WR Methodological Module

Estimation of emission sources (E-E)

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module allows for *ex-ante* estimation of greenhouse gas emissions for the baseline case and project case and for *ex-post* estimation of greenhouse gas emissions for the project case. Uncertainty of estimates is treated in module X-UNC. Identification of baseline land-uses is treated in modules BL-WR-HM and BL-WR-HM-WL.

Applicability

This module is applicable for estimating emission sources related to Wetland Restoration (WR) when project activities include hydrologic management and it has been determined through BL-WR-HM or BL-WR-HM-WL that project activities increase emissions beyond the baseline scenario.

Output parameters

This methodology produces the following parameters:

Parameter	SI Unit	Description
ΔGHG_{E_BSL}	t CO_2-e	Cumulative GHG emissions for the baseline scenario
ΔGHG_{E}	t CO_2-e	Cumulative GHG emissions due to project activities

II. PROCEDURES

Gaseous fluxes from wetland surfaces and open waters should be measured using the static chamber method[1,2,3] or equivalent method. Measurements of greenhouse gases should ensure

[1] Livingston, G.P. and G.L. Hutchinson, 1995. Enclosure-based Measurement of Trace Gas Exchange: Application and Sources of Error. P. 14-51 In: P.A. Matson and R.C. Harris (eds.) Biogenic Trace Gases: Measuring Emissions from Soil and Water. Blackwell Science Ltd., London.

[2] Klinger, L.F., Zimmerman, P.R., Greenberg, J.P., Heidt, L.E., and Guenther, A.B., 1994. Carbon Trace Gas Fluxes Along a Successional Gradient in the Hudson Bay Lowland. J. Geophys. Res. 99 (D1):1469–1494

that temporal variations are accounted for, or be measured during the time of greatest anticipated flux (e.g., during late summer) in order to conservatively underestimate net GHG emission reductions/removal enhancements. It should be clarified that use of the time of greatest anticipated flux measurements for the baseline scenario but annual averages for the project case would be inappropriate as it may underestimate increases or overestimate decreases in emissions for the project.

ESTIMATION OF EMISSION SOURCES

1.0 GHG Emissions for the Baseline Scenario

The baseline GHG emissions from the project area shall be estimated from direct measurement of gaseous fluxes prior to project activity using the static chamber sampling method or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature, approved local or national parameters. Project Proponents using extrapolated values must make conservative estimates.

Cumulative GHG emissions for the baseline scenario (ΔGHG_{E_BSL})

The total greenhouse gases emitted over a given period for the baseline scenario (ΔGHG_{E_BSL}) should be carried out using the equation below.

$$\Delta GHG_{E\_BSL} = \left(\frac{1}{n}\sum_{t=1}^{n} f\,GHG_{E\_BSL,t}\right) * T * 8766 \tag{1}$$

where:

ΔGHG_{E_BSL}	Cumulative GHG emissions for the baseline scenario; t CO_2-e
$f\,GHG_{E\_BSL,t}$	Rate of GHG emissions from the project area prior to project activity; t CO_2-e hr^{-1}
T	Period of time; yr
t	*1,2,3, …n* monitoring event
8766	Number of hours in a year, including accounting for leap years

Rate of GHG emissions for the baseline scenario

Use the following equation to determine the instantaneous flux of greenhouse gases from

[3] Lindau, C. W., and R. D. DeLaune, 1991. Dinitrogen and Nitrous Oxide Emission and Entrapments in 'Spartina alterniflora' Saltmarsh Soils Following Addition of N-15 Labeled Ammonium and Nitrate. Estuarine, Coastal and Shelf Science 32: 161-172.

the project area:

$$f\,GHG_{E\_BSL,t} = \sum_{i=1}^{n} f\,GHG_{CH_4\_BSL\,i,t} * GWP_{CH4} + \sum_{i=1}^{n} f\,GHG_{N_2O\_BSL\,i,t} * GWP_{N2O} \tag{2}$$

where:

$f\,GHG_{E\_BSL,t}$	Rate of GHG emissions from the project area prior to project activity; t CO_2-e hr^{-1}
$f\,GHG_{CH4\_BSL,i,t}$	Rate of CH_4 emissions from the project area in stratum *i* at monitoring event *t*; t C hr^{-1}
GWP_{CH4}	Global warming potential for CH_4 (= 21 per ACR Standard); t CO_2-e (t CH_4)$^{-1}$
$f\,GHG_{N2O\_BSL,i,t}$	Rate of N_2O emissions from the project area in stratum *i* at monitoring event *t*; t C hr^{-1}
GWP_{N20}	Global warming potential for N_2O (= 310 per ACR Standard); t CO_2-e (t N_2O)$^{-1}$
i	*1, 2, 3, … n* strata in the project scenario
t	*1,2,3, …* monitoring event

2.0 GHG Emissions for the Project Scenario

Total project greenhouse gas emissions (ΔGHG_E)

Total project GHG emissions should be extrapolated from average instantaneous measurements using the following equation:

$$\Delta GHG_E = \left(\frac{1}{n} \sum_{t=1}^{n} f\,GHG_{E,t}\right) * T_p * 8766 \tag{3}$$

where:

ΔGHG_E	Total GHG emissions from the project area after start of project activities; t CO_2-e
$f\,GHG_{E,t}$	Rate of GHG emissions from the project area at monitoring event *t*; t CO_2-e hr^{-1}
T_p	Time since start of project activities; yr
t	*1,2,3, …n* monitoring event
8766	Number of hours in a year, including accounting for leap years

Instantaneous greenhouse gas fluxes (*f* $GHG_{E,t}$)

The GHG emissions should be estimated from periodic measurement of gaseous fluxes at the project area using the static chamber sampling method or equivalent method and the following equation:

$$f\,GHG_{E,t} = \sum_{i=1}^{n} f\,GHG_{CH_4\_i,t} * GWP_{CH4} + \sum_{i=1}^{n} f\,GHG_{N_2O\_i,t} * GWP_{N2O} \quad (4)$$

where:

$f\,GHG_{E,t}$	Rate of GHG emissions from the project area at monitoring event *t*; t CO_2-e hr^{-1}
$f\,GHG_{CH4\_i,t}$	Rate of CH_4 emissions from the project area in stratum *i* at monitoring event *t*; t C hr^{-1}
GWP_{CH4}	Global warming potential for CH_4 (= 21 per ACR Standard); t CO_2-e (t CH_4)$^{-1}$
$f\,GHG_{N2O\_i,t}$	Rate of N_2O emissions from the project area in stratum *i* at monitoring event *t*; t C hr^{-1}
GWP_{N20}	Global warming potential for N_2O (= 310 per ACR Standard); t CO_2-e (t N_2O)$^{-1}$
i	*1, 2, 3, … n* strata in the project scenario
t	*1,2,3, …* monitoring event

EX-ANTE ESTIMATION METHODS

The Project Proponent must make an *ex-ante* calculation of all net anthropogenic GHG removals and emissions for all included sinks and sources for the entire Crediting Period. Project Proponent shall provide estimates of the values of those parameters that are not available before the start of monitoring activities. Project Proponent must retain a conservative approach in making these estimates.

Ex-ante net GHG removals by sinks can be estimated using empirical methods or modeling based on peer-reviewed literature or field monitoring, reference sample plots or field monitoring of similar sites, and approved local or national parameters that confirm to the applicability conditions of this methodology in order to assess the verifiable changes in carbon pools. The methodology ensures that the net anthropogenic GHG removals by sinks are estimated under the project in a conservative manner taking into account the uncertainties associated with the secondary data.

This methodology provides for the use of empirical methods as stand alone or as complements to modeling based on peer-reviewed literature for the purpose of *ex-ante* estimation of carbon stock changes. The empirical methods are the methods used in forest/wetland inventory and wetland management studies for estimating biomass, productivity etc. The data from research and published literature that use scientifically accepted empirical methods can be used for *ex-ante* estimation purposes provided such data are based on valid sampling and statistical procedures and are in agreement with the methods, steps and procedures outlined for the estimation of carbon pools under this methodology. For example, species data based on yield tables, peer-reviewed literature, national inventory data or default data, allometric equations, growth models, mortality studies, biomass estimation and nutrient cycling studies and local research such as land records, field surveys, archives, maps or satellite images of the land use/cover before the start of the proposed project activity, field surveys, and expert opinion that confirms to the methods outlined for estimation of carbon stock changes under this methodology can be utilized.

DATA AND PARAMETERS MONITORED

Data /parameter:	$f\ GHG_{CH4\_BSL,i,t}$
Data unit:	ton C hr^{-1}
Used in equations:	2
Description:	Rate of CH_4 emissions from the project area in stratum *i* at monitoring event *t*
Source of data:	Sample collected using the static chamber sampling method or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature, approved local or national parameters. Methane is measured using gas chromatography equipped with a dual FID/TCD system with hydrogen carrier gas. Standards are used to determine the percent recovery of the sample.
Measurement procedures (if any):	Methane (CH_4) and nitrous oxide (N_2O) emissions can be measured using static gaseous flux chambers or equivalent method. This method involves placing a chamber over a section of the wetland surface and measuring CH_4 and N_2O concentrations over time. Gas chambers consist of an upper open-ended box placed on top of a lower sleeve-base positioned approximately 10 cm into the wetland soil. The lower base unit must be put in place several days prior to measurements being taken to allow for soil conditions to equilibrate. Chambers should be placed over emergent vegetation (clipped if necessary) as well as above open water for various stratums in the project area, with sufficient replication to meet the required confidence level (i.e., 90%). Chambers positioned over open water should be fitted with a floatation collar. Chambers should be deployed for long enough to ensure that temporal variations are

	measured. Generally, two to several hours should be sufficient, but longer exposure times, up to 24 hours or several days, may be used to provide longer time-integrated results.
Monitoring frequency:	Monitoring must occur for baseline renewal. Where carbon stock enhancement is included, the monitoring frequency can range from 5 to 20 years. In situations where the project adopts a 40-year renewable crediting period, the monitoring frequency can be fixed to coincide with the crediting period. Field sampling should be conducted seasonally for one year to determine the effects of temperature on greenhouse gas flux, - or - measurements should be taken during period of peak emissions (i.e., summer).
QA/QC procedures:	Insulate the chambers (e.g., with foam) to minimize temperature anomalies, and record chamber temperature during deployment to document any temperature anomalies if they occur.
Any comment:	

Data /parameter:	$f\ GHG_{N2O\_BSL,i,t}$
Data unit:	ton C hr^{-1}
Used in equations:	2
Description:	Rate of N_2O emissions from the project area in stratum *i* at monitoring event *t*
Source of data:	Sample collected using the static chamber sampling method or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature, approved local or national parameters. Nitrous oxide is measured using gas chromatography equipped with an electron capture detector gas. Standards are used to determine the percent recovery of the sample.
Measurement procedures (if any):	Methane (CH_4) and nitrous oxide (N_2O) emissions can be measured using static gaseous flux chambers or equivalent method. This method involves placing a chamber over a section of the wetland surface and measuring CH_4 and N_2O concentrations over time. Gas chambers consist of an upper open-ended box placed on top of a lower sleeve-base positioned approximately 10 cm into the wetland soil. The lower base unit must be put in place several days prior to measurements being taken to allow for soil conditions to equilibrate. Chambers should be placed over emergent vegetation (clipped if necessary) as well as above open water for various stratums in the project area, with sufficient replication to meet the required confidence level (i.e., 90%). Chambers positioned over open water should be fitted with a floatation collar. Chambers should be deployed for long enough to ensure that temporal variations are measured. Generally, two to several hours should be sufficient, but longer exposure times, up to 24 hours or several days, may be used to provide longer

	time-integrated results.
Monitoring frequency:	Monitoring must occur for baseline renewal. Where carbon stock enhancement is included, the monitoring frequency can range from 5 to 20 years. In situations where the project adopts a 40-year renewable crediting period, the monitoring frequency can be fixed to coincide with the crediting period. Field sampling should be conducted seasonally for one year to determine the effects of temperature on greenhouse gas flux, - or - measurements should be taken during period of peak emissions (i.e., summer).
QA/QC procedures:	Insulate the chambers (e.g., with foam) to minimize temperature anomalies, and record chamber temperature during deployment to document any temperature anomalies if they occur.
Any comment:	

Data /parameter:	$f\ GHG_{CH4\_i,t}$
Data unit:	ton C hr^{-1}
Used in equations:	4
Description:	Rate of CH_4 emissions from the project area in stratum *i* at monitoring event *t*
Source of data:	Sample collected using the static chamber sampling method or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature, approved local or national parameters. Methane is measured using gas chromatography equipped with a dual FID/TCD system with hydrogen carrier gas. Standards are used to determine the percent recovery of the sample.
Measurement procedures (if any):	Methane (CH_4) and nitrous oxide (N_2O) emissions can be measured using static gaseous flux chambers or equivalent method. This method involves placing a chamber over a section of the wetland surface and measuring CH_4 and N_2O concentrations over time. Gas chambers consist of an upper open-ended box placed on top of a lower sleeve-base positioned approximately 10 cm into the wetland soil. The lower base unit must be put in place several days prior to measurements being taken to allow for soil conditions to equilibrate. Chambers should be placed over emergent vegetation (clipped if necessary) as well as above open water for various stratums in the project area, with sufficient replication to meet the required confidence level (i.e., 90%). Chambers positioned over open water should be fitted with a floatation collar. Chambers should be deployed for long enough to ensure that temporal variations are measured. Generally, two to several hours should be sufficient, but longer exposure times, up to 24 hours or several days, may be used to provide longer time-integrated results.
Monitoring	Monitoring must occur for baseline renewal. Where carbon stock enhancement

frequency:	is included, the monitoring frequency can range from 5 to 20 years. In situations where the project adopts a 40-year renewable crediting period, the monitoring frequency can be fixed to coincide with the crediting period. Field sampling should be conducted seasonally for one year to determine the effects of temperature on greenhouse gas flux, - or - measurements should be taken during period of peak emissions (i.e., summer).
QA/QC procedures:	Insulate the chambers (e.g., with foam) to minimize temperature anomalies, and record chamber temperature during deployment to document any temperature anomalies if they occur.
Any comment:	

Data /parameter:	$f\ GHG_{N2O\_i,t}$
Data unit:	ton C hr^{-1}
Used in equations:	4
Description:	Rate of N_2O emissions from the project area in stratum *i* at monitoring event *t*
Source of data:	Sample collected using the static chamber sampling method or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature, approved local or national parameters. Nitrous oxide is measured using gas chromatography equipped with an electron capture detector gas. Standards are used to determine the percent recovery of the sample.
Measurement procedures (if any):	Methane (CH_4) and nitrous oxide (N_2O) emissions can be measured using static gaseous flux chambers or equivalent method. This method involves placing a chamber over a section of the wetland surface and measuring CH_4 and N_2O concentrations over time. Gas chambers consist of an upper open-ended box placed on top of a lower sleeve-base positioned approximately 10 cm into the wetland soil. The lower base unit must be put in place several days prior to measurements being taken to allow for soil conditions to equilibrate. Chambers should be placed over emergent vegetation (clipped if necessary) as well as above open water for various stratums in the project area, with sufficient replication to meet the required confidence level (i.e., 90%). Chambers positioned over open water should be fitted with a floatation collar. Chambers should be deployed for long enough to ensure that temporal variations are measured. Generally, two to several hours should be sufficient, but longer exposure times, up to 24 hours or several days, may be used to provide longer time-integrated results.
Monitoring frequency:	Monitoring must occur for baseline renewal. Where carbon stock enhancement is included, the monitoring frequency can range from 5 to 20 years. In situations where the project adopts a 40-year renewable crediting period, the monitoring

	frequency can be fixed to coincide with the crediting period. Field sampling should be conducted seasonally for one year to determine the effects of season on greenhouse gas flux, - or - measurements should be taken during period of peak emissions (i.e., summer).
QA/QC procedures:	Insulate the chambers (e.g., with foam) to minimize temperature anomalies, and record chamber temperature during deployment to document any temperature anomalies if they occur.
Any comment:	

Data /parameter:	T
Data unit:	yr
Used in equations:	1
Description:	Period of time
Source of data:	This is the period of time of *ex-ante* estimation of baseline soil carbon stocks (e.g., 5, 10 years).
Measurement procedures (if any):	
Monitoring frequency:	Since monitoring must occur for baseline renewal, and can range from 5 to 20 years if carbon stock enhancement is included, time periods shall occur at these intervals.
QA/QC procedures:	Values should be given to one decimal place (e.g., 5.2 yrs).
Any comment:	

Data /parameter:	T_p
Data unit:	yr
Used in equations:	3
Description:	Time since start of project activities
Source of data:	Project schedule log
Measurement procedures (if any):	
Monitoring frequency:	Since monitoring must occur for baseline renewal, and can range from 5 to 20 years if carbon stock enhancement is included, time periods shall occur at these intervals.

QA/QC procedures:	Values should be given to one decimal place (e.g., 5.2 yrs).
Any comment:	