances in the project.
MRR.118	Project activity instance start dates.
MRR.119	Map indicating locations of project activity instances added to the group.
MRR.120	List of additional stratifications used for additional project activity instances; justification for why flux measurements are still located in the most conservative stratum (9.2.2, 9.2.3).
MRR.121	As project activity instances are added, the monitoring plan must be updated to reflect additional monitoring times and plot locations.

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APPENDIX A: DEFAULT STRATIFICATION AND SAMPLE UNIT ALLOCATION METHODS

Stratification, in which a population to be sampled is divided into sub-populations of known size, can be used in measurements of many variables to improve sampling effectiveness, and can help reduce uncertainty when it would be cost-prohibitive to conduct statistical sampling of sufficient density to adequately represent the entire population. The default stratification methods, including guidelines for the stratification criteria of individual variables, are described in Sections 9.1, 9.2.1.2, 9.2.2.3.1, and 9.3.2.3.1. Here, formulas that can be used to estimate means and totals from stratified samples are provided, as well as guidelines for efficiently allocating sampling units to identified strata.

Stratification should always be done prior to measurement, such that the stratum sizes are known exactly. Stratification may be performed prior to any measurement event. Different stratification schemes may be used for estimating different variables according to the preferences of the project proponent.

A.1 Sample Size and Plot Allocation

In stratified random sampling, the following equations may be used to estimate the sample size required to attain a targeted precision level. Note that this methodology does not require that sample size be calculated in this way—these equations are provided solely for the convenience of the user. Estimating sample size as described here requires an estimate of the mean and standard deviation of the variable to be estimated. These quantities may be estimated from literature or from a pilot sample. The project proponent should recognize that actual standard error of a sampled statistic will be subject to random error, and that if the mean and standard deviation used to estimate the sample size differ significantly from those properties in the actual population, the sample size actually required for the targeted precision level will also from that estimated. The most efficient allocation of plots to strata depends on the relative sizes of the strata, the estimated means and within strata variability, and potentially the costs of sampling each stratum. Three methods are available for allocating sample units, which are described below. Actual sampling units within strata should be chosen systematically with a random starting point or randomly.

A.1.1 Proportional Allocation

Proportional allocation allocates sampling units to strata in proportion to their size. Given a targeted precision level, the total required sample size may be calculated as:

$$\hat{n}_{TOTAL} = \frac{1}{\left(\frac{\mathrm{E} \times \bar{x}}{Z \times \hat{\sigma}_{\bar{x}}}\right)^2 + \frac{\mathrm{n}}{\mathrm{N}}}$$ [A.1]	
Variables	E - The allowable degree of error (eg, 0.15 for +/- 15%) $\bar{x}$ - The estimated mean of the quantity to be estimated Z - Z statistic from a normal distribution associated with the desired confidence level (1.96 for 95% confidence). $\hat{\sigma}_{\bar{x}}$ - The estimated standard deviation of the quantity to be estimated $\frac{\mathrm{n}}{\mathrm{N}}$ - The relative size of a sampling unit with respect to the entire population to be sampled (for example, in sampling with fixed area plots, this is the ratio of the plot size to the total project area size)
Section References	9.2.1, Appendix D, Appendix E
Comments	The estimated required sample size

The plots are allocated to strata in proportion to strata size as follows:

$$\hat{n}_{(k)} = \hat{n}_{TOTAL} \frac{a_{(k)}}{A_{PA}}$$ [A.2]	
Variables	$\hat{n}_{TOTAL}$ - The estimated total required number of plots $a_{(k)}$ - The area of stratum *k* A_{PA} - The total project area
Section References	9.2.1, Appendix D, Appendix E
Comments	The number of plots to be allocated to stratum *k*

A.1.2 Neyman Allocation

Sometimes strata differ in their degree of within-stratum variability. In this case, the overall standard error will be minimized if sampling efforts are concentrated toward those strata with highest variability. If estimates of the standard deviation of each stratum are available, the following equations may be used to allocate sampling units:

$$w_{(k)} = \frac{a_{(k)}\hat{\sigma}_{(k)}}{\sum_{(j)\in\mathcal{S}} a_{(j)}\,\hat{\sigma}_{(j)}}$$ [A.3]	
Variables	$a_{(k)}$ - The area of stratum *k* $\hat{\sigma}_{(k)}$ - The estimated standard deviation of the quantity to be estimated within stratum $\mathcal{S}$ - The set of all strata $a_{(i)}$ – The area $\hat{\sigma}_{(j)}$ – The standard deviation
Section References	9.2.1, Appendix D, Appendix E
Comments	The proportion of total sample size to be allocated to stratum k

$$\hat{n}_{TOTAL} = \frac{\sum_{(k)\in\mathcal{S}} \frac{a^2_{(k)}\hat{\sigma}^2_{(k)}}{w_{(k)}}}{\left(\frac{\mathrm{E}\times\bar{x}}{\mathrm{Z}} \times \frac{\mathrm{n}}{\mathrm{N}}\right)^2 + \sum_{(k)\in\mathcal{S}} a_{(k)}\,\hat{\sigma}_{(k)}{}^2}$$ [A.4]	
Variables	${a^2}_{(k)}$ - $a_{(k)}$ - The area of stratum *k* ${\hat{\sigma}^2}_{(k)}$ - The estimated standard deviation of the quantity to be estimated within stratum $\mathcal{S}$ - The set of all strata E - The allowable degree of error (eg, 0.15 for +/- 15%) $\bar{x}$ - The estimated mean of the quantity to be estimated $w_{(k)}$ – proportion of total sample size to be allocated to stratum k Z - Z statistic from a normal distribution associated with the desired confidence level (1.96 for 95% confidence). $\frac{\mathrm{n}}{\mathrm{N}}$ - The relative size of a sampling unit with respect to the entire population to be sampled (for example, in sampling with fixed area plots, this is the ratio of the plot size to the total project area size)
Section References	9.2.1, Appendix D, Appendix E
Comments	The estimated total required number of plots

$$\hat{n}_{(k)} = \hat{n}_{TOTAL} w_{(k)}$$	[A.5]
Variables	$w_{(k)}$ – proportion of total sample size to be allocated to stratum k $\hat{n}_{TOTAL}$ - The estimated total required number of plots
Section References	9.2.1, Appendix D, Appendix E
Comments	The number of plots to be allocated to stratum *k*

A.1.3 Optimal Allocation

A third allocation method incorporates both information about within strata variability and the potential for varying costs for sampling different strata:

$$w_{(k)} = \frac{a_{(k)} \hat{\sigma}_{(k)} / \sqrt{c_{(k)}}}{\sum_{(j) \in \mathcal{S}} a_{(j)} \, \hat{\sigma}_{(j)} / \sqrt{c_{(j)}}}$$	[A.6]
Variables	$a_{(k)}$ - The area of stratum *k* $a_{(j)}$ – The area of stratum *j* $\hat{\sigma}_{(k)}$ - The estimated standard deviation of the quantity to be estimated within stratum $\mathcal{S}$ - The set of all strata E - The allowable degree of error (eg, 0.15 for +/- 15%) $c_{(k)}$ or $c_{(j)}$ - The cost of sampling stratum *k* or *j*
Section References	9.2.1, Appendix D, Appendix E
Comments	The proportion of total sample size to be allocated to stratum k

A.2 Totals and Standard Errors from Stratified Samples

The total of a quantity of interest may be estimated from a stratified sample

$$\hat{T} = \sum_{(k)\in\mathcal{S}} \frac{a_{(k)}}{n_{(k)}} \sum_{(j)\in\mathcal{P}_{(k)}} y_{(j,k)}$$	[A.7]
Variables	$a_{(k)}$ - The area of stratum *k* $\mathcal{S}$ - The set of all strata $n_{(k)}$ – Number of sampling units in stratum k $\mathcal{P}_{(k)}$ – Set of all sampling units in stratum k $y_{(j,k)}$ - A quantity estimated for or measured on sampling unit j in stratum k
Section References	9.2.1, Appendix D, Appendix E
Comments	The estimated total quantity in the sampled area

$$\sqrt{\sum_{(k)\in\mathcal{S}} \left[\frac{a_{(k)}^2 \hat{\sigma}_{(k)}^2}{\#(\mathcal{P}_{(k)})} \left(\frac{N_{POSSIBLE\ (k)} - \#(\mathcal{P}_{(k)})}{N_{POSSIBLE\ (k)}}\right)\right]}$$	[A.8]
Variables	$a_{(k)}$ - The area of stratum *k* $\hat{\sigma}_{(k)}^2$ - The estimated within-stratum variance of stratum *k* $\mathcal{S}$ - The set of all strata $\mathcal{P}_{(k)}$ – Set of all sampling units in stratum k $N_{POSSIBLE\ (k)}$ = total number of possible plots in stratum k
Section References	D.1, D.2
Comments	The estimated standard error of the total

APPENDIX B: DEFAULT STATIC CHAMBER MEASUREMENT METHODS

The project proponent may deviate from the methods provided in this appendix per the requirements of Section 9.

GHG emissions fluxes have been measured with the static (closed) or dynamic (with air circulation) chamber techniques on a wide variety of wetland sites (Moore and Roulet 1991). There are a number of chamber techniques that are used to isolate soil respiration or develop carbon budgets and sophisticated soil flux systems are commercially available. While there are acceptable variations in equipment and techniques, this guidance focuses on describing a static chamber method, with discrete time series of gas measurements during each monitoring period, to calculate methane flux for baseline and project monitoring. Nitrous oxide or carbon dioxide fluxes may be sampled in the same manner, depending on project requirements. With attention to minimizing chamber and soil disturbance, periodic sampling with static chambers can provide an estimate of project area GHG emissions on a daily time scale, which is then extrapolated to annual estimates.

The methods described here are specific to herbaceous marshes where vegetation heights are typically less than 1.0 m, and present optimal conditions to sample all contributions of GHG exchange, particularly soil diffusion, ebullition, and plant-mediated transport of methane. Closed chamber methods that only isolate soil processes, by excluding vegetation, may underestimate the contribution of methane release from plants (through xylem transport to the atmosphere), which can be considerable from certain wetland 'shunt' species that have well developed aerenchyma. Therefore, vegetation must not be excluded from wetland-based sampling, but an exception exists when open water sampling may be necessary for quantifying fluxes from this habitat type. Clipping of emergent plants above the water level to accommodate the dimensions of the flux chamber is allowable immediately prior to sampling. The technique of using dynamic chambers with semi-continuous measurements of GHGs may also be used but will require a justification of the technique and description by the project proponent.

B.1 Chamber Description

Chamber size or design must be scaled to accommodate the existing vegetation height and seal the soil surface so that plant-mediated, diffusion, and ebullition fluxes are captured. Chamber design guidelines described here follow that of Yu et al. (2008) and Parkin and Venterea (2010). A cylinder or box chamber must not have a cross-sectional area less than 200 cm^2. The base seals the soil column and is permanently installed and left in the field during the monitoring period. If the base is disturbed by natural or human causes, it must be reinstalled and allowed to equilibrate for a minimum of two weeks prior to additional sample collection.

The chamber top must be less than 1.0 m in vertical height, and is only installed or fit to the permanently installed base during sampling periods. It contains two or more sealed (syringe septa) gas collection ports that allow sampling when water levels are high or low. One port will have a tube that extends lower in the chamber for retrieving samples when water level is low, and the other port(s) must have a shorter tube(s) to collect samples higher in the chamber when water level is high. Where the chamber base and top seal together there must be a gas-impermeable gasket or water trough.

Cylinder or box chamber materials may consist of stainless steel, aluminum, PVC, polypropylene, polyethylene, or plexiglass. Opaque or clear chambers are acceptable. Black material must not be used given its potential for excessive heating of the chamber in sunlight. The chamber base must have drainage ports along its vertical length to eliminate chamber flooding between monitoring periods.

For sampling open water habitats, chamber specifications are the same as above; however, a permanent chamber base or collar is not required. Rather the chamber top may be outfitted with floatation that can form a seal with the water surface.

B.2 Plot Establishment for Chambers

B.2.1 Replication

Within a stratum, there must be a minimum of two plots comprising three replicate chambers per plot. Each plot must occur within a 100 m radius of a randomly chosen sampling location center point.

From the center point, chambers may be randomly located within a 100 m radius of habitat that is representative of the stratum. Factors that must be considered for plot location include dominant vegetation type and marsh surface elevation. In choosing sample locations, project proponents must justify that the locations chosen are conservative – that is, within a stratum, chambers should be located in areas in which methane flux is expected to be greatest (see section 9.2.2.3.1 for a description methane flux indications). Typically, this involves positioning chambers in areas that occupy lower elevations in the landscape that still support dense vegetation coverage. The arrangement of chambers within this radius will be dependent on the marsh topography and a suitable amount of existing habitat to re-locate chamber plots if needed in the future. There are no minimum or maximum distance requirements between replicate chambers but the chambers should be placed such that sampling can occur within the prescribed time intervals.

B.3 Chamber Installation

Most wetland conditions will require the construction of boardwalks to minimize soil disturbance during chamber deployment and subsequent sampling. Site specific conditions (water table depth, soil permeability) will dictate the depth to which the base of the chamber is fitted into the soil; the base should be installed to a depth no lower than the mean water table depth of the site. Installation of chambers may take place anytime of the year and should occur when water levels are at or below the soil surface.

The chamber base is installed to the soil by slicing and excavating a trench that will accommodate its dimensions. The base must capture representative vegetation cover and species and disturbance to vegetation in the chamber area must be minimized. To allow soil/plant disturbance effects to diminish, the chamber must equilibrate for a minimum of two weeks prior to any sampling. Drainage ports will remain open during the equilibration period and between verification events.

PD Requirements: Chamber Description
The project description must include the following: **PDR.90** A description of the chamber design, with its dimensions or total volume, and cross-sectional area. **PDR.91** Diagram of chamber plot randomization design and the resulting chamber locations within each stratum, with the chambers identified as replicates. Provide dates when chambers were deployed in each stratum. Provide a justification that the locations chosen are conservative (ie, that they are likely to predict methane emissions flux for the entire stratum for which they are representative.)

B.4 Chamber Sampling

Flux chamber measurements require collecting syringe gas samples of ambient air outside of the chamber, replicate samples within the chamber base prior to sealing with the chamber top, and then successive samples over an incubation period less than 2 hours after sealing the chamber. A minimum of three sample intervals should be collected: time = 0 hours (unsealed chamber), time = 0.5 hours (30 min after chamber sealed), t = 1.0 hours (60 min after chamber sealed). Exact sample times are recorded during sampling.

Steps:

1. Inspect the chamber base for any physical disturbance.
2. Drainage ports that are open to atmosphere are plugged before inserting the chamber top.
3. Sample vials are vacuumed with a 10 ml syringe.
4. Collect one ambient atmosphere gas sample outside of the chamber and inject into the sample vacuum vial.
5. Duplicate (n=2) gas samples are collected inside the chamber base prior to sealing with the top of the chamber.
6. The chamber top is sealed to the base. Stopwatch is started at t=0.
7. With the chamber sealed, duplicate samples are collected at 30 min intervals and injected into vacuum vials. One minute prior to each sample collection, a stirring procedure is done by

inserting a 30 ml syringe into the chamber septa and withdrawing and expelling the full volume twice.

8. After sampling is complete, the chamber top is removed and the drainage ports are unplugged.

Samples must be stored out of direct sunlight during transport to the laboratory. A chain of custody form should be completed by the field lead and submitted to the laboratory with the samples to be maintained with their records. The steps for open water sampling follow those for wetland-based sampling.

B.5 Data Processing and Analysis

Gas concentration data from lab analyses are in volumetric units (L trace gas : L total gas) and are corrected for chamber volume, cross-sectional area and linear change with time to yield flux volume (L trace gas m^{-2} hr^{-1}), according to the following equation:

$$f_v = v_{CHAM} * c_v * 1/a_{CHAM} \qquad [B.1]$$

Variables	f_v - flux of trace gas (volume basis) in the chamber headspace over the enclosure period, corrected for chamber volume and cross sectional area (L trace gas m^{-2} hr^{-1}) v_{CHAM} - chamber volume (L) c_v - change in gas concentration over the enclosure period, or slope of best fit line calculated from simple linear regression (L trace gas L^{-1} total gas hr^{-1}) a_{CHAM} - cross-sectional area of soil enclosed by the chamber base (m^2).
Section References	9.2.2.3
Comments	Guidance for assessing goodness of fit is provided in section F.3 of Appendix F. Curve fitting methods for non-linear rates of trace gas change are outlined in: Parkin, T.B. and R.T. Venterea. 2010. Sampling protocols. Chapter 3. Chamber–based Trace Gas Flux Measurements. In: Sampling Protocols R. F. Follett, ed. P.3-1 to 3-39. www.ars.usda.gov/research/GRACEnet

To convert from volumetric to mass flux basis, the ideal gas law is used in the following equation:

$$f_{P\,\Delta} = \frac{f_v * P}{R * T} * M * 24 * 0.000001 * GHGcf \quad [B.2]$$

Variables	$f_{P\,\Delta}$ - mass of trace gas flux (tCO_2e ac/day) f_v - flux of trace gas (volume basis) (L trace gas m^{-2} hr^{-1}) *P* - barometric pressure (atm) *T* - air temperature (°K) *R* - universal gas constant (0.0820575 L atm/°K mol) *M* - molecular weight of trace gas (g/mol)
Section References	9.2.2.3
Comments	24 = conversion from hr to day 0.000001 = conversion from g to tonnes $GHGcf$ = GHG correction factor to CO2e, use 21 (CH_4) and 310 (N_2O)

With the series of repeated measures of gas concentration from a chamber, simple linear regression is used to compute the slope of gas concentration with time (c_t), which represents one replicate of gas flux (see equation [B.1]). A minimum of three replicate chambers (or plots) must be used to compute a mean flux (±1SEM) for a given location within a stratum for each verification event or sample date. Refer to Section 9.2.2.3 for chamber flux calculations.

APPENDIX C: DEFAULT EDDY COVARIANCE MEASUREMENT METHODS FOR METHANE

The project proponent may deviate from the methods provided in this appendix per the requirements of Section 9.

Eddy covariance or eddy correlation is a widely accepted micrometeorological technique to estimate flux of heat, water, atmospheric trace gases and pollutants and relies on turbulence to calculate fluxes. The semi-continuous nature of sampling allows for diurnal, seasonal, and annual budgets of energy and GHGs between the biosphere and atmosphere. Measuring carbon fluxes with the eddy covariance method has the advantage of covering broader space and more continuous measurements, unlike chamber flux techniques. The two methods may be used in concert in a heterogeneous landscape to evaluate flux contribution of distinct landforms (hummocks, hollows, ditches, open water; Teh et al. 2011, Baldocchi et al. 2011) to create a more accurate landscape or project area GHG budget.

Standard operating procedures for designing flux studies and data analyses are being unified by global and regional bio-meteorological communities, such as FLUXNET and AMERIFLUX, respectively. The information presented here draws from their basic guidelines for eddy covariance methods. Open source software is increasingly available for computing GHG fluxes that have been validated by a 'Gold Standard' (see AMERIFLUX, http://public.ornl.gov/ameriflux/sop.shtml) and a selection of the available software is given in Section 9.2.8.4.

Eddy flux is equivalent to the mean dry air density, multiplied by the mean covariance of instantaneous deviations of vertical wind velocity and the mixing ratio of a constituent (methane and carbon dioxide) in air. These covariances are corrected for density fluctuations due to water vapor (Baldocchi et al. 2011).

The eddy covariance technique, while applied in many different ecosystems, is most easily applied in areas where the canopy is relatively homogeneous and the terrain is horizontal. Thus herbaceous wetlands lend themselves well to this technique. Caution is needed when deploying eddy covariance stations, so that vertical disruptions (canopy height changes, trees, buildings) to the boundary layer of interest are minimized. The seven main assumptions for eddy covariance technique are outlined here (from Burba and Anderson 2007) and specific requirements to satisfy these assumptions are described throughout this appendix.

1. Measurements at a point represent an upwind area
2. Measurements are collected in the layer of interest (eg, constant flux layer)
3. The fetch is assumed to be adequate and measures the area of interest
4. Flux is fully turbulent
5. Terrain is horizontal
6. Average of vertical fluctuations is zero, density fluctuations are negligible, and flow convergence and divergence does not occur.

7. Instruments are capable of detecting small changes and measuring at a high frequency (>10 Hz).

There are sources of error that can affect flux computations; however, these errors, such as time lags in measurements and unleveled instruments, are adjusted according to accepted methods during data processing (see Section 9.2.8.4).

C.1 Eddy Covariance Instrumentation

Direct measurements of methane at high frequencies (10-20 Hz) are needed for eddy covariance calculations. For methane, laser absorption spectroscopy is common, and suitable instrumentation is equivalent to those of the closed path Los Gatos tunable diode laser spectrometer (DLT-100 Fast Methane Analyzer), the open path LICOR 7700 (Wave Modulated Spectroscopy), and the Campbell Scientific Trace Gas Analyzers. The chosen methane analyzer must have a resolution of ≤5 ppb methane at 10 Hz (@ 2000 ppb methane) and measurement frequencies must not be less than 10 Hz.

In addition to methane, other meteorological variables must be measured at a frequency (≥10 Hz) equivalent to the gas measurements, including wind and turbulence (three-dimensional sonic anemometer), water vapor, and air temperature. The chosen water vapor analyzer must have a resolution ≤ 0.005 mmol H20/mol air (@ 10 mmol H20/mol air). The sonic anemometer must have a resolution ≤ 0.01 m/sec (@ standard velocity of 12 m/sec). Water vapor measurements will be used to correct for air density fluctuations.

C.2 Tower Configuration

C.2.1 Orientation of Sensors and Equipment

A single tower must be used with the elevated array of eddy covariance instruments contained within a 3 m radius from the center of the tower. If a platform is used, the maximum footprint of the platform and support equipment (solar panels, flow modules, batteries) must not exceed a 5 m radius from the center of the tower base.

High frequency measurements of air properties for eddy covariance require short distances between sensors to minimize time response errors. Instrumentation on the tower must be integrated (ie, trace gas analyzers, anemometer, and temperature sensors) such that distance and orientation between sensors sample the representative air mass properties and allow frequency response corrections.

While configurations may vary depending on the wind direction of interest, the maximum horizontal distance of methane sensor or water vapor intake must not exceed 1.0 m from the center of the anemometer, unless the project proponent provides justification. The distance of the intake sensor for air density and methane sensor must be measured and recorded for elevation, in addition to the northward and eastward separation relative to the center of the sonic anemometer.

C.2.2 Landscape Location of Tower

For conservative project emissions estimates, a primary requirement is to locate the tower within the strata where the highest emissions are anticipated, and at least one-half of the footprint area (as defined by the 80% mean footprint distance) must include the highest emitting strata (see Section 9.2.2.3.1, which defines criteria for determining areas likely to have highest emissions).

The slope of the site must not exceed 1% (1 m vertical /100 m horizontal distance) in any direction within a 200m radius of the eddy covariance tower. The tower may be positioned in the landscape to capture specified wind direction(s) or it may be centrally placed within a homogeneous habitat with adequate fetch to measure all wind directions. In either case, the terrain must be homogeneous with respect to the *mean 80% footprint distance*. Homogeneous terrain here is defined as an area that contains no more than 25% areal coverage of patch vegetation that exceeds twice the dominant plant canopy height. A patch is defined as ≥100 m^2 of species (twice the dominant plant canopy height) covering >70% of the 100 m^2.

C.2.3 Sensor Height

As a general rule a sensor height of 1.0 m above the canopy can integrate fluxes from 100 m upwind under turbulent conditions. Sensor height above the canopy must be no less than one and one-half greater than the dominant plant canopy height in the footprint area. It is permissible to increase or decrease sensor height on the tower to accommodate changes in plant canopy height, as long as the sensor height is maintained above twice the canopy height. Alternately, during data post-processing vegetation canopy height may be adjusted without changing sensor height. Physical changes in sensor height must be recorded and incorporated as offsets during data processing.

C.2.4 Fetch and Flux Footprint

Fetch is described as the horizontal extent from the tower where flux is sampled, whereas the flux footprint describes how much of the measured flux comes from an area at a given horizontal distance. Sufficient fetch is needed to develop an internal boundary layer where fluxes are constant with height (Baldocchi et al. 2001). For every 1.0 m increase in vertical plant structure above an effective surface, approximately 100 m of fetch is needed to readjust the internal boundary layer (Businger 1986, in Baldocchi et al. 1988). To provide adequate fetch, the effective surface (dominant canopy height of interest) must be provided by the project proponent and the sensor height must be twice the dominant canopy height within a minimum radius of 100 m from the tower. If patch vegetation is present it must not exceed the 25% area threshold identified in Section C.2.2.

C.2.4.1 Footprint Distance Estimation

The *mean 80% footprint distance* provides the verifier with information to confirm that flux measurements are being collected within an area that is homogeneous. Here, *mean 80% footprint distance* can be estimated with a predictive model and using daytime turbulence parameters that are typical of the region (ie, from a nearby meteorological station) and the characteristics of the site.

The predicted *mean 80% footprint distance* must be estimated by the project proponent based on the methodology by Klujn et al. (2004), which uses turbulence parameters to predict the location or distance that influences a percentage of the flux. In this case, the project proponent must provide parameter estimates and the results of the predicted footprint distance with 80% flux contribution (online footprint parameterization, http://footprint.kljun.net/varinput.php) to the verifier, based on data known for the project site or estimates from local meteorological stations for the time period of measurement. The parameter estimates must include:

σ_W = standard deviation of daytime vertical velocity fluctuations (m/s)
u_* = surface friction velocity (m/sec)
z_m = measurement height (m)
h_m = planetary boundary layer height (m) or 1000 m
z_m = roughness length (m) or 1/10th of the average canopy height

C.2.5 Calibration

Calibration of methane sensors must be performed by the factory or user according to manufacturer guidelines. When LICOR equipment is used, the intervals for checks and calibration are provided here, while detailed calibration/zero instructions can be accessed via the LICOR website. The methane analyzer (LI-7700) must be fully calibrated spanning a 0 and 10 ppm methane concentration standard at least once annually with standard gases (1% accuracy). Zero and 10 ppm checks of the methane analyzer with hydrocarbon-free and 10 ppm standard gases (accuracy for zero gases = <0.1 ppm Total Hydrocarbon Concentration; accuracy for 10 ppm methane = <0.5 ppm methane) must be conducted at a minimum of twice every six months over one year of data collection. The LI-7200, which measures water vapor and carbon dioxide, must be returned to the factory at least once every three years to confirm the stability of coefficient values on the factory drift table.

C.3 Scale to Project Area

Project field monitoring designs may fall into one of several general approaches that may embrace one uniform habitat type or multiple habitat types in a single location, periodic habitat sampling, or multiple eddy covariance towers contemporaneously measuring different habitats.

1. Stationary single habitat: The simplest case is restricting long-term measurements to a single location that maximizes flux estimates from a homogeneous habitat across seasonal atmospheric and environmental events. The assumption of this approach is that the range of project-scale variability in GHG emissions is adequately characterized over an annual period.

2. Stationary multiple habitats: The eddy covariance tower may be placed a single location that generates information from different habitats that have different source/sink effects. In this case,

data are isolated by the wind direction or quadrant that corresponds to the habitat (open water, scrub-shrub, herbaceous).

3. Complete or periodic coverage of multiple habitats: For project areas with diverse habitats, each habitat type is individually instrumented and measuring simultaneously for valid inter-habitat comparisons. Another approach is to make periodic movements to different habitats with an eddy covariance tower. The degree to which periodic deployments in different locations approximate average conditions must be demonstrated by the project proponent.

Regardless of the method chosen above to scale from the tower location to the project area, project proponents must justify that the tower locations selected result in conservative estimates of methane emissions flux. To do this, project proponents must:

1. Stratify the project area based on measureable factors expected to impact methane emissions flux. These factors may include but are not limited to elevation, vegetation cover, and salinity.

2. Calculate the percentage of the total project area that falls into each methane emissions flux stratum.

3. Using the mean 80% footprint distance defined above, calculate the percentage of the expected tower footprint that falls within each stratum.

4. Demonstrate that, if the proportion of the tower footprint area that falls within each stratum differs from the proportion of the total project area that falls within each stratum, the tower footprint area contains a proportionally greater area of strata expected to have high methane emissions flux. For example, if two strata are identified (low and high emissions flux), and the project area is 40% low and 60% high, a tower footprint that includes 70% high emissions flux strata and 30% low is acceptable, while a footprint that includes 55% high emissions flux strata and 45% low is not. If evidence can be presented that a tower footprint is completely homogenous and all strata are sampled separately, this requirement can be considered satisfied.

$$f_{P\,\Delta\,CH4} = (\,\overline{\rho a}\,\overline{w's'}) \times 5.61 \times 10^{-3} \times 21$$ [C.1]	
Variables	$f_{P\,\Delta\,CH4}$ = CH_4 daily flux (tCO_2e/ac/day) $\overline{\rho a}$ - mean air density for a 0.5 hour sample interval (μmol air/m^3) $\overline{w's'}$ - mean covariance of instantaneous vertical wind velocity and mixing ratio of CH_4 in air w' - instantaneous vertical wind velocity (m/sec) s' - instantaneous mixing ratio of CH_4 in air (μmol gas/μmol air)
Section References	9.2.2.3
Comments	5.61 x 10^{-3} = unit conversion of μmol CH_4/m^2/s to tCH_4/ac/day 21 = conversion of tCH4 to tCO_2e

C.4 Data Processing and Analyses

Decades of eddy covariance methodology research has resulted in some widely accepted sequences of processing steps and corrections that should be applied. As an evolving science, however, there are debatable topics under discussion. The traditional steps in eddy covariance data processing are outlined below and the project proponent is responsible for specifying how data processing conforms to accepted methods (adapted from Burba and Anderson 2007).

Table 16: Steps to eddy covariance data processing

	Step	Accepted methods	References
1.	**Raw data unit conversion**	- raw voltage to unit conversion	
2.	**Despike**	-signals greater than 6 times the standard deviation for a given averaging period (30 min) must be removed for vertical wind velocity and gas concentration	
3.	**Calibration coefficients**	-may be done during data post processing; or, -user input corrections embedded in the instrument software and metadata	
4.	**Coordinate rotation**	- rotation to mean vertical velocity is equal to zero over a 30 min sample interval; or, -planar fit method; or, -sonic tilt correction algorithms	
5.	**Detrending**	-30 min block averaging must be used -linear and non-linear de-trending should be justified by project proponent	
6.	**Frequency response corrections**	-corrections may include: sensor separation, scalar path averaging, high-low pass filtering.	Moore, C.J. 1986. Frequency response corrections for eddy correlation systems. Boundary Layer Meteorology, 37:17-35.
7.	**Density fluctuation**	WPL correction applied to uncorrected covariances or final fluxes.	Webb, E.K., Pearman, G., and Leuning, R. 1980. Correction of flux measurements for density effects due to heat and water vapor transfer. Quarterly Journal of the Royal Meteorological Society, 106:85-100.

C.5 Flux Footprint Calculations

Flux footprint calculations must employ one of the following methods: Klujn et al. 2004 or Kormann and Meixner 2001. With either method, the project proponent must provide a summary table describing the measured meteorological conditions and the mean 80% footprint distance for the monitoring period. See equation [C.1].

APPENDIX D: DEFAULT BIOMASS MEASUREMENT METHODS

The project proponent must develop a detailed sampling protocol for the purposes of field crew consistency and documentation. The project proponent may deviate from the methods provided in this appendix per the requirements of Section 9.

D.1 Above Ground Tree Biomass

Above ground tree (AGT) biomass includes only trees above a specified diameter and is estimated using allometric equations. For each tree within a given measurement plot, diameter at breast height (dbh) is measured and input into an equation to yield an estimate of above ground biomass. Some equations may also require tree height and/or wood density. Tree biomass is then summed for each plot, and plot biomass estimates are extrapolated across the entire project area to estimate total carbon stocks in AGT biomass.

Project proponents must choose plot size and design. For example, a nested plot configuration may be utilized in order to decrease sampling size necessary to obtain an acceptable level of error. The sampling protocol should reflect the selected sampling scheme.

In each plot, required measurements are taken on every tree falling within the plot based on the sampling protocol. The sampling protocol should explain how to determine whether a given tree is "in" or "out." The project proponent may decide whether to collect height or wood density based on which metrics are required by selected allometric equations.

When a list of tree species present in the project area is available, allometric equations are to be compiled. Equations may be obtained from peer-reviewed scientific journals or developed by the project proponent, and may be species-specific, genus-specific, or generic form equations. Equations must be validated. When form equations are used, the project proponent must justify that they are conservative for species considered in the project. Since small errors in equations can lead to significant error in the biomass estimate across the entire project, it is important that equations are representative of the trees for which they are utilized—species, locale, and diameter range used to develop the equations should be considered when making selections. If equations require wood density, the project proponent may choose to employ species- or genus-specific values from peer-reviewed scientific journals instead of using field-collected data.

After field measurements are complete, the following steps are taken to calculate total project area carbon stocks in AGT:

- Using Equation [D.1], apply the appropriate allometric equation and convert the resulting biomass to carbon stocks for each tree.
- Using Equation [D.2], AGT carbon stocks are summed for each plot then divided by plot area to yield plot-wide carbon stock density.
- Using Equation [D.4], carbon stocks in each stratum are extrapolated from plot-wide carbon stock density and summed across all strata to yield average AGT carbon stocks for the project.

- Using Equations [A.8], calculate standard error of the average project carbon stock estimate.

D.2 Above Ground Non-Tree Biomass

Grasses, sedges, other herbaceous plants, shrubs, and trees smaller than the AGT pool minimum diameter are included in above ground non-tree (AGNT) biomass. Woody plants (small trees and shrubs) may be measured using either destructively-sampled clip plots or allometric equations, while herbaceous plants, if included, must be measured using clip plots. If a distinction in sampling is made between woody and herbaceous plants, a procedure to ensure that each plant is counted only once must be outlined in the sampling protocol.

Plot size will be chosen by the project proponent and will likely be much smaller than AGT plots. Though plots for AGNT sampling are separate measuring units from AGT plots, they may exist within AGT plots.

D.2.1 Destructive Sampling – Clip Plots

In the destructive sampling method, all plants in the sampling frame within a plot are cut and weighed to measure plot-wide AGNT biomass. Plants should be cut at a consistent height as close to the ground as possible. To aid in determining the extent of the plot, a sampling frame of the desired plot size must be laid on the ground and all plants within must be cut. If possible, biomass must be refrigerated as soon as possible after clipping in order to avoid mass loss due to respiration.

If the project proponent desires, woody and herbaceous plants may be destructively sampled separately, with a smaller plot size for herbaceous plants to improve sampling efficiency.

After harvest, all biomass should be placed in a drying oven at 70° C and weighed periodically until weight is static, indicating that drying is complete. Weigh all dry biomass to determine plot-wide dry weight.

Alternatively, the project proponent may elect to measure wet weight of all biomass in the field and collect a representative and well mixed subsample of which to measure dry weight. The ratio of dry-to-wet weight determined by the subsample would then be multiplied by the plot-wide wet weight to determine plot-wide dry weight.

After measurements are complete, the following steps must be taken to calculate total project area carbon stocks in AGNT:

- Using Equation [D.3], AGNT biomass is converted to carbon stocks and then divided by plot area to yield plot-wide carbon density.
- Using Equation [D.4], carbon stocks in each stratum are extrapolated from plot-wide carbon stock density and summed across all strata to yield average AGNT carbon stocks for the project.
- Using Equations [A.8], calculate standard error of the average project carbon stock estimate.

D.2.2 Allometric Equations

Allometric equations may be used to estimate biomass of trees smaller than the AGT minimum and small shrubs. It is not only less important but also potentially impractical for equations to be specific to the species level in this scenario. The project proponent may wish to destructively sample a subset of shrubs in order to develop one or more allometric equations since doing so for shrubs is far easier than for trees.

The same procedure used to estimate biomass through allometric equations used for AGT biomass must be used to find AGNT; refer to the AGT section. Note that shrub equations may use a different metric such as diameter near root collar (drc) as the independent variable.

D.3 Below ground Biomass

Below ground biomass must be estimated using proportional relationships between above ground and below ground biomass (ie, root-shoot ratios) or by SOC measurement, but not both.

D.3.1 Coarse roots

Coarse roots are defined as roots ≥ 2 mm in diameter, the IPCC suggested minimum diameter for below ground biomass. In partially or wholly forested wetlands, below ground biomass may be estimated with either root-shoot ratios or SOC measurement. In herbaceous wetland creation projects, carbon stock in coarse roots (> 2 mm) is captured by SOC measurement (see Appendix E); root-shoot ratios may not be used to calculate coarse root carbon stock in herbaceous wetlands.

D.3.1.1 Estimation using root-shoot ratios

Carbon stocks in below ground biomass may be estimated by applying a root-shoot ratio to the estimate of above ground tree and/or non-tree biomass yielded in Equation [D.4]. Root-shoot ratios from peer-reviewed literature (eg, Vadeboncoeur, Hamburg, & Yanai, 2007) in a comparable ecosystem and latitude must be used when available. If not available, the root-shoot ratios from the IPCC 2006 Guidelines may be used if appropriate for the ecosystem. The carbon concentration of roots may be determined by taking samples from roots leaving the tree base, using 50% carbon content, or by using the carbon content of above ground biomass.

If this approach is utilized, roots ≥ 2 mm must be removed from soil samples prior to analysis (see Appendix E).

D.3.1.2 SOC Measurement

In the case of herbaceous wetlands—and in forested wetlands, if the project proponent prefers—carbon stocks in coarse root biomass may be included in the SOC pool. If this approach is utilized, root-shoot ratios must not be used.

D.3.2 Fine roots

The carbon stock in fine roots (< 2 mm) is included in the SOC pool (see Appendix E).

D.4 Biomass Measurement Equations

$$x_{(i,j,k)} = \frac{44}{12} \times \frac{1}{1{,}000} \times f_{SPC}(\bullet) \times p_{(SPC)CF}$$ [D.1]	
Variables	$f_{SPC}(\bullet)$ - allometric equation for species SPC, with output in kg $p_{(SPC)CF}$ - carbon fraction for species SPC
Section References	D.1
Comments	Carbon stocks in the i^{th} tree in plot j in stratum k (tCO_2e). $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1{,}000}$ represents a conversion from kg to tonnes.

$$y_{(j,k)} = \frac{1}{a_{(j,k)}} \sum_{i \in \mathcal{X}_{(j,k)}} x_{(i,j,k)}$$ [D.2]	
Variables	$a_{(j,k)}$ - area of plot j in stratum k (ac) $x_{(i,j,k)}$ - estimated carbon stocks in the i^{th} tree in plot j in stratum k (tCO_2e) $\mathcal{X}_{(j,k)}$ - set of all measurements of a type in plot j in stratum k
Section References	D.1
Comments	Carbon stock density in above ground tree biomass in plot j in stratum k (tCO_2e/ac).

$$y_{(j,k)} = \frac{44}{12} \times \frac{1}{1{,}000} \times \frac{p_{(SPC)CF} \times md_{(j,k)}}{a_{(j,k)}}$$ [D.3]	
Variables	$p_{(SPC)CF}$ - carbon fraction for species SPC $md_{(j,k)\_}$ - dry mass of non-tree sample harvested from clip plots in plot j, stratum k (kg) $a_{(j,k)}$ - area of plot j in stratum k (ac)
Section References	D.2.1
Comments	Carbon stock density in above ground non-tree biomass in plot j in stratum k (tCO_2e/ha).

$$C_{P\ CS\ (c)} = \sum_{k \in \mathcal{S}} \frac{A_{(k)}}{n_{(k)}} \sum_{j \in \mathcal{P}_{(k)}} y_{(j,k)}$$ [D.4]	
Variables	$A_{(k)}$ - the area of stratum k (ac) $n_{(k)}$ - number of plots in stratum k $y_{(j,k)}$ - Carbon stock density in plot j in stratum k (tCO_2e/ac) $\mathcal{S}$ - set of all strata for monitoring period m $\mathcal{P}_{(k)}$ - set of all plots in stratum k
Section References	D.1, D.2
Comments	Carbon stocks in pool c in the sampled area (tCO_2e).

$$c_{BG\ (p,i)} = c_{AG\ (p,i)} \times r/s$$ [D.5]	
Variables	$c_{(p,i)AGx}$ - carbon in above ground biomass in pool p in stratum i for a given monitoring period r/s – root-shoot ratio selected
Section References	D.3
Comments	Carbon stock in below ground biomass for a given pool in stratum i.

APPENDIX E: DEFAULT SOC MEASUREMENT METHODS

Wetland soil carbon can comprise elemental (charcoal, soot), inorganic (carbonates) and organic states (dead and living plant-animal tissue). The organic form is dominant in alluvial soils which are typically poor in carbonate or calcite content. Elemental analyzers can provide direct measurements of total soil carbon, whereas the loss on ignition technique of organic matter combustion can provide an estimate of organic carbon. Chemical oxidation of organic carbon may also be used (Nelson and Sommers 1996).

Soil organic carbon (OC) in mature gulf coast wetlands is relatively constant with depth and averages 26 mg/ml (Gosselink and Hatton 1984). This vertical consistency develops as soils are saturated for extended periods and compaction/oxidation is minimal. Once wetland creation projects attain full plant coverage and long-duration hydroperiods, the process of organic matter vertical accumulation can proceed rapidly (1.0 cm/yr) both above the soil surface (via litter deposition and adventitious root growth) and within the emplaced soil (via root growth). Wetland creation projects will typically begin with a mineral-based soil that is homogeneous in elevation, soil texture, and relatively low in carbon content. The created wetland surface, or original project soil surface, becomes a long-lived marker where carbon accumulation rates can be estimated by measuring changes: (1) within the original project soil, and (2) in vertical accretion above the original project soil surface.

Accretion above the surface and within the original project soil compartments may have carbon infilling (via root growth) and vertical accretion rates. With time, the wetland soil in general may reach an equilibrium point with regards to carbon density. When this happens, changes in soil carbon stocks largely take the form of increasing vertical accretion and not necessarily increasing soil carbon density. A combined approach of soil coring and artificial marker horizons (such as feldspar clay; Knaus and Cahoon 1990) or reference devices (such as sediment reference pins; Steiger et al. 2003; USACE 1993) may be used to account for changes in carbon stocks within both compartments.

E.1 Sampling Design

Project proponents must choose plot size and design. For example, a nested plot configuration may be utilized in order to decrease sampling size necessary to obtain an acceptable level of error. The sampling protocol should reflect the selected sampling scheme.

Guidance for the design, allocation, and demarcation of core locations within a soil measurement plot is provided in VCS Module VMD0021: Estimation of Stocks in the Soil Carbon Pool.

E.2 Description of Soil Compartments

Two soil compartments may be monitored for changes in carbon stocks with time: (1) the original project soil, and (2) newly accreted material above the original project soil surface.

The project proponent may monitor both compartments, or choose to monitor stock changes only within a fixed soil sample depth, for the project lifetime. The project proponent must identify prior to the project start date either of these two methods:

1) fixed soil sample depth; or,

2) fixed soil sample depth *plus* accretion depth.

If for any reason during a monitoring event accretion measurements become unreliable, the fixed soil sample depth becomes the basis for detecting stock changes for the monitoring period.

E.2.1 Original Project Soil

Prior to the project start date, the project proponent must specify a fixed soil sample depth for the original project soil, and this depth will be fixed for the life of the project. The fixed soil sample depth must not exceed 100 cm. The fixed soil sample depth must be sampled in a manner to inventory carbon and bulk properties on a mass- volume basis. There is no requirement on the number of additional depth intervals from the original project soil that must be sampled and analyzed separately.

E.2.2 Accretion above the Original Project Soil Surface

Artificial marker horizons (described in Section E.4) must be used to assess the vertical depth ($d_{accretion}$) of material that has accreted above the original project soil from $t^{[m-1]}$ to $t^{[m]}$. Marker horizons must be deployed at a minimum of once every five years.

E.3 Coring Devices

When soils are sampled for carbon and bulk property analyses, coring devices must be used that are adequate to retrieve volumetrically intact samples. Accretion depth measurements may be taken on soil samples that are excavated with a knife or slicing instrument, but the accretion layer must be collected with a volumetrically controlled corer for carbon and bulk property analysis.

Soil density largely determines the smallest diameter corer than can be used without creating significant compaction. Highly compressible organic soils (bulk density ≤0.20 g/ cm^3) should be collected with a core tube diameter ≥7.6 cm. Soils with a bulk density >0.20 g/cm^3 can be sampled with a core tube diameter < 7.6 cm. Corer materials may consist of but are not limited to aluminum, stainless steel, PVC, or acrylic.

Core devices must allow inspection/measurement of vertical compaction of sample versus field condition. Piston corers should have a sampling base that limits the sample collection to the specified depth. McCauley peat augers may be used to collect organic soils and are designed to minimize compaction.

E.4 Artificial Marker Horizon Establishment

Marker horizons may be established with a feldspar marker technique (Knaus and Cahoon 1990; Folse et al. 2012), which consists of a 1-cm layer of white feldspar clay that is evenly sprinkled on the wetland sediment surface to create a white layer which is easily distinguishable from the natural substrate and can be used to measure surface accretion of sediments over time. Plot size must be approximately 0.25 m^2 or greater. A minimum of three marker horizon plots must be deployed in each stratum.

E.5 Soil Sample Collection

Soil from the accretion layer and the original project soil may be collected as one unit unless discrete horizons are identifiable within the sampling depth found in the original project soil, in which case the soil must be sampled in sub-increments of the sampling depth. However, the accretion layer formed from $t^{[m-1]}$ to $t^{[m]}$ must be separated from the original project soil. The accretion layer and the original project soil must be analyzed for bulk density and carbon content separately, except when an accretion layer is < 1.0 cm, in which case the accretion layer may be incorporated and analyzed for bulk density and carbon content with the original project soil. To properly adjust coring depth, a mean accretion estimate from a stratum must be known prior to sampling soil from the fixed soil sample depth. Thus, there are two soil sampling depth options available for monitoring.

- Soil Sampling Depth Option 1: fixed soil sample depth
- Soil Sampling Depth Option 2: fixed soil sample depth plus accretion depth.

Specific methods for efficient sampling will depend on local soil conditions, so prescriptive requirements for sample size, volume, and sampling depth are not provided in this methodology. Rather, project proponents must develop a locally appropriate sampling plan. In developing this plan, care must be taken that the sampling procedures employed across the depth profile do not bias the estimation of soil organic carbon. In the case that discrete soil horizons can be identified within the selected fixed soil sample depth, each horizon must be sampled separately. The volume of each soil sample taken should be large enough to capture inherent soil structure variability across the depth range represented by the sample.

In the case that a single sample is used to represent a depth range, the sample must be well homogenized prior to analysis, and care must be taken that the sample used for organic carbon determination and bulk density determination are representative of the same depth range. If multiple samples are taken across a vertical soil profile (such as by division of a core into segments), a weighted average should be used to estimate the mean carbon content across the entire depth profile, where the weights are proportional to the percentage of the total sample depth range represented by each subsample.

Refer to the most recent version of VCS Module VMD0021: Estimation of Stocks in the Soil Carbon Pool, the IPCC Good Practice Guidance for Land Use, Land Use Change, and Forestry, and Nelson and Sommers (1996) for more detailed guidance on establishing appropriate sampling protocols.

E.5.1 Accretion above the Original Project Soil Surface

The accretion depth will be measured from a minimum of three feldspar plots per sampling location within a stratum. The mean of the individual measurements from each plot will represent ($d_{accretion}$). The accretion depth from the marker horizons may be sampled by conventional coring, knife excavation, or cryogenic coring techniques. Regardless of technique, at least three measurements of the material thickness above the marker horizon must be taken with calipers or a ruler to the nearest 1.0 mm and recorded on a data sheet. The mean accretion depth will inform the total depth of subsequent soil sampling. The accretion depth must be known prior to determining the overall depth required for soil coring.

E.5.2 Original Project Soil

The original project soil must be sampled with a coring tube of an appropriate diameter (as described in Section E.3). The thickness of ($d_{accretion}$) sediment accretion above the original project soil must be accounted for, when applicable. Otherwise the original project soil is sampled to the fixed soil sample depth defined for the project.

Soil Coring Process:

1. Locate pre-determined sample plot. Remove emergent vegetation by clipping to the soil surface. Insert core tube and drive approximately 5-10 cm deeper than the fixed soil sample depth or the sum of the fixed depth and accretion depth.

2. Measure the vertical height of the soil surface relative to top of the core tube, both inside and outside of core tube to calculate compaction. If height difference is ≥ 10% of the sample depth, remove the core tube and re-sample. If height difference ≤ 10%, remove the core, aided by a cap on the top of the core tube to create a vacuum, or by inserting a hand at the base of the core tube. The core compaction estimate must be documented.

3. Transfer core to an extruding base, which may consist of a 'Meriwether extruder' (Folse et al. 2012) or equivalent device that permits extrusion from the base of the core, such that the upper soil is sectioned first, and deeper layers thereafter.

4. If the accretion depth ($d_{accretion}$) is ≤1 cm, it must be considered to be conservative to include this layer within the original project soil (ie, only core to the original fixed soil sample depth). If the accretion layer is > 1 cm, record the layer thickness as $d_{accretion}$.

5. Extrude the core to the mean accretion depth ($d_{accretion}$) as defined by the marker horizon technique (described in Section E.4 and E.5.1). The soil from this sample depth is removed and placed in a plastic bag labeled with sample location information and the sample depth to the nearest 1.0 cm.

6. After the surface accretion layer has been removed, continue the extrusion process to the original fixed soil sample depth, sectioning at the pre-defined intervals of the original project soil (as described in section E.2.1). Place the sample in a plastic bag with sample location information and deposit depth to the nearest 1.0 cm.

E.6 Soil Sample Analyses

All soil samples must be stored on ice following collection and during transport. A chain of custody form should be completed by the field lead and submitted to the laboratory with the samples to be maintained with their records.

Soil samples must be analyzed for bulk density and SOC by a qualified laboratory following the methods of Nelson and Sommers 1996 and Ball 1964, respectively, or comparable methods.

The chosen laboratory must have a rigorous Quality Assurance program that meets or exceeds the USEPA QA/QC requirements or similar international standards for laboratory procedures, analysis reproducibility, and chain of custody. The laboratory must also provide a document that defines the pre-analysis sample processing procedures, and the specific chemistry test methods they use at the laboratory, including the minimum detection limits for each constituent analyzed.

If root-shoot ratios are used to estimate carbon stocks in coarse roots (≥ 2 mm), such roots must be removed from soil samples prior to analysis. In this case, note that although coarse roots do not count toward mass or carbon content in SOC calculations, their volume should still contribute to soil core volume.

E.6.1 Bulk Density

For bulk density determination, core samples of known volume are collected in the field and oven dried to a constant weight at 105°C (for a minimum of 48 hours). The total sample is then weighed.

The bulk density of the soil core is estimated as:

$$\rho_{SOIL} = M_{soil} / V_{soil} \quad [E.1]$$	
Variables	M_{soil} - oven-dried mass of sample soil core (g) V_{soil} - volume of soil core (cm^3)
Section References	
Comments	Bulk density of soil core *j* in stratum *k* (g/cm^3)

Further guidance is provided in Nelson and Sommers (1996).

E.6.2 Direct Carbon Determination

For direct soil carbon determination, individual core samples collected in the field are oven dried to a constant weight at 105°C (for a minimum of 48 hours). Dried samples must be homogenized or ground with a Wiley Mill or ball grinder.

The prepared sample is analyzed for percent organic carbon or g C/g soil (cf_{soil}) using either dry combustion using a controlled-temperature furnace (eg, LECO CHN-2000, LECO RC-412 multi-carbon analyzer, or equivalent), dichromate oxidation with heating, or Walkley-Black method. Further guidance is provided in the IPCC LULUCF Good Practice Guidance (2003) and in Nelson and Sommers (1996).

E.6.3 Indirect Carbon Determination

Indirect carbon estimation techniques may be substituted for direct determination. Organic carbon (OC) can be estimated reliably with the loss-on-ignition (LOI) method, which combusts organic matter from a soil sample, leading to a direct relationship between soil organic matter content and organic carbon content. LOI lab techniques should adhere to those of described in Ball 1964 or Henri et al. 2001. While some variability may exist among samples, OC content should not exceed 50% of the OM content. Table 17 presents the relationships that are acceptable for converting from organic matter to organic carbon.

Table 17: Default equations for estimating organic carbon content from organic matter content with soil samples analyzed with the loss-on-ignition technique

Region	Relationship (OC and OM on a percent dry basis)	Reference
Atlantic	$OC = 0.40 * OM + 0.0025 * OM^2$	Craft et al. 1991
Gulf of Mexico	$OC = 0.4541 * OM$	Steyer et al. 2012
Pacific	$OC = 0.38 * OM + 0.0012 * OM^2$	Callaway et al. 2012

$$c_{SOC\ j} = \left[\sum_{l}^{1-x}\left(cf_{soil,l} * \rho_{soil,l} * \ d_{soil,l}\right) + \sum_{l}^{1-x}\left(cf_{soil,l} * \rho_{soil,l} * \ d_{accretion,l}\right)\right] * \frac{44}{12} * 40.47 - \ c_{alloch,j}$$ [E.2]	
Variables	$c_{SOC\ j}$ = total soil carbon measured at plot *j* ($tCO_2e\ ac^{-1}$) *x* =number of soil layers *l* = soil layer cf_{soil} = organic carbon content of the soil sample in plot *j* in stratum *k* (g C/g soil) ρ_{soil} = soil bulk density of sample in plot *j* in stratum *k* (g/cm3) d_{soil} = depth of a soil sample collected below the surface of the original project soil surface in plot *j* in stratum *k* (cm) $d_{accretion}$ = depth of soil sample collected above a marker horizon (feldspar) or control rod or pin in plot *j* in stratum *k* (cm) $c_{alloch,j}$ = allochthonous soil carbon measured at plot *j* (tCO2e/ac). This quantity is zero if the project meets the criteria in section 5.2.1.
Section References	
Comments	$\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. 40.47= conversion to t/ac

$$C = \sum_{k \in \mathcal{S}} \frac{A_{(k)}}{n_{(k)}} \sum_{j \in \mathcal{P}_{(k)}} y_{(j,k)}$$	[E.3]
Variables	$A_{(k)}$ - the area of stratum k $n_{(k)}$ - number of plots in stratum k $y_{(j,k)}$ - a quantity estimated for or measured on plot j in stratum k $\mathcal{S}$ - set of all strata for monitoring period m $\mathcal{P}_{(k)}$ - set of all plots in stratum k
Section References	D.1
Comments	Estimated total SOC stock in the sampled area

E.6.4 Allochthonous Carbon Determination

Allochthonous carbon is estimated using a marker horizon technique in order to determine the amount of mineral matter that has been deposited over the monitoring period. The mineral-associated carbon is the component that is classified as allochthonous carbon.

1. Measure the total amount of soil accumulation (accretion depth) during the monitoring period.
2. From the accretion depth, collect soil sediment samples and analyze the samples for bulk density.
3. Calculate the mineral fraction of the soil sample.
4. Use a correction factor to estimate the amount of mineral-associated carbon (allochthonous carbon) to be deducted from the carbon stocks associated with recently deposited sediment.

Core samples of known volume are collected in the field, homogenized in the laboratory, and the homogenized material is sub-sampled for combustion (with the loss-on-ignition technique, described in Section E.6.3), which removes the organic matter/carbon. (The dry bulk density of total sample is measured first; then the organic and mineral content are separated by combustion.) The total remaining material is mineral, and mineral density of the sample is calculated from the original soil sample volume.

The mass of allochthonous carbon of the soil sample above the marker horizon is estimated as:

$$c_{alloch,j} = \sum_{l}^{1-x} \left(mcf_{soil,l} * \rho_{minsoil,l} * d_{accretion,l} \right) * \frac{44}{12} * 40.47$$ [E.4]	
Variables	$c_{alloch,j}$- allochthonous soil carbon measured at plot *j* (tCO2e/ac) *x* =number of soil layers *l* = soil layer mcf_{soil} – mineral-associated carbon fraction of the soil sample in plot j in stratum k (%) $\rho_{minsoil}$ – mineral density of sample in plot j in stratum k (g cm^{-3}) $d_{accretion}$- depth of soil sample collected above a marker horizon (feldspar) or control rod or pin in plot j in stratum k (cm)
Section References	9.2.6
Comments	$\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. 40.47= conversion to t/ac Mineral associated carbon fraction of estuarine soils is typically less than 3% and a locally relevant data source may be used, or see, Andrews JE, Jickells TD, Adams CA, Parkes DJ, and Kelly SD (2011) Sediment Record and Storage of Organic Carbon and the Nutrient Elements (N, P, and Si) in Estuaries and Near-Coastal Seas. In: Wolanski E and McLusky DS (eds.) Treatise on Estuarine and Coastal Science, Vol 4, pp. 9–38. Waltham: Academic Press)

APPENDIX F: MODEL ASSESSMENT REQUIREMENTS

The project proponent may not deviate from the methods provided in this appendix because these methods are not related to monitoring or measurement. This appendix must be followed to select and assess proxy models from sections 9.2.2.2 and 9.2.3.2.

All models must be fit using a sample size of at least 30 measurements.

F.1 Model Selection

A candidate set of models to predict methane or nitrous oxide flux (the response) must be fit using an unbiased estimator of model parameters. All models must be fit to the same response data and covariate data. An estimate of Akaike Information Criterion (AIC) must be used for model selection. The model with the lowest AIC must be used to predict methane and nitrous oxide flux.

F.2 Checking Assumptions

The assumptions of the statistical methods used to fit the selected model must be listed. If ordinary least squares (OLS) is used to fit the model, this statistical method assumes the following:

1. Residuals are uncorrelated.
2. Residuals are homoscedastic.
3. Residuals are independent of each other.
4. Residuals are normally distributed.

The assumptions of the statistical method must be confirmed on the basis of sampling design, statistics and diagnostic plots. Diagnostic plots must be used to check for ‘outlier’ data points, which must be included in the model fitting unless they are determined to be erroneous. If the assumptions of the statistical method are not confirmed, then in some cases, a correction factor may be required. The correction factor must be applied from peer-reviewed literature or a statistical publication.

The selected model must not be used if the assumptions of the model are unconfirmed or if an appropriate correction factor has not been applied.

F.3 Determining Goodness of Fit

Goodness of fit must be determined based on the parameter values of the selected model. The parameter estimates must be unbiased and predictions must be monotonic on the interval of the range of plausible predicted emissions. The covariate and response data used to parameterize the model must be obtained per the requirements of Sections 9.2.2.3 or 9.2.3.3 to ensure conservativeness of model predictions. Because data for the parameterization of the model is derived from conservative measurements as described in these sections, there are no requirements on the precision of the model predictions or parameter estimates.

F.3.1 Estimates of Parameter Bias

Leave-one-out cross validation must be used to estimate the bias of parameter estimates. The estimated bias must not exceed 15% of the estimated parameter value, on average across parameters.

F.3.2 Confirmation of Monotonicity

In order to confirm that the selected model is conservative, the project proponent must provide graphical plots of the model predictions across the range of plausible input covariate values. Within this range, the function must be monotonic—that is, predictions must not change concavity and be increasing throughout the range of plausible predicted emissions. For example, if the function is increasing at a decreasing rate, it must continue to increase at a decreasing rate across the interval of plausible predicted emissions.

APPENDIX G: EQUATIONS IN METHODOLOGY

$$d_{P\,\Delta}^{[m]} = p_{SLD}{}^{[m]} d_{SLD}^{[m]} + (1 - p_{SLD}{}^{[m]}) d_{LQD}^{[m]}$$	[G.1]
Variables	$\boldsymbol{d_{P\,\Delta}^{[m]}}$, $\boldsymbol{p_{SLD}{}^{[m]}}$, $\boldsymbol{d_{SLD}^{[m]}}$, $\boldsymbol{d_{LQD}^{[m]}}$
Section References	9.2.5
Comments	Density of sediment dredged from sediment source.

$$M_{P\,\Delta}^{[m]} = \frac{V_{P\,\Delta}^{[m]} d_{P\,\Delta}^{[m]}}{1000}$$	[G.2]
Variables	$\boldsymbol{M_{P\,\Delta}^{[m]}}$, $\boldsymbol{V_{P\,\Delta}^{[m]}}$, $\boldsymbol{d_{P\,\Delta}^{[m]}}$
Section References	9.2.5
Comments	Mass of sediment dredged from the sediment source as a result of project activities.

$$E_{B\,\Delta\,EC}^{[m]} = -M_{P\,\Delta}^{[m]} \sum_{(ty)\in\mathcal{T}_{B\,EC}} e_{(ty)}\, g_{B\,(ty)}$$	[G.3]
Variables	$\boldsymbol{E_{B\,\Delta\,EC}^{[m]}}$, $\boldsymbol{M_{P\,\Delta}^{[m]}}$, $\boldsymbol{e_{(ty)}}$, $\boldsymbol{g_{B\,(ty)}}$
Section References	8.1.1
Comments	Total baseline emissions from energy consumption in the monitoring period (tCO_2e).

$$F^{[m]}_{B\,\Delta\,CH4} = A_{PA} \times f^{[m]}_{B\,\Delta\,CH4}$$	[G.4]
Variables	$\boldsymbol{F^{[m]}_{B\,\Delta\,CH4}}$, $\mathrm{A_{PA}}$, $\boldsymbol{f^{[m]}_{B\,\Delta\,CH4}}$
Section References	8.1.2, 9.2.2
Comments	Baseline methane emissions flux (tCO_2e/day).

$$E^{[m]}_{B\,\Delta\,CH4} = -\left(t^{[m]} - t^{[m-1]}\right)F^{[m]}_{B\,\Delta\,CH4}$$	[G.5]
Variables	$\boldsymbol{E^{[m]}_{B\,\Delta\,CH4}}$, $\boldsymbol{t^{[m]}}$, $\boldsymbol{t^{[m-1]}}$, $\boldsymbol{F^{[m]}_{B\,\Delta\,CH4}}$
Section References	8.1.2
Comments	Total baseline methane emissions from methane over monitoring period (tCO_2e).

$$E^{[m]}_{B\,\Delta} = E^{[m]}_{B\,\Delta\,EC} + E^{[m]}_{B\,\Delta\,CH4}$$	[G.6]
Variables	$\boldsymbol{E^{[m]}_{B\,\Delta}}$, $\boldsymbol{E^{[m]}_{B\,\Delta\,EC}}$, $\boldsymbol{E^{[m]}_{B\,\Delta\,CH4}}$
Section References	8.1
Comments	Total baseline emissions over monitoring period (tCO_2e). (If dredging is not included in the baseline scenario, emissions from energy consumption are zero (see section 6.2); if methane ebullition is not included in the baseline scenario, methane emissions are zero.)

$$C_{P\,CS}^{[m]} = \sum_{(c)\in\mathcal{C}} C_{P\,CS\,(c)}^{[m]}$$	[G.7]
Variables	$\boldsymbol{C_{P\,CS}^{[m]}}$, $\boldsymbol{C_{P\,CS\,(c)}^{[m]}}$
Section References	9.2.1, 9.2.1.1
Comments	Cumulative carbon stocks in project area at end of monitoring period.

$$E_{P\,\Delta\,CS}^{[m]} = C_{P\,CS}^{[m]} - C_{P\,CS}^{[m-1]} - 0.131E_{P\,\Delta\,CH4}^{[m]}$$	[G.8]
Variables	$E_{P\,\Delta\,CS}^{[m]}$, $\boldsymbol{C_{P\,CS}^{[m]}}$, $\boldsymbol{C_{P\,CS}^{[m-1]}}$, $\boldsymbol{E_{P\,\Delta\,CH4}^{[m]}}$,
Section References	8.2.1
Comments	Total carbon stock emissions or emissions reductions and/or removals in the project area for the monitoring period (tCO_2e). For the first monitoring period $C_{P\,CS}^{[m-1]} = C_{P\,CS}^{[m=0]}$ or the carbon stocks in the project area prior to the project start date. Last term in equation ($0.131E_{P\,\Delta\,CH4}^{[m]}$) is included in order to avoid double-counting of sequestered carbon that subsequently was released as a methane flux. The coefficient (0.131) represents a conversion for the differences in mass (44 CO_2 = 16 CH_4) and global warming potential (1 CO_2 = 21 CH_4): 1 ton CO2 = (44/16)*(1/21) = 0.131.

$$E^{[m]}_{P\,\Delta\,CS} = -0.131E^{[m]}_{P\,\Delta\,CH4} + \sum_{(i)\in\mathcal{G}} C^{[m]}_{P\,CS\,(i)} - C^{[m-1]}_{P\,CS\,(i)}$$ [G.9]	
Variables	$\boldsymbol{E^{[m]}_{P\,\Delta\,CH4}}$, $\boldsymbol{C^{[m-1]}_{P\,CS}}$, $\boldsymbol{C^{[m]}_{P\,CS}}$ $\boldsymbol{E^{[m]}_{P\,\Delta\,CS}}$
Section References	8.2.1
Comments	Total carbon stock emissions or emissions reductions and/or removals in the project area for the monitoring period for project activity instances in a grouped project (tCO_2e). First term in equation ($0.131E^{[m]}_{P\,\Delta\,CH4}$) is included in order to avoid double-counting of sequestered carbon that subsequently was released as a methane flux. The coefficient (0.131) represents a conversion for the differences in mass (44 CO_2 = 16 CH_4) and global warming potential (1 CO_2 = 21 CH_4): 1 ton CO2 = (44/16)*(1/21) = 0.131.

$$F^{[m]}_{P\,\Delta\,CH4} = A_{PA} \times f^{[m]}_{P\,\Delta\,CH4}$$ [G.10]	
Variables	$\boldsymbol{F^{[m]}_{P\,\Delta\,CH4}}$, $\boldsymbol{A_{PA}}$, $\boldsymbol{f^{[m]}_{P\,\Delta\,CH4}F^{[m]}_{P\,\Delta\,CH4}}$
Section References	8.2.2, 9.3.2.3
Comments	Methane emissions flux within project area (tCO_2e/day).

$$E_{P\,\Delta\,CH4}^{[m]} = -\left(t^{[m]} - t^{[m-1]}\right) F_{P\,\Delta\,CH4}^{[m]}$$	[G.11]
Variables	$\boldsymbol{E_{P\,\Delta\,CH4}^{[m]}}$, $\boldsymbol{t^{[m]}}$, $\boldsymbol{t^{[m-1]}}$, $\boldsymbol{F_{P\,\Delta\,CH4}^{[m]}}$
Section References	8.2.2, 9.2.2, 9.2.2.1
Comments	Total methane emissions in project area over monitoring period (tCO_2e).

$$F_{P\,\Delta\,N2O}^{[m]} = A_{PA} \times f_{P\,\Delta\,N2O}^{[m]}$$	[G.12]
Variables	$\boldsymbol{F_{P\,\Delta\,N2O}^{[m]}}$, $\boldsymbol{A_{PA}}$, $\boldsymbol{f_{P\,\Delta\,N2O}^{[m]}}$
Section References	9.3.3.3
Comments	Nitrous oxide emissions flux within project area (tCO_2e/day).

$$E_{P\,\Delta\,N2O}^{[m]} = -\left(t^{[m]} - t^{[m-1]}\right) F_{P\,\Delta\,N2O}^{[m]}$$	[G.13]
Variables	$\boldsymbol{E_{P\,\Delta\,N2O}^{[m]}}$, $\boldsymbol{t^{[m]}}$, $\boldsymbol{t^{[m-1]}}$, $\boldsymbol{F_{P\,\Delta\,N2O}^{[m]}}$
Section References	8.2.3, 9.2.3, 9.2.3.1
Comments	Total nitrous oxide emissions in project area over monitoring period (tCO_2e).

$$E^{[m]}_{P\,\Delta\,EC} = -\sum_{(ty)\in\mathcal{T}_{P\,EC}} G^{[m]}_{P\,\Delta\,(ty)} e_{(ty)}$$ [G.14]	
Variables	$\boldsymbol{E^{[m]}_{P\,\Delta\,EC}}$, $\boldsymbol{G^{[m]}_{P\,\Delta\,(ty)}}$, $e_{(ty)}$
Section References	8.2.4
Comments	Total emissions from energy consumption in project area over monitoring period (tCO_2e).

$$E^{[m]}_{P\,\Delta} = E^{[m]}_{P\,\Delta\,CS} + E^{[m]}_{P\,\Delta\,CH4} + E^{[m]}_{P\,\Delta\,N2O} + E^{[m]}_{P\,\Delta\,EC}$$ [G.15]	
Variables	$\boldsymbol{E^{[m]}_{P\,\Delta}}$, $\boldsymbol{E^{[m]}_{P\,\Delta\,CS}}$, $\boldsymbol{E^{[m]}_{P\,\Delta\,N2O}}$, $\boldsymbol{E^{[m]}_{P\,\Delta\,CH4}}$, $\boldsymbol{E^{[m]}_{P\,\Delta\,EC}}$
Section References	8.2
Comments	Total emissions or emissions reductions and/or removals in project area over monitoring period (tCO_2e).

$$E^{[m]}_{GER\,\Delta} = E^{[m]}_{P\,\Delta} - E^{[m]}_{B\,\Delta}$$ [G.16]	
Variables	$\boldsymbol{E^{[m]}_{GER\,\Delta}}$, $\boldsymbol{E^{[m]}_{B\,\Delta}}$, $\boldsymbol{E^{[m]}_{P\,\Delta}}$
Section References	8.4.1
Comments	Total gross emissions reductions and/or removals over monitoring period (tCO_2e).

$$E_{GER}^{[m]} = \sum_{m \in \mathcal{M}} E_{GER\,\Delta}^{[m]}$$ [G.17]	
Variables	$\boldsymbol{E_{GER}^{[m]}}$, $\boldsymbol{E_{GER\,\Delta}^{[m]}}$ $\boldsymbol{E_{GER\,\Delta}^{[m]}}$
Section References	8.4.1.1
Comments	Cumulative gross emissions reductions and/or removals over monitoring period (tCO_2e).

$$U_{P\,CS}^{[m]} = \sqrt{\sum_{(c) \in \mathcal{C}} \left(U_{P\,CS\,(c)}^{[m]}\right)^2}$$ [G.18]	
Variables	$\boldsymbol{U_{P\,CS}^{[m]}}$, $\boldsymbol{U_{P\,CS\,(c)}^{[m]}}$
Section References	8.4.2.1
Comments	Total standard error of carbon stocks over monitoring period (tCO_2e).

$$E_{U\,\Delta}^{[m]} = E_{GER\,\Delta}^{[m]} \left[\frac{1.645 \times U_{P\,CS}^{[m]}}{C_{P\,CS}^{[m]}} - 0.15\right]$$ [G.19]	
Variables	$\boldsymbol{E_{U\,\Delta}^{[m]}}$, $\boldsymbol{E_{GER\,\Delta}^{[m]}}$, $\boldsymbol{U_{P\,CS}^{[m]}}$, $\boldsymbol{C_{P\,CS}^{[m]}}$
Section References	8.4.2.1
Comments	Confidence deduction for monitoring period (tCO_2e). This quantity must be greater than or equal to zero.

$$E_{BA\,\Delta}^{[m]} = b^{[m]} E_{P\,\Delta\,CS}^{[m]}$$	[G.20]
Variables	$\boldsymbol{E_{BA\,\Delta}^{[m]}}$, $\boldsymbol{b^{[m]}}$, $\boldsymbol{E_{P\,\Delta\,CS}^{[m]}}$
Section References	8.4.2.2
Comments	Total emissions reductions and/or removals allocated to AFOLU pooled buffer account over monitoring period.

$$E_{NER\,\Delta}^{[m]} = E_{GER\,\Delta}^{[m]} - E_{U\,\Delta}^{[m]} - E_{BA\,\Delta}^{[m]} + E_{BR\,\Delta}^{[m]}$$	[G.21]
Variables	$\boldsymbol{E_{NER\,\Delta}^{[m]}}$, $\boldsymbol{E_{GER\,\Delta}^{[m]}}$, $\boldsymbol{E_{U\,\Delta}^{[m]}}$, $\boldsymbol{E_{BA\,\Delta}^{[m]}}$, $\boldsymbol{E_{BR\,\Delta}^{[m]}}$
Section References	8.4.2
Comments	Total net emissions reductions and/or removals over monitoring period (tCO_2e).

APPENDIX H: SUPPORTING INFORMATION ON DEVELOPMENT OF POSITIVE LIST

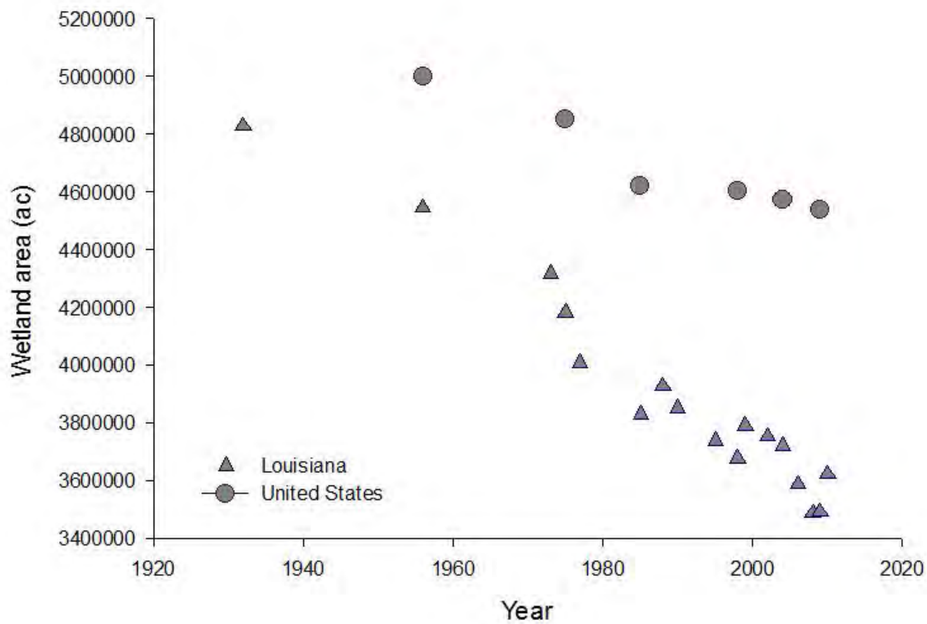
The methodology specifies a positive list for additionality based on activity penetration in specific geographic scopes. The level of activity penetration for a project activity in a given geographic region is determined using appropriate credible data, including from federal agencies (eg, USACE, USGS, USFWS). In order to define the activity and geographic scope for the positive list, the methodology developer demonstrated both the maximum adoption potential and the observed adoption of the project activity (eg, the number and extent of the activity which has been implemented). The calculated level of activity penetration of RWE project activities is currently determined to be less than 5 percent and the level of activity penetration of ARR+RWE project activities meeting the applicability conditions of this methodology is negligible.

The maximum adoption potential takes into account the relevant factors affecting the adoption of the activity within the applicable geographic scope, including implementation potential (ie, the extent of wetland loss within the geographic scope), resource availability (ie, the local supply of dredged sediments), technological capacity (ie, the amount of locally available dredging equipment), level of service (ie, the availability of dredging equipment), socio-economic conditions (ie, the presence of competing economic activities occurring in the coastal zone), and climatic conditions (ie, the incidence of hurricanes and extreme tidal fluctuations). In the case of socio-economic conditions and competing economic activities (eg, oyster farming), the methodology developers concluded that such competing activities are not common enough to limit or displace coastal wetland reestablishment activities, and moreover such economic activities do not vary significantly among regions within the geographic scope. The methodology developers also considered the spatial heterogeneity of climate conditions across the geographic scope, and concluded that regardless of the likelihood of such extreme climate events, the project proponent must demonstrate a long-term trend of wetland loss (see section 6.1). Further, once a project has been established, the methodology ensures that the impacts of a climate event will be captured by the monitoring activities and will be reflected in the carbon accounting. Maximum adoption potential does not consider cost of adoption, cultural or behavioral barriers, and laws, statues, regulatory frameworks or policies.

H.1 Synopsis

This methodology deems project activities as additional, and qualifies them for a positive list based on low rates of adoption in the United States. The total need or adoption potential for coastal wetland creation is conservatively ~1.482 million ac, based on historic loss in the lower 48 states since the 1930's (Figure 1). Approximately 2.7% (39,834) ac of the total coastal wetlands lost in the U.S. has been rebuilt. Therefore, creation of wetlands as described in this methodology, for both RWE and ARR+RWE projects, is deemed additional in accordance with VCS requirements.

Figure 1: Estimates of estuarine vegetated wetland in the U.S. and coastal land area in Louisiana



The following sections—*Analysis* and *Supporting Technical Information*—present the adoption potential analysis and summaries of national and region-specific wetland changes and creation efforts.

H.2 Analysis

This analysis demonstrates that the level of “activity penetration” for creation of coastal wetlands is currently much less than 5%. Substantial needs exist for rebuilding of wetlands lost due to various direct and indirect anthropogenic factors. However, due to funding constraints only a small fraction of the need has been satisfied as of the completion of this methodology.

The positive list for activities established under this methodology is based on a demonstration that the project activities have achieved a low level of penetration relative to their maximum adoption potential, in accordance with VCS requirements. This activity penetration level is estimated using the following equation:

$$AP_y = OA_y / MAP_y$$

Where,

AP_y =	Activity penetration of the project activity in year y (percentage)
OA_y =	Observed adoption of the project activity in year y (eg, total number of instances installed at a given date in year y, or amount of energy supplied in year y)
MAP_y =	Maximum adoption potential of the project activity in year y (eg, total number of instances that potentially could have been installed at a given date in year y, or the amount of energy that potentially could have been supplied in year y)

The following analysis estimates penetration level, current as of 2012, for the conterminous United States. Since a key location for application of this methodology is Louisiana, it will also be demonstrated using state-specific data.

Given adequate time and funding, adequate supplies of sediment for wetland are available, either from rivers or nearshore/offshore locations where they are routinely dredged. Resource availability is not a constraint. As an ecosystem restoration activity, total demand, market access, and market price are not relevant factors in this analysis. Implementation potential is the need for wetland restoration and is therefore considered equal to maximum adoption potential.

In order to arrive at a conservative estimate for the maximum adoption potential, data from two studies are used. The first (Couvillion et al. 2012) provides data from Louisiana only and indicates that total coastal wetland loss in Louisiana amounted to 1,205,120 ac. This study provides a comprehensive and detailed estimate of wetland loss, including both coastal fresh and saltwater wetlands. The second is a national level study (Dahl 2000, 2006, 2011) that estimates total U.S. wetland loss of 461,000 ac, but includes only estuarine vegetated wetlands, thus excluding the losses of tidal freshwater wetlands. Because coastal Louisiana loss is commonly accepted to be 40% of the national total, the national vegetated estuarine wetland loss excluding Louisiana was estimated at 276,000 ac. Adding in the long-term historic wetland loss in Louisiana of 1,205,120 ac with the less-comprehensive national estimate of 276,000 ac yields 1,481,720 ac. The two studies used to derive the maximum adoption potential are described in more detail below.

Based on USGS data (Couvillion et al. 2012), approximately 1.205 million acres of Louisiana's coastal wetlands have been lost and converted to open water since the 1930's. Louisiana's Coastal Protection and Restoration Authority (CPRA) has tracked engineered wetland creation projects by the State, in addition to USACE beneficial use projects. CPRA estimates that approximately 16,137 acres have been created since 2005, including both the State's projects and USACE beneficial use projects (Table H3, *Supporting Technical Information*). Therefore, the current level of activity penetration in Louisiana is approximately 1.3% (16,137 ac created/1,205,000 ac lost).

At a national scale, the U.S. Fish & Wildlife Service Status & Trends reports (Dahl 2000, 2006, 2011) estimate that 461,000 acres of vegetated estuarine wetlands have been lost since the 1950s (Table H2, *Supporting Technical Information).* This estimate excludes the losses of tidal freshwater wetlands, which results in a conservative (underestimate) of total tidal and estuarine wetland loss (tidal freshwater wetlands are now reported as 'Palustrine,' which typically includes all inland freshwater systems). For example, a more detailed analysis by Stedman and Dahl (2008) showed that the *coastal watersheds* of the Gulf of Mexico and the Atlantic states lost a total of 370,760 ac and 14,980 ac, respectively, of freshwater and saltwater wetlands.

Given that total coastal wetland creation as described in Section H.3.5 was 39,834 ac and the maximum adoption potential is 1,481,720 ac, the resulting activity penetration level is approximately 2.7%. With observed adoption less than the need for replacement of wetlands, adoption potential is below the 5% threshold set by VCS requirements. Therefore, coastal wetland creation projects are deemed additional.

H.3 Supporting Technical Information

H.3.1 Estuarine Vegetated Wetland Loss in the United States

Estuarine vegetated wetland loss in the United States since the 1950's to 2009 has been estimated at approximately 461,000 ac (Table H1). Based on the most recent analysis from 2004-2009 (Dahl 2011), approximately 111,000 ac of estuarine vegetated wetlands were lost over the 4.5 year period, or approximately 25,000 ac/yr.

Wetland loss prior to the 1980's may have included direct conversion of wetlands to agriculture and coastal development. Since the 1980's, however, conversion of wetlands to deep open water has been responsible for wetland losses, as excerpted from Dahl's analyses:

> "[The 1998-2004 rate of loss] *was consistent with the rate of salt marsh loss recorded from 1986 to 1997 (Dahl 2000). Urban and rural development activities, and the conversion of wetlands to other upland land uses, accounted for an estimated loss of 1,732 acres (700 ha) or about 3.0 percent of all losses of estuarine emergent wetland. Most of the losses of estuarine emergent wetland were due to loss to deep salt water and occurred in coastal Louisiana*." (Dahl 2006)
>
> "[The 2004-2009 rate of loss] *of intertidal emergent wetland increased to three times the previous loss rate between 1998 and 2004. The majority of these losses (83%) was to deepwater bay bottoms or open ocean.*"

H.3.2 Vegetated Wetland Loss in Coastal Watersheds in the Atlantic and Gulf of Mexico

An analysis of *coastal watershed* vegetated wetland changes in the eastern United States (1998-2004) (Stedman and Dahl 2008) showed that the Gulf of Mexico and Atlantic states had net wetland losses in coastal watersheds totaling 370,760 ac and 14,980 ac, respectively, when including both fresh and saltwater wetlands. Total saltwater vegetated wetland loss was 64,970 ac, of which 96% (or 62,370 ac) was conversion to open saltwater.

Table H1: Historic and contemporary estimates of estuarine vegetated wetland acreage since the mid-1950's for the United States and Atlantic/Gulf of Mexico regions based on similar mapping techniques

Time period	**Conterminous US** Estuarine vegetated wetland (ac) (Dahl 2006, Dahl 2011)	**Atlantic Coastal Watershed** Vegetated wetland (ac) (Stedman and Dahl 2008)	**GOM Coastal Watershed** Vegetated wetland (ac) (Stedman and Dahl 2008)
1950's	5,000,000		
1970's	4,854,000		
1980's	4,623,000		
1998	4,604,200	1,842,320	3,108,110
2004	4,571,700	1,822,780	3,062,680
2009	4,539,700		
Notes	US wetland loss (1950's-2009) 461,000 ac	Atlantic wetland loss (98-04) 19,540 ac	GOM wetland loss (98-04) 45,430 ac

H.3.3 Wetland Loss in Louisiana

The most recent study by Couvillion et al. (2012) summarized wetland loss during 1932-2010 and intervals in between. Cumulative wetland loss in Louisiana from 1932-2010 was estimated at 1,205,120 ac. Trend analyses of comparable satellite imagery were limited to the 1985-2010[4] time period, which showed a loss rate of 10,605 ac/yr.

H.3.4 Proportion of Coastal Wetland Loss in Louisiana Compared to the U.S.

Based on a number of analyses, Louisiana wetland loss has been commonly accepted to be ~ 40% of the national total. This is supported by the recent analyses by Couvillion et al. (2012) and Dahl (2011), which showed that the annual loss rate in Louisiana (-10,605 ac/yr, from 1985-2010) was 42% of the national rate (-25,000 ac/yr 2004-2009).

[4] The calculation of wetland loss rates in Louisiana is sensitive to water level during imagery acquisition. More recent and frequent satellite imagery has allowed for a large number of images to be analyzed and reduced uncertainty.

H.3.5 Wetland Creation in the United States and Louisiana

The most significant nationwide wetland creation effort has been accomplished with beneficial placement of dredged sediments by the USACE (Table H2). More recently, a state wetland creation program has been developed in Louisiana by the Coastal Protection and Restoration Authority (CPRA) (Table H3).

Including Louisiana, marsh creation and nourishment by the USACE has totaled approximately 32,355 ac from 2007-2012 (Table H2). There are several reasons why these data produce a conservative overestimate of actual wetland creation. First, the USACE presents both wetland 'creation' and 'nourishment' together. Second, there are 11 non-coastal districts which are included in the statistics presented in Table H2 (although the non-coastal districts comprise only 5 percent of the total dredging conducted by the USACE). Third, the assumed conversion value of 1 ac = 6,250 CY may be low for some areas. For example, the actual CY of sediment needed for an acre of wetland creation ranges from approximately 6,000 CY to 16,000 CY (calculated from data in Table H3).

In Louisiana, engineered wetland creation projects have been tracked more precisely than USACE nationwide projects. Based on CPRA's data set, approximately 7,479 ac of wetlands have been created in Louisiana during FY 2005-2012 Table H3), not including the USACE's beneficial use projects (which are included in Table H2).

Combining both data sets results in an estimate of 39,834 ac (nationwide USACE = 32,355 ac; Louisiana state projects = 7,479 ac) of wetland creation and nourishment that has occurred nationwide through efforts of the USACE and the State of Louisiana, which comprise the most significant sources of wetland creation with dredged material.

Table H2: Estimated nationwide USACE wetland creation and nourishment from both coastal and non-coastal areas of the U.S. Acreage estimates are derived from dredge disposal statistics from the USACE Navigation Data Center: http://www.navigationdatacenter.us/dredge/drgdisp.htm (Disposal Type = Wetland Creation and Nourishment). For more information, contact U.S. Army Corps of Engineers, CEIWR-NDC, 7701 Telegraph Road, Casey Bldg., Alexandria, Virginia 22315-3868, point of contact: NDC (703) 428-9061**.**

Year	Contracts	Cubic Yards (Bid)	Dollars (Bid)	Estimated Acres[5]
2007	9	38,075,031	$69,878,722	6,092
2008	9	49,108,000	$55,467,694	7,857

[5] Assumes that 6,250 CY of sediment is needed to create one acre of wetland, based on USACE, 2006, Louisiana Coastal Area Beneficial Use of Dredge Material: http://www.lca.gov/Studies/budmat.aspx.

2009	7	25,582,361	$56,902,237	4,093
2010	9	37,481,966	$107,437,192	5,997
2011	6	17,705,385	$28,221,454	2,833
2012	8	34,263,868	$94,759,277	5,482
			Estimated Total	32,355 ac

Table H3: Wetland creation acreage constructed in Louisiana during FY2005-2012 by CPRA and USACE (data courtesy of CPRA)

	Louisiana (Federal/State/Other)		Louisiana (USACE Beneficial Use)		Total
Year	CY	AC	CY	AC	AC
2004-2005	244,441	26	14,686,790	515	541
2005-2006	0	0	9,286,170	604	604
2006-2007	6,099,372	920	16,018,350	1,228	2,148
2007-2008	1,593,629	262	8,726,625	522	784
2008-2009	11,653,148	1,350	8,134,849	248	1,598
2009-2010	21,303,000	3,483	19,613,374	1,591	5,074
2010-2011	6,300,000	94	27,325,000	2,514	2,608
2011-2012	16,764,560	1,344	15,125,000	1,437	2,781
Total	63,958,150	7,479	118,916,158	8,658	**16,137**

H.4 References

Couvillion, B.R.; Barras, J.A.; Steyer, G.D.; Sleavin, William; Fischer, Michelle; Beck, Holly; Trahan, Nadine; Griffin, Brad; and Heckman, David, 2011, Land area change in coastal Louisiana from 1932 to 2010: U.S.

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Dahl, T.E. 2011. Status and trends of wetlands in the conterminous United States 2004 to 2009. U.S. Department of the Interior; Fish and Wildlife Service, Washington, D.C. 108 pp.

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APPENDIX I: JUSTIFICATION FOR THE EXCLUSION OF ALLOCHTHONOUS CARBON IN THE LOUISIANA COASTAL ZONE

I.1 Introduction

Many estuarine wetlands are exporters or sources of carbon to the continental shelf, typically termed ‘carbon outwelling’. Net burial of carbon in tidal wetland soils is usually on the order of <200 g C/m^2/yr (McLeod et al. 2011), while an excess of 100-200 g C/m^2/yr of carbon is exported to inshore and offshore areas (Nixon 1980; also see Table 1). The source, transport and fate of carbon along the estuary-offshore gradient are complicated processes, but largely, estuarine wetland systems are typically understood as carbon sources to estuarine-offshore systems. High energy, macrotidal salt marshes may receive substantial mineral sediments (and associated carbon) near the mouth of the estuary. The source of carbon may come from upland habitats, which may be replenished, or within the estuarine system as wetlands are eroded or reworked.

Stevenson et al. (1988) raised the consideration of sea level rise and sediment supply as to why estuaries—especially southern microtidal systems—are susceptible to wetland loss. In addition to sea level rise, the authors maintain that sediment starvation through reductions in terrigenous sediment sources is a key factor of undernourishment of wetlands:

> From Stevenson et al. 1988*: Differences in tidal dynamics, seasonal changes in sea levels and higher temperatures may help explain why, in the U.S., southern marshes are more susceptible to export and eventual erosion than northern marshes. We hypothesize that another factor, the recent reductions of terrigenous sediment inputs from the southern river systems of the U.S., may also be critical. Sediment starvation may have led to undernourishment of wetland systems of the coastal zone over the last half century which may be reflected in the net export measured in the tidal marshes in this region. Furthermore, we postulate that changes in sediment inputs are more important than eustatic sea level rise in causing the past losses of marshes which are now undergoing mass erosion.*

There has been a systemic reduction in sediment delivery to coastal wetlands nationwide due to changes in land-use (European settlement and land clearing) and expansion of dam building on major rivers (Syvitski et al. 2009). The Chesapeake Bay area and Louisiana delta serve as examples of the observed modern sediment-driven degradation of wetlands to open water (Kirwan et al. 2011).

I.2 Support from the Literature

The literature from coastal Louisiana broadly supports the understanding that its wetlands are sources of carbon to the Gulf of Mexico (see estimates in Table I.1). Moreover, in the last century there has been a systematic reduction in allochthonous mineral sediment (with its associated carbon) to the wetlands due to construction of levees along the Mississippi River (Blum and Roberts 2009). As a consequence, the estuaries are not receiving substantial external sources of sediments or carbon. The following summary provides a description on carbon exchange in Louisiana estuaries and provides the rationale as to why accounting for the import of carbon to created wetlands projects is not relevant for the coastal region of Louisiana. Namely, there is an absence of real external sources of carbon to the coastal basins, most of the carbon is exchanged among habitats in the coastal basins, and any import of carbon in the project area will be substantially offset by the carbon that the project will export.

1. *Export of Carbon from Louisiana Estuaries*: Louisiana estuaries are ebb-dominated systems exhibiting a consistent pattern of exporting of Particulate Organic Carbon (POC) and Total Organic Carbon (TOC) to the Gulf of Mexico. This has been shown for most of the Louisiana coastal areas, including: Barataria Basin (Li et al. 2011; Das et al. 2010, 2011; Wilson and Allison 2008; Feijtel et al. 1985; Happ et al. 1977), Breton Sound (Wilson and Allison 2008), and Fourleague Bay (Stern et al. 1991; Madden et al., 1988; Perez et al. 2000). Wilson and Allison (2008) estimated that Barataria and Breton Sound estuaries export 3.7×10^4 and 4.6×10^4 MT POC annually, respectively, and the magnitude of these estimates was corroborated by Das et al. 2011. The magnitude of Dissolved Organic Carbon (DOC) that is exported is six fold greater than particulate forms (Das et al. 2011).

2. *External Sediment Supply Constraints to Louisiana Wetlands*: An allochthonous sediment deficit to Louisiana coastal wetlands occurred following the levee construction along the Mississippi River and persists today (Blum and Roberts 2009). In a review paper of mineral and organic contributions to tidal freshwater wetland accretion from Maine to Louisiana, Neubauer (2008) showed that Louisiana freshwater wetlands exhibited the lowest mineral accumulation rates. Much of the contemporary sediment deposition in Louisiana wetlands is a result of the redistribution of sediment and organic matter within the system. Organic matter (or carbon) can come from upper basin wetlands and be deposited in downstream project areas, or may arrive at the project site from lower in the basin with storms and fronts (Reed 1989). In any case, the source of the carbon comes from either the natural export of surrounding healthy wetlands or from shoreline erosion. DeLaune et al. (2013) described one example of how non-restored wetland erosion can serve as a source of sediments that are transported through the estuary: “as marshes degrade and erode, there is a loss of material through net transport of mineral and organic matter through tidal inlets to the coastal ocean (Li et al 2009, 2011). The translocation of organic and mineral material from the marsh to the coastal waters further exacerbates coastal land loss.”

3. *Carbon Quality, Storage, and Averting Emissions*: Das et al. (2011) proposed that “the fate of carbon from eroded wetlands remains incompletely known” but evidence from their study as well as another recent study (Wilson and Allison, 2008) “potentially suggest that about 40% of POC released from eroding marshes is exported to the coastal Gulf of Mexico”. Thus, organic matter storage is occurring within the estuary’s wetlands and bays. While the fate and transformation of organic matter from interior wetlands to the offshore environment isn’t entirely certain, there is reasonable evidence that the source of allochthonous carbon to a project area in Louisiana will be similar in quality to that which will be released from the project area (Wilson and Allison, 2008). That is, the source of carbon is largely derived within the system. There is also increasing

evidence that Mississippi River water, which could enter from the mouth of adjacent estuaries in Louisiana, has a higher fraction of labile carbon than previously assumed (Mayer et al. 2008).

The design and location of wetland creation projects offer benefits in the form of capturing organic sediments that could otherwise be lost offshore or potentially oxidized in shallow bay waters. The decay of organic matter in the emergent wetland environment is slower than the estuarine open water setting due to the presence of anaerobic conditions, acidic porewater, and the presence of decay inhibitors (secondary metabolic compounds or humic acids) (Bianchi et al. 2011). Along the terrestrial to marine gradient, the likelihood of emissions with organic matter decay is increased as exposure or residence time under oxic conditions is prolonged, a process termed 'diagenetic oxygen exposure time' (Bianchi et al. 2011). The combination of physical energy, photo-degradation, oxygen exposure, and strong ionic gradients can accelerate the carbon decay process along the estuarine-offshore gradient. Thus, under the project condition, allochthonous carbon has a greater likelihood of preservation in the wetland system.

In summary, for Coastal Louisiana, it can be conservatively assumed that transport of organic matter will not cause carbon accretion estimates to be significantly overestimated, and thus allochthonous carbon may be neglected.

Table I.1: Summary of carbon export from estuaries, with special consideration of Louisiana estuaries

Location	Carbon Export[6]	Habitat Type	Source
Review of estuaries	100-200	Salt marshes	Nixon 1980
Barataria Bay, LA	165	Forested upland-estuary interface	Hopkinson and Day 1979
Barataria Bay, LA	150-250	Entire estuary	Feijtel et al. 1985
Barataria Bay, LA	25-540 (150)[7]	Entire estuary	Happ et al. 1977
Barataria Bay, LA	57	Estuary open water area	Das et al. 2010

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[6] Units: g C m^{-2} yr^{-1}

[7] Considering the magnitude of errors involved in the assumptions upon which the calculations were based, the study reported an organic carbon export of 25 to 540 g C m^{-2} yr^{-1} to inshore waters, with the most probable value around 150 g C m^{-2} yr^{-1}.

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APPENDIX J: LIST OF VARIABLES

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
A_{PA}	acre	Area of project area	GIS analysis prior to sampling		[G.10], [G.12]	-	-
$b^{[m]}$	%	Buffer withholding percentage calculated as required by the VCS AFOLU Non-Permanence Risk Tool	VCS AFOLU Non-Permanence Risk Tool	N/A	[G.20]	Every monitoring period	N/A
$C_{P\ CS}^{[m]}$	tCO_2e	Cumulative project carbon stocks at end of current monitoring period	Sampling activities	[G.7]	[G.8], [G.9], [G.19]	At least every five years	Independent review of equations and check against literature estimates. See Section 9.2.8.3
$C_{P\ CS}^{[m-1]}$	tCO_2e	Cumulative project carbon at beginning of current monitoring period	Sampling activities	[G.7]	[G.8], [G.9]	At least every five years	Independent review of equations and check against literature estimates. See Section 9.2.8.3
$C_{P\ CS\ (c)}^{[m]}$	tCO_2e	Cumulative project carbon in pool *c* at end of current monitoring period	Sampling activities	Appendix D	[G.7]	At least every five years	Independent review of equations and check against literature estimates. See Section 9.2.8.3

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$d_{LQD}^{[m]}$	kg/m³	Density of liquid in dredged sediment	Monitoring records, direct measurement	9.2.5	[G.1]	Every monitoring period when sediment is transported	Compare data from multiple samples. See Section 9.2.8.1
$d_{SLD}^{[m]}$	kg/m³	Density of solids in dredged sediment	Monitoring records. direct measurement	9.2.5	[G.1]	Every monitoring period when sediment is transported	Compare data from multiple samples. See Section 9.2.8.1
$d_{P\,\Delta}^{[m]}$	kg/m³	Density of sediment dredged from sediment source	Monitoring records, direct measurement	9.2.5	[G.2], [G.1]	Every monitoring period when sediment is transported	Compare data from multiple samples. See Section 9.2.8.1
$E_{BA\,\Delta}^{[m]}$	tCO_2e	Emissions reductions and/or removals allocated to AFOLU pooled buffer account over current monitoring period	Monitoring records	8.4.2	[G.21], [G.20]	Every monitoring period	Independent review of equations and monitoring records. See Section 9.2.8.2
$E_{B\,\Delta}^{[m]}$	tCO_2e	Total baseline emissions over current monitoring period	Monitoring records	8.1	[G.6], [G.16]	Every monitoring period	Independent review of equations and monitoring records. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$E^{[m]}_{B\,\Delta\,CH4}$	tCO_2e	Total baseline emissions from methane over current monitoring period	Monitoring records	8.1.2	[G.5]	Every monitoring period	Independent review of equations and monitoring records. See Section 9.2.8.2
$E^{[m]}_{B\,\Delta\,EC}$	tCO_2e	Total baseline emissions from energy consumption over current monitoring period	Monitoring records	8.1.1	[G.6], [G.3]	Every monitoring period when sediment is transported	Independent review of equations and monitoring records. See Section 9.2.8.2
$E^{[m]}_{BR\,\Delta}$	tCO_2e	Total emissions reductions and/or removals for buffer release over current monitoring period	Monitoring records	8.4.2	[G.21]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E^{[m]}_{GER}$	tCO_2e	Cumulative gross emissions reductions and/or removals at end of current monitoring period	Monitoring records	8.4.1.1	[G.17]	Every monitoring period	Independent review of GER calculations. See Section 9.2.8.2
$E^{[m]}_{GER\,\Delta}$	tCO_2e	Total gross emissions reductions and/or removals over current monitoring period	Monitoring records	8.4.1, 8.4.2	[G.16],[G.17], [G.19], [G.20], [G.21]	Every monitoring period	Independent review of GER calculations. See Section 9.2.8.2
$E^{[m]}_{NER\,\Delta}$	tCO_2e	Total net emissions reductions and/or removals over current monitoring period	Monitoring records	8.4.2	[G.21]	Every monitoring period	Independent review of NER calculations. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$E_{P\,\Delta}^{[m]}$	tCO_2e	Total project area emissions/ emissions removals over current monitoring period	Monitoring records	8.2	[G.15], [G.16]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{P\,\Delta\,CH4}^{[m]}$	tCO_2e	Total methane emissions in project area over current monitoring period	Monitoring records	8.2.2	[G.15],[G.8], [G.9], [G.11]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{P\,\Delta\,CS}^{[m]}$	tCO_2e	Total carbon stock emissions or emissions reductions and/or removals in project area over current monitoring period	Monitoring records	8.2.1	[G.15], [G.8], [G.9],	Every monitoring period	Independent review of calculations and monitoring records. See Sections 9.2.8.2 and 9.2.8.3
$E_{P\,\Delta\,EC}^{[m]}$	tCO_2e	Total emissions from energy consumption in project area over current monitoring period	Monitoring records	8.2.4	[G.15], [G.14]	Every monitoring period when sediment is transported	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{P\,\Delta\,N2O}^{[m]}$	tCO_2e	Total nitrous oxide emissions within project area over current monitoring period	Monitoring records	8.2.3,	[G.15], [G.13]	Every monitoring period	Independent review of calculations. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$e_{(ty)}$	tCO_2e /gal, tCO_2e /scf, tCO_2e /kWh	Emissions coefficient for energy type *ty*	Emission factors in Section 8.1.1, Table 10	Selected from published values	[G.3], [G.14]		
$E_{U\,\Delta}^{[m]}$	tCO_2e	Confidence deduction for current monitoring period	Monitoring records	8.4.2.1	[G.19], [G.21]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$f_{B\,\Delta\,CH4}^{[m]}$	tCO_2e /ac/day	Baseline methane emissions flux per unit area	Monitoring records and static chamber or eddy covariance measurement	9.2.7	[G.5]	Every monitoring period	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$F_{B\,\Delta\,CH4}^{[m]}$	tCO_2e /day	Baseline methane emissions flux	Monitoring records and static chamber or eddy covariance measurement	9.2.7	[G.5]	Every monitoring period	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$f^{[m]}_{P\,\Delta\,CH4}$	tCO_2e /ac/day	Methane emissions flux per unit area within project area	Monitoring records and static chamber or eddy covariance measurement	9.2.2.3	[G.10]	Every monitoring period	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$f^{[m]}_{P\,\Delta\,N2O}$	tCO_2e /ac/day	Nitrous oxide emissions flux per unit area within project area	Monitoring records and static chamber or eddy covariance measurement	9.2.3.3	[G.12]	Every monitoring period	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$F^{[m]}_{P\,\Delta\,CH4}$	tCO_2e /day	Methane emissions flux within project area	Monitoring records and static chamber or eddy covariance measurement	9.2.2.3	[G.11], [G.10]	Every monitoring period	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$F^{[m]}_{P\,\Delta\,N2O}$	tCO_2e /day	Nitrous oxide emissions flux within project	Monitoring records and direct measurement, default values, or proxy values developed by the project proponent	9.2.3	[G.13], [G.12]	Every monitoring period	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$g_{B\,(ty)}$	gal/tonne, scf/tonne, kWh/tonne	Energy consumed per metric tonne of sediment dredged in the baseline	Documentation provided by proponent	Direct measurement	[G.3]	-	-
$G^{[m]}_{P\,\Delta\,(ty)}$	gal, scf, kW	Energy consumed in project area for energy type *ty* over current monitoring period	Monitoring records and direct measurement or cost approach	8.2.4	[G.14]	Every monitoring period when sediment is transported	Independent review of calculations and monitoring records. See Sections 9.2.8.1 and 9.2.8.2
$M^{[m]}_{P\,\Delta}$	tonnes	Mass of sediment dredged from the sediment source over current monitoring period	Monitoring records	8.1.1, 9.2.5	[G.3], [G.2]	Every monitoring period when sediment is transported	Project verification and independent review of calculations. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$p_{B\,(ty)}$	proportion (unitless)	Proportion of energy for energy type *ty* consumed in the baseline scenario	Documentation provided by proponent	Calculated from direct measurement	[G.3]	-	-
$p_{SLD}{}^{[m]}$	proportion (unitless)	Proportion of solids by weight in the dredged sediment	Sampling activities, direct measurement	9.2.5	[G.1]	Every monitoring period when sediment is transported	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1 and 9.2.8.2
$t^{[m]}$	days	Elapsed time from project start at the end of the current monitoring period	Monitoring records	N/A	[G.11], [G.13]	Every monitoring period	N/A
$t^{[m-1]}$	days	Elapsed time from project start at the beginning of the current monitoring period	Monitoring records	N/A	[G.11], [G.13]	Every monitoring period	N/A
$U_{P\,CS}^{[m]}$	tCO_2e	Total standard error in project carbon stocks measured during the current monitoring period	Monitoring records	N/A	[G.19], [G.18]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$U_{P\ CS\ (c)}^{[m]}$	tCO_2e	Total standard error in project carbon stocks for pool *c* measured during the current monitoring period	Monitoring records	[A.8]	[G.18]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$V_{P\ \Delta}^{[m]}$	m^3	Volume of sediment dredged from the sediment source over current monitoring period	Monitoring records	9.2.5	[G.2]	Every monitoring period when sediment is transported	Independent review of calculations and monitoring records. See Section 9.2.8.2

APPENDIX K: SUMMARY OF PROJECT DESCRIPTION REQUIREMENTS

PDR#	Category	Requirements
PDR.1	Applicability Conditions	For each applicability condition, credible evidence in the form of analysis, documentation or third-party reports to satisfy the condition.
PDR.2	GHG Sources	A list of the included GHG sources.
PDR.3	Carbon Pools	A list of the selected carbon pools.
PDR.4	Allochthonous Carbon in Soil Carbon Pool	Narrative justification that the import of organic matter will not cause carbon accretion estimates to be significantly overestimated including citations to case studies, literature or models.
PDR.5	Allochthonous Carbon in Soil Carbon Pool	Description of the dominant sources of sediments with respect to external (ie, fluvial) inputs or internal (within estuary or tidal freshwater wetland) recycling.
PDR.6	Allochthonous Carbon in Soil Carbon Pool	Proximity of the project area with respect to direct fluvial inputs or near-shore sediment sources.
PDR.7	Allochthonous Carbon in Soil Carbon Pool	An annual mass estimate of the total carbon imported or exported from the estuary or tidal freshwater wetland where the project is located.
PDR.8	Allochthonous Carbon in Soil Carbon Pool	Description of the project area with respect to tidal energy (such as flood- or ebb-dominated) or tidal dispersive flux.
PDR.9	Delineating Spatial Boundaries	GIS-based maps of the project area with, at a minimum, the features listed above.
PDR.10	Delineating Spatial Boundaries	Documentation that the entire project area is/was open water at the project start date.
PDR.11	Delineating Spatial Boundaries	Evidence that the project area meets the definition of tidal or estuarine open water wetlands which once supported emergent wetland vegetation.
PDR.12	Delineating Spatial Boundaries	Evidence that the project area is compliant with the most current version of the VCS AFOLU Requirements regarding the clearing of native ecosystems.
PDR.13	Delineating Spatial Boundaries	If emissions from methane are included in the baseline scenario, an estimate of the average water depth in the project area prior to the implementation of project activities (see Section 6.3).
PDR.14	Delineating Spatial Boundaries	Documentation that the project proponent has control over the project area as described in most recent version of the VCS AFOLU Requirements, Section 3.4.
PDR.15	Delineating Spatial Boundaries	Documentation of the assessment of effects to hydrologically connected areas as further

		described in Section 8.3.1.
PDR.16	Delineating Spatial Boundaries	Documentation of projected sea level rise in the vicinity of the project area, evidence that existing landforms or constructed features are expected to withstand project sea level rise, and a description of the post-construction soil surface elevation relative to mean sea level.
PDR.17	Temporal Project Boundaries	The project start date.
PDR.18	Temporal Project Boundaries	The project crediting period start date and length.
PDR.19	Temporal Project Boundaries	The date by which mandatory baseline reassessment must occur after the project start date.
PDR.20	Temporal Project Boundaries	A timeline including the first anticipated monitoring period showing when project activities will be implemented.
PDR.21	Temporal Project Boundaries	A timeline for anticipated subsequent monitoring periods.
PDR.22	Grouped Projects	A list and descriptions of all enrolled project activity instances in the group at the time of validation.
PDR.23	Grouped Projects	A map of the designated geographic area within which all project activity instances in the group may be located, indicating that all instances are in the same region.
PDR.24	Grouped Projects	A list of eligibility criteria for project activity instances.
PDR.25	Baseline Scenario	Results of a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives, and justification for the most plausible baseline scenario.
PDR.26	Baseline Scenario	Documentation to demonstrate that the project area previously met the definition of a wetland before converting to open water or similar degraded state. Documentation must include hydrological data to show evidence of long-term patterns of wetland loss.
PDR.27	Baseline Scenario	The selected method for demonstrating the baseline scenario in the project area (regional land use change or spatial analysis).
PDR.28	Regional Land Use Change For Baseline Scenario	A reference to the document providing evidence of continued land loss or static condition in the basin for a period of 10 years prior to the project start date.
PDR.29	Regional Land Use Change For Baseline Scenario	A summary of the referenced document indicating where in the document the evidence is provided.
PDR.30	Regional Land Use Change For Baseline Scenario	Documentation of water management activities (eg, river diversions) that could influence the baseline scenario.
PDR.31	Spatial Analysis for Baseline Scenario	A report describing how the analysis was conducted, including data sources and dates, demonstration of conformance with the requirements listed in Section 6.1.2, and justification

		for the selection of the region in which the analysis was conducted.
PDR.32	Spatial Analysis for Baseline Scenario	A map of the region in which the analysis was conducted.
PDR.33	Spatial Analysis for Baseline Scenario	The quantified change in water area.
PDR.34	Determination of Dredging	Determination (yes or no) whether dredging is included in the baseline scenario.
PDR.35	Determination of Dredging	If dredging is included in the baseline scenario, a description of the single event or programmatic dredging projects, including the likely fate of dredged sediments in the baseline scenario.
PDR.36	Demonstration of Navigability	Map of dredging activities, including justification for planned dredging locations.
PDR.37	Demonstration of Navigability	Documents that demonstrate dredging would have occurred.
PDR.38	Determination of Baseline Energy Consumption	For each energy type in Table 11, the estimate of the unit of energy consumed per metric tonne of sediment dredged.
PDR.39	Determination of Baseline Energy Consumption	Description of equipment types and method or process of sediment dredging, transport, disposal, re-handling, sediment production rates, duration of operations and conveyance distances.
PDR.40	Determination of Baseline Energy Consumption	Estimates of cumulative sediment quantity excavated and re-handled, including temporary disposal and displacement activities, if applicable.
PDR.41	Determination of Baseline Energy Consumption	Source of procedures or data on which these estimates are based.
PDR.42	Determination of Baseline Methane Emissions	Description and justification for the selected reference area.
PDR.43	Demonstration of Project Additionality	Demonstration that pertinent laws and regulations have been reviewed and that none mandate the project activities.
PDR.44	Demonstration of Project Additionality	Evidence that project activities comply with all applicability conditions set out under Section 4.
PDR.45	Emissions or Emissions Reductions and/or Removals Events in Project Area	The selected definition of a significant disturbance.
PDR.46	Hydrologic Effects	Description of the expected impacts on hydrologically connected areas, and the agency process which is expected to take place prior to the commencement of project activities.
PDR.47	Monitoring Plan	A summary of carbon stock sampling procedures for the project area, with a copy of a sampling protocol used by field personnel to carry out measurements.
PDR.48	Monitoring Plan	A summary of flux measurement procedures for the project area, with a copy of a flux

		measurement protocol used by field personnel to carry out measurements.
PDR.49	Monitoring Plan	A reference to the monitoring plan.
PDR.50	Monitoring Plan	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
PDR.51	Stratification	Justification for not stratifying carbon stocks.
PDR.52	Stratification for SOC	Description for how the strata were delineated.
PDR.53	Stratification for SOC	Map(s) of the initial strata boundaries.
PDR.54	Stratification for Biomass	Description for how the strata were delineated.
PDR.55	Stratification for Biomass	Map(s) of the initial strata boundaries.
PDR.56	Measuring Carbon Stocks	Proposed method for allocating plots to stratum.
PDR.57	Measuring Carbon Stocks	Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.
PDR.58	Soil Plot Design	Diagram of a soil plot showing the locations of artificial marker horizons and core samples within the plot over time.
PDR.59	Soil Plot Design	Description of the fixed soil sample depth.
PDR.60	Frequency of Carbon Stock Measurements	The anticipated frequency of monitoring for each plot and flux measurement location – all carbon stock plots should be measured for the first verification.
PDR.61	Monitoring Methane	The selected approach for monitoring methane.
PDR.62	Methane Models from Literature	Justification of methane flux model from the literature, per the requirements of Section 9.2.2.1.
PDR.63	Covariates for Proxy Methane Models	A list of possible covariates and the sources of data available for each.
PDR.64	Covariates for Proxy Methane Models	A list of selected covariates to be used for model fitting.
PDR.65	Stratification for Methane Emissions	Description for how the strata were delineated.
PDR.66	Stratification for Methane Emissions	Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest methane emissions flux.
PDR.67	Stratification for Methane Emissions	Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest methane emissions flux.
PDR.68	Instrumentation for Chambers	Diagram of chamber design.

PDR.69	Eddy Covariance Measurements	The type of analyzer selected for direct measurements of methane, including a description of the resolution of measurements (in ppb) and the frequency at which measurements are to be taken (in Hz).
PDR.70	Eddy Covariance Measurements	A table of meteorological variables selected for measurement. For each variable in the table, justification for its selection, the unit of measurement, resolution of measurement and frequency of measurement.
PDR.71	Eddy Covariance Measurements	A description the eddy covariance tower configuration including the distances between sensors (vertical, northward and eastward separation).
PDR.72	Eddy Covariance Measurements	A scale diagram of the eddy covariance tower configuration showing the relative location and distance of the anemometer relative to the methane sensor.
PDR.73	Eddy Covariance Measurements	Plan view diagram or map of the eddy covariance tower delineating strata and the area of highest anticipated emissions within a 100m radius of the tower. Delineation of any patch vegetation (twice the dominant canopy height and occupying >100m^2 in area) occurring within the estimated 80% footprint area.
PDR.74	Eddy Covariance Measurements	Description of dominant plant canopy height (in m) over an annual cycle. An estimate of the 80% flux footprint distance (in m) and parameter estimates, as follows: σw= standard deviation of the vertical velocity fluctuations (m/s) $u *$= surface friction velocity (m/sec) zm= measurement height (m) hm= planetary boundary layer height (m) or 1000m zm= roughness length (m) or 1/10th of the average canopy height
PDR.75	Monitoring Nitrous Oxide	The selected approach for monitoring nitrous oxide.
PDR.76	Determining Project Area Exposure to Nitrogen Loading	Location of the project area within a minimum definable watershed, using a USGS, EPA or state delineated watershed.
PDR.77	Determining Project Area Exposure to Nitrogen Loading	Locations of all NPDES major dischargers and public works projects producing > 1 MGD of elevated nitrogen effluent (>3 mg TN/L) discharging into the project area and located within the minimum definable watershed.
PDR.78	Determining Project Area Exposure to Nitrogen Loading	List of EPA CWA Section 303d designated impaired waters for the state.
PDR. 79	Default Values for Nitrous Oxide Monitoring	Justification for the selected default value.
PDR.80	Covariates for Proxy Nitrous Oxide Models	A list of possible covariates and the sources of data available for each.
PDR.81	Covariates for Proxy Nitrous Oxide Models	A list of selected covariates to be used for model fitting.

PDR.82	Model Fit for Nitrous Oxide	Justification that the proxy is an equivalent or better method (in terms of reliability, consistency or practicality) to determine the value of interest than direct measurement.
PDR.83	Stratification for Nitrous Oxide Emissions	Description for how the strata were delineated.
PDR.84	Stratification for Nitrous Oxide Emissions	Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest nitrous oxide emissions flux.
PDR.85	Stratification for Nitrous Oxide Emissions	Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest nitrous oxide emissions flux.
PDR.86	Field Training for Field Sampling	A description of the type and frequency of training of field personnel responsible for sampling carbon stocks, fluxes, and covariates.
PDR.87	Quality Control and Assurance of Eddy Covariance Data	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
PDR.88	Data and Parameters Available at Validation	The value of each variable, data and parameter in Appendix I.
PDR.89	Data and Parameters Available at Validation	The units, descriptions, source, purpose and comments for each variable reported in the PD.
PDR.90	Chamber Description	A description of the chamber design, with its dimensions or total volume, and cross-sectional area.
PDR.91	Chamber Description	Diagram of chamber plot randomization design and the resulting chamber locations within each stratum, with the chambers identified as replicates. Provide dates when chambers were deployed in each stratum. Provide a justification that the locations chosen are conservative (ie, that they are likely to predict methane emissions flux for the entire stratum for which they are representative.)

APPENDIX L: SUMMARY OF MONITORING REPORT REQUIREMENTS

MRR#	Category	Requirements
MRR.1	Project Activities	Plan for establishment of permanent wetland plant community after project construction. Plan must include tracking aerial extent of emergent vegetation long-term monitoring of such communities, as well as plans for continued maintenance if necessary. This documentation must demonstrate that the project activity results in the accumulation or maintenance of soil carbon stock and that, upon completion of the project activities, the project area must meet the definition of a wetland.
MRR.2	Project Activities	Evidence that the project engineering and design takes into account local water level elevation, tidal range, geotechnical characteristics, sea level rise projections, and the range of plant growth within those constraints.
MRR.3	Substrate Establishment	Post-construction report, including an as-built drawing showing plan view and cross section of the project area along with an estimate of post-construction sediment elevation relative to a geodetic or tidal datum.
MRR.4	Substrate Establishment	Aerial image of the project area within three years prior to construction and an aerial image within one year post-construction.
MRR.5	Vegetation Establishment	A description of the quantity, species, date and location of vegetation establishment, and photographs of the operation. This documentation must demonstrate that the project activity results in the accumulation or maintenance of soil carbon stock.
MRR.6	Vegetation Establishment	Aerial image of the project area indicating where species were established.
MRR.7	Temporal Project Boundaries	The project start date.
MRR.8	Temporal Project Boundaries	The project crediting period start date and length.
MRR.9	Temporal Project Boundaries	Evidence of the start of monitoring per the frequency requirements described in Sections 5.4, 9.2.1.1, 9.2.2.4, and 9.2.3.4.
MRR.10	Grouped Projects	A list and description of all project activity instances in the group, including project activity instance start dates.
MRR.11	Grouped Projects	A map of the boundaries of all project activity instances in the group demonstrating that all instances are in the designated geographic region.
MRR.12	Baseline Emissions	Calculations of current baseline emissions $\mathrm{EB}\ \Delta\mathrm{m}$ as of the monitoring period.
MRR.13	Baseline Emissions	Calculations of baseline emissions $\mathrm{EB}\ \Delta\mathrm{m}-1$ from prior monitoring periods.

MRR.14	Emissions Coefficients	Source and date of the emission coefficient.
MRR.15	Emissions Coefficients	Reference to the exact page number or worksheet cell in the source.
MRR.16	Project Emissions or Emissions Reductions and/or Removals	Calculations of current project emissions or emissions reductions and/or removals $\mathrm{EP}\ \Delta\mathrm{m}$ as of the monitoring period.
MRR.17	Project Emissions or Emissions Reductions and/or Removals	Calculations of project emissions or emissions reductions and/or removals $\mathrm{EP}\ \Delta\mathrm{m}-1$ from prior monitoring periods.
MRR.18	Emissions or Emissions Reductions and/or Removals Events in Project Area	The selected definition of a significant disturbance.
MRR.19	Emissions or Emissions Reductions and/or Removals Events in Project Area	A map of the boundaries of any significant disturbance in the project area during the monitoring period.
MRR.20	Emissions or Emissions Reductions and/or Removals Events in Project Area	Evidence that plots were installed into these disturbed areas and were measured per Section 9.2.1.
MRR.21	Hydrologic Effects	Documentation that the project will not have a significant negative impact on hydrologically connected areas. This may include a Clean Water Act permit issued by the USACE, NEPA decision (ROD or FONSI) issued by the appropriate lead federal agency, or compliance documentation from local floodplain management agencies.
MRR.22	Quantification of GERs	Quantified GERs for the monitoring period including references to calculations.
MRR.23	Quantification of GERs	Quantified GERs for the prior monitoring period.
MRR.24	Quantification of GERs	A graph of GERs by monitoring period for all monitoring periods to date.
MRR.25	Quantification of NERs	Quantified NERs for the monitoring period including references to calculations.
MRR.26	Quantification of NERs	Quantified NERs for the prior monitoring period.
MRR.27	Quantification of NERs	A graph of NERs by monitoring period for all monitoring periods to date.
MRR.28	Confidence Deduction	The calculated confidence deduction and supporting calculations.
MRR.29	Confidence Deduction	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

MRR.30	AFOLU Pooled Buffer Account	Reference to the VCS requirements used to determine the AFOLU pooled buffer account allocation.
MRR.31	AFOLU Pooled Buffer Account	Reference to calculations used to determine the AFOLU pooled buffer account allocation.
MRR.32	Buffer Release	Reference to the VCS requirements used to determine the release from the AFOLU pooled buffer account.
MRR.33	Buffer Release	Reference to calculations used to determine the buffer release.
MRR.34	Vintages	Quantified NERs by vintage year for the monitoring period including references to calculations.
MRR.35	Project Performance	Comparison of NERs presented for verification relative to those from *ex-ante* estimates.
MRR.36	Project Performance	Description of the cause and effect of differences from *ex-ante* estimates.
MRR.37	Monitoring Plan	Documentation of training for field measurement crews.
MRR.38	Monitoring Plan	Documentation of data quality assessment.
MRR.39	Monitoring Plan	References to plot allocation for carbon stock measurement.
MRR.40	Monitoring Plan	List of plot GPS coordinates for plots and flux measurement devices.
MRR.41	Monitoring Plan	Description and diagram of flux measurements devices for methane and/or nitrous oxide.
MRR.42	Monitoring Plan	The estimated carbon stock, standard error of the total for each stock, and the sample size for each stratum in the project area.
MRR.43	Monitoring Plan	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
MRR.44	Monitoring Plan	Frequency of monitoring for each plot and flux measurement location – all carbon stock plots should be measured for the first verification.
MRR.45	Stratification for SOC	Map(s) of the current strata boundaries.
MRR.46	Stratification for SOC	A description of changes to the strata boundaries (if applicable).
MRR.47	Stratification for Biomass	Map(s) of the current strata boundaries.
MRR.48	Stratification for Biomass	A description of changes to the strata boundaries (if applicable)
MRR.49	Measuring Carbon Stocks	Method for allocating plots to stratum.
MRR.50	Measuring Carbon Stocks	Map of the location of plots within strata.
MRR.51	Measuring Carbon Stocks	Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.

MRR.52	Soil Plot Design	For each measured soil plot, a diagram showing the location of installed artificial marker horizons and sampled cores.
MRR.53	Soil Plot Design	Field report describing soil sample depths (accretion depth and fixed soil sample depth) and coring devices used to collect samples. The report must also include number of soil samples and their identification in a chain of custody form submitted to the laboratory.
MRR.54	Frequency of Carbon Stock Measurements	List of plots measured during the monitoring period – all carbon stock plots should be measured for the first verification.
MRR.55	Methane Models from Literature	Demonstration that the selected model is applicable to the project area per the requirements of Section 9.2.2.1.
MRR.56	Methane Models from Literature	Description of how model predictions are converted to tCO_2e/day.
MRR.57	Data Collection for Proxy Methane Model	Complete references to the source of any data collected from literature or reports.
MRR.58	Data Collection for Proxy Methane Model	Data collection procedures, plans or protocols for any data collected directly from the project area.
MRR.59	Model Fit for Methane	The form of the selected model.
MRR.60	Model Fit for Methane	Summary statistics of the model fit as appropriate to the fitting of the model.
MRR.61	Model Fit for Methane	The estimated model parameters.
MRR.62	Model Fit for Methane	A description of the range of covariate data with which the model was fit.
MRR.63	Model Prediction for Methane	The values of any measured covariates.
MRR.64	Model Prediction for Methane	The predicted methane flux.
MRR.65	Processed Chamber and Eddy Covariance Flux Data	A table of chamber flux or eddy covariance emission summary statistics of the mean (±1SEM) and number of samples for each mean in tCO_2e/ac/day for each sample location within a stratum.
MRR.66	Stratification for Methane Emissions	Map(s) of the current strata boundaries.
MRR.67	Stratification for Methane Emissions	A description of changes to the strata boundaries (if applicable).
MRR.68	Instrumentation for Chambers	Diagram of chamber design.

MRR.69	Instrumentation for Chambers	Map showing the location of chambers in the project area.
MRR.70	Instrumentation for Eddy Covariance	Diagram or map of eddy covariance tower delineating the selected footprint area where flux was integrated from and the computed mean 80% footprint distance (including the footprint model used) from the tower during the period of analysis. A table of computed estimates for each of the following parameters: σ_w = standard deviation of the vertical velocity fluctuations (m/s) u^*= surface friction velocity (m/sec) z_m= measurement height (m) z_0= roughness length (m) (or canopy height and density to be used to estimate roughness length)
MRR.71	Instrumentation for Eddy Covariance	Description of the published model used to define the footprint.
MRR.72	Instrumentation for Eddy Covariance	Map showing the location of eddy covariance towers in the project area.
MRR.73	Instrumentation for Eddy Covariance	Documentation of adherence to manufacturer-recommended procedures for calibration of the methane analyzer.
MRR.74	Eddy Covariance Data Processing and Flux Computation	Frequency diagram of wind direction (0-359° with 30° intervals) and velocity (m/s) for the period of analysis.
MRR.75	Eddy Covariance Data Processing and Flux Computation	Summary of the dates of data collection, the selected approach for averaging over each period, explicit formulas used for computing flux, number of 0.5-hr samples used in calculations.
MRR.76	Eddy Covariance Data Processing and Flux Computation	Graphical plot of 0.5-hr GHG concentration (ppmv), wind velocity and direction, and temperature used for the flux calculations
MRR.77	Eddy Covariance Data Processing and Flux Computation	Summary statistics (number of samples, mean, median, variance) of GHG flux for each averaging period.
MRR.78	Chamber Sampling for Methane	Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature.
MRR.79	Chamber Sampling for Methane	Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.
MRR.80	Eddy Covariance Measurement	A table of meteorological variables selected for measurement. For each variable in the table, an indication of whether the variable was measured, the make and model of the instrument used for measurement.
MRR.81	Eddy Covariance Measurement	For each measured variable, a graphical plot or table of the data with respect to time during the monitoring period. A data table or plot must include at minimum: air temperature, methane concentration, methane flux. A list of interpolated/missing samples.

MRR.82	Eddy Covariance Measurement	Documentation of calibration dates and zero checks for methane analyzer. Provide the date of last full calibration (0-10 ppm methane standard). Provide dates of carbon-free air gas checks for methane analyzer.
MRR.83	Data Collection for Proxy Nitrous Oxide Model	Complete references to the source of any data collected from literature or reports.
MRR.84	Data Collection for Proxy Nitrous Oxide Model	Data collection procedures, plans or protocols for any data collected directly from the project area.
MRR.85	Model Fit for Nitrous Oxide	The form of the selected model.
MRR.86	Model Fit for Nitrous Oxide	Summary statistics of the model fit as appropriate to the fitting of the model.
MRR.87	Model Fit for Nitrous Oxide	The estimated model parameters.
MRR.88	Model Fit for Nitrous Oxide Covariance Data	A description of the range of covariate data with which the model was fit.
MRR.89	Model Prediction for Nitrous Oxide	The values of any measured covariates.
MRR.90	Model Prediction for Nitrous Oxide	The predicted nitrous oxide flux.
MRR.91	Stratification for Nitrous Oxide Emissions	Map(s) of the current strata boundaries.
MRR.92	Stratification for Nitrous Oxide Emissions	A description of changes to the strata boundaries (if applicable).
MRR.93	Chamber Sampling for Nitrous Oxide	Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature.
MRR.94	Chamber Sampling for Nitrous Oxide	Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.
MRR.95	Energy Consumption Measurement Method	The selected approach to monitoring energy consumption.
MRR.96	Direct Measurement of Energy Consumption	Energy consumption for each energy type listed in Section 8.1.1.
MRR.97	Direct Measurement of Energy Consumption	References to records of energy consumption.
MRR.98	Cost Approach to Energy	Justification for the proportion of dredging budget allocated for fuel (or electricity) purchases.

	Consumption	
MRR.99	Cost Approach to Energy Consumption	Justification for choice of energy type(s).
MRR.100	Cost Approach to Energy Consumption	Documentation of historic energy costs at the time of dredging activities.
MRR.101	Cost Approach to Energy Consumption	Justification of estimate of energy consumption.
MRR. 102	Monitoring Sediment Transport	Justification for the estimate of volume of dredged sediment transported.
MRR. 103	Monitoring Sediment Transport	Justification for the estimate of the density of dredged sediment.
MRR.104	Monitoring Sediment Transport	Estimated mass of sediment transported.
MRR.105	Monitoring Allochthonous Carbon	Reference(s) to the regionally appropriate literature used to determine the correct factor for mineral-associated carbon.
MRR.106	Field Training for Field Sampling	The type and frequency of training of field personnel during the monitoring period.
MRR.107	Carbon Stock Measurements	Biomass and SOC carbon stock data for all plots, along with any ancillary spreadsheets or computer code used to generate these predictions.
MRR.108	Carbon Stock Measurements	List of outliers with unusually high or low biomass or SOC, including justification for their continued inclusion.
MRR.109	Carbon Stock Measurements	Results of accuracy assessment if non-destructive sampling techniques are used. Otherwise, justification for why accuracy need not be formally addressed.
MRR.110	Quality Control and Assurance of Eddy Covariance Data	Description of processing software used, assumptions, and data quality control measures, which must include the selected method of coordinate rotation, detrending, and density fluctuation correction.
MRR.111	Laboratory Analyses	Documentation of the laboratory QA/QC protocols, the methods of sample analysis, and general calibration procedures used the laboratories conducting the analysis.
MRR.112	Data and Parameters Monitored	The value of each variable, data and parameter in Section 9.4.
MRR.113	Data and Parameters Monitored	The units, descriptions, source, purpose, references to calculations and comments for each variable reported in the Monitoring Report.
MRR.114	Data and Parameters Monitored	For those variables obtained from direct measurement, a description of measurement methods and procedures. These may simply be references to components of the monitoring plan.

MRR.115	Data and Parameters Monitored	For those variables obtained from direct measurement, a description of monitoring equipment including type, accuracy class and serial number (if applicable). These may simply be references to components of the monitoring plan.
MRR.116	Data and Parameters Monitored	Procedures for quality assurance and control, including calibration of equipment (if applicable).
MRR.117	Monitoring Grouped Projects	List and descriptions of all project activity instances in the group.
MRR.118	Monitoring Grouped Projects	Project activity instance start dates.
MRR.119	Monitoring Grouped Projects	Map indicating locations of project activity instances added to the group.
MRR.120	Monitoring Grouped Projects	List of additional stratifications used for additional project activity instances; justification for why flux measurements are still located in the most conservative stratum (9.2.2, 9.2.3).
MRR.121	Monitoring Grouped Projects	As project activity instances are added, monitoring plan must be updated to reflect additional monitoring times and plot locations.

APPENDIX M: SOURCE OF EMISSIONS FACTORS FOR ENERGY CONSUMPTION

		CO2		CH4		N20				
Fuel Type	Proponent reports as:	Emissions (kg/MMBtu)	tCO2 / MMBtu	Emissions (kg/MMBtu)	tCO2e / MMBtu	Emissions (kg/MMBtu)	tCO2e / MMBtu	Total Emissions (tCO2e/MMBtu)	Energy Content (MMBtu/unit)	**Emission Coefficient**
Diesel	gal	73.96	0.07396	0.003	0.000063	0.0006	0.000186	0.07421	0.138	**0.010241**
Gasoline	gal	70.22	0.07022	0.003	0.000063	0.0006	0.000186	0.07047	0.125	**0.008809**
Biodiesel	gal	73.84	0.07384	0.0011	0.0000231	0.00011	0.0000341	0.07390	0.128	**0.009459**
CNG	scf	53.02	0.05302	0.001	0.000021	0.0001	0.000031	0.05307	0.001028	**0.000055**
Electricity	kWh	see eGRID regional emissions factor								

Sources:

- Emissions factors and energy content for fuels: EPA Final Mandatory Reporting of Greenhouse Gases Rule Table C-1, C-2 (http://www.epa.gov/ghgreporting/documents/pdf/2009/GHG-MRR-FinalRule.pdf). Emissions in kg/MMBtu are taken directly from the EPA Mandatory reporting Rule. Emissions in tCO2e/MMBtu apply a unit conversion to tons (1 ton = 1,000 kg) and multiply by the appropriate global warming potential (1 for CO_2, 21 for CH_4, 310 for N_2O – the project proponent must confirm the global warming potentials per the current version of VCS Standard). Total emissions are a simple sum of the emissions in tCO2e/MMBtu of each of the three covered gases. The emission coefficient is calculated as the product of the total emissions and the energy content of the fuel type.
  For updates to these factors, refer to the EPA website (http://www.epa.gov/ghgreporting/reporters/subpart/c.html) or the federal regulations (40 C.F.R. § 98, Subpart C, Tables C-1 and C-2).
- eGRID regional emissions factors for electricity:
  http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_GHGOutputrates.pdf ('annual total output emission rates'). Note the unit conversions required to calculate the emissions from electricity usage in terms of tCO_2e, given that eGRID factors are stated in terms of lb/MWh and lb/GWh, and in terms of CH_4 and N_2O emissions (vs. CO_2e).
  For the current version of emissions factors, refer to http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html. Locate the eGRID GHG output summary file for the correct emission year (eg, eGRID2012 provides actual generation data from 2009). Because there is typically a lag of several years, if data for the current year or recent years are not available, use the most recent data (eg, if eGRID2012 is the most recent data available in 2013, then eGRID2012 with 2009 data should be used for all years 2009-2013). In the GHG summary file, use data for the appropriate eGRID subregion for 'annual total output emission rates.'

DOCUMENT HISTORY

Version	Date	Comment
v1.0	30 Jan 2014	Initial version released