City of Richmond Northeast bog forest carbon project: methodology for including peat emissions (v.1.2.1)

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Introduction

Peatlands contain a vast reservoir of terrestrial carbon. In Canada, most peatlands are located within the permanently frozen soil (permafrost) at higher latitudes, though not exclusively. The Metro Vancouver region, for example, has more than 10,200 ha of freshwater wetland ecosystems, including bogs, shallow water, and marshes (Meidinger et al. 2014)[1], which collectively represent a significant reservoir of peat. The total stock of peat-based carbon has declined steadily throughout Metro Vancouver and elsewhere, as sites were drained for peat extraction, agricultural use, or development; these activities are ongoing. Undrained peatlands store carbon by removing atmospheric carbon dioxide (CO_2) but they also naturally produce small amounts of methane (CH_4), which is a more potent GHG than CO_2. Human-induced reductions in water table levels constitute an additional source of greenhouse gas (GHG) emissions because GHG fluxes are strongly correlated with changes in water levels (Couwenberg et al., 2008). A lowered water table dries out the surface organic layers which reduces CH_4 production. It can substantially increase emissions of CO_2, however, via peat oxidation such that there is a significant net increase in the warming potential from the change in GHG emissions (Gorham 1991).

One approach to reducing the loss of peatlands and their stored carbon is to issue carbon 'credits' for activities that either preserve the existing carbon pool (by preventing drainage, for example) thereby pre-empting GHG emissions or restore carbon sequestration capabilities through, for example, rewetting drained sites (Waddington and Price 2000). To quantify the net carbon benefits of these activities, reliable assessments of GHG fluxes are required. Direct measurements of GHG fluxes are complex and expensive, and so datasets of this type are relatively rare. Furthermore, few carbon projects would possess the financial means to undertake these activities at temporal and spatial scales sufficient to make such measurements worthwhile for the purposes of a carbon project. The Green Communities Committee (GCC) Avoided Forest Conversion Project (AFCP) program is a case in point; its Option 1 project profile is applicable to lands that are as little as one hectare (ha) in size and no larger than 650 ha. Though relatively small, this area restriction is well suited to local governments because it encompasses the majority of lands they own or can acquire for purposes of a carbon project.

The GCC AFCP protocol is used to estimate the emission reduction potential associated with preventing the conversion of existing forested land to a non-forest use and provides a simplified set of instructions for local governments to implement this type of GHG reduction project. One limitation of the approach is that it accounts only for carbon benefits derived from living forest biomass. There is no consideration of soil carbon in the protocol. The assumption is that in upland soils, this carbon pool is relatively stable such that any increase in emissions

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[1] Wetland ecosystems, as potential areas of peat deposition, are found where soils are saturated by water for enough time that the excess water and resulting low oxygen levels influence the vegetation and soil. The water influence is generally seasonal or year-round and occurs either at or above the soil surface or within the root zone of plants (Meidinger et al. 2014).

associated with land-use would occur only very slowly. In the case of peatlands (whether forested or not), the vast majority of ecosystem carbon is stored in the peat deposit itself (Gorham 1991), and so a (large) potential source of GHG emissions is ignored. Thus, for this project type to be included within the GCC program, a set of proxy variables and associated equations will need to be developed that can be used for estimating the anticipated peat carbon losses associated with the baseline and for monitoring the carbon benefits from the alternative (project) scenario.

Net ecosystem exchange (NEE) is the difference between vegetation productivity (atmospheric carbon captured from gross ecosystem photosynthesis) and emissions from ecosystem respiration (Strack 2008). Although NEE is difficult to measure and shows considerable regional and annual variability (Couwenberg 2009), water table depth appears to be a major controlling factor (Waddington and Price 2000; Abdalla et al. 2016). A proposed approach that incorporates the impact of water table depth on ecosystem carbon balance is therefore detailed below. It is designed as a modification to the current GCC AFCP protocol in that the proponent (the local government) can use accepted AFCP principles to estimate the carbon balance in the forested component but include (optionally) the GHG benefits of preserving the peat component, should the latter be present.

Applicability criteria:

In addition to meeting the seven Project Eligibility Requirements under the Carbon Neutral Framework, application of this framework is as follows:

1. Considers only the GHGs, CO_2 and CH_4. N_2O is not considered a significant GHG in forested bogs or wetland areas that have not been impacted by fertilizer use (Oleszczuk et al. 2008). Fertilizer use is disregarded in the baseline case; this is a conservative assumption.
2. Meets the definition of a bog forest[2].
3. Located on a ‘Wet’ soil moisture regime:

Soil moisture regime (SMR) describes the annual “average” water regime (Klinka et al. 1995). A Wet or Very Wet SMR is the prerequisite to wetland formation. Wet sites have a water table within 30 cm of the surface and for a least some of the year have an aerated surface layer; Very Wet sites remain saturated at the surface year-round.

4. Soils have one or more of the following features: (a) Peaty organic horizons greater than 40 cm thick; (b) Non-sandy soils with blue-grey gleying within 30 cm of the surface; (c) Sandy soils with prominent mottles within 30 cm of the surface or blue-grey matrix; (4) Hydrogen sulphide (rotten egg smell) detectable within the upper soil layer[3].

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[2] Although the methodology is developed within the context of forested peatlands, it could also be applicable to small (in terms of area), ‘healthy’ sphagnum-dominated sites without trees.

[3] https://www.for.gov.bc.ca/hfd/pubs/docs/en/en45.pdf

5. Presence of facultative hydrophytes, such as Labrador tea (*Rhododendron groenlandicum*) and other members of the Ericaceae family, characteristic of bog forests (see Klinka et al. 1995)**.**

Baseline case: Conversion to agriculture

At the project start date, the baseline scenario must consist of land suitable for development and that can be cleared of trees, drained, and then converted to agricultural production. Drainage is used to achieve sufficient aeration in the soil for cultivated crops and pasture. The combination of altered hydrology and vegetation, and cultivation measures (e.g., tillage, fertilization), can change the carbon sequestration and sink functions of the land, leading to large-scale emissions. Land use patterns in the surrounding area should be used to justify the baseline. The impacts of converting peatlands to agriculture on ecosystem properties and losses in carbon storage are reviewed in Laine et al. (2008) and Oleszczuk et al. (2008).

Project case: Conservation and enhancement

The project scenario represents activities designed to preclude baseline activities thereby conserving and potentially enhancing, carbon stocks by maintaining or increasing water levels. This can include ditch blocking, conserving the existing vegetation community and/or promoting vegetation establishment.

Additionality

Additionality is realized through conservation of the property and where the annual water table is maintained or enhanced, as a feasible alternative to the counterfactual argument under the baseline scenario of land conversion. Protections need to be above and beyond legislated requirements, and also be compliant with all GCC AFCP eligibility requirements.

Calculating baseline emissions

Calculation of carbon emissions from the vegetative component is as per GCC AFCP guidelines[4].

Carbon emissions from peat are calculated, as follows.

A regression model between GHG fluxes and mean annual water table depth will be utilized. Couwenberg et al (2011) have developed a set of regressions based on data from published and other sources covering peatlands in temperate Europe[5].

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[4] AFCP guidance document: http://www.toolkit.bc.ca/Plan-Do-How/how/Becoming-Carbon-Neutral-Local-Government#downloaddocuments

[5] As noted by Gorham (1991, and references therein), peatland vegetation and landforms are relatively similar in North America and Europe, so that generalizations from one continent to another are reasonable. In an additional step outlined in Couwenberg et al., (2011) vegetation types from the project area can be compared with vegetation

Annual methane emissions from peat soils in relation to the mean annual water level are estimated as:

$y = 16.79(x+20)$; $n=24$; $r^2 =0.76$, $p = 0.01$ (1)

where y are annual methane emissions (kg CH_4 ha^{-1} $year^{-1}$), and x the mean annual water level (cm). This relationship applies only to sites with mean annual water level $\geq$ -20 cm and aerenchymous shunt species present (see Jung et al. 2008). Deeper water levels have zero methane emissions.

Net annual CO_2 fluxes (kg CO_2 ha^{-1} $year^{-1}$) from peat soils in relation to mean annual water level (x), can be estimated as:

$y = - 752x - 4750$; $n = 35$; $r^2 = 0.71$, $p = 0.01$ (2)

This relationship applies to sites where mean water levels are above -50 cm. For deeper water levels, emissions are assumed to be equal to that at the 50-cm depth.

These equations are considered suitable as default values for application in British Columbia. This is because climatic conditions and many of the dominant plant species in coastal regions and low elevation forests, are not dissimilar to those reported in Couwenberg et al. (2011). The regression relationships can be replaced, however, if sufficient data become available. One concern is that climate conditions at higher latitudes in the province may be considerably colder and drier than the more temperate climate from which equations 1 and 2 were derived (see Couwenberg et al. 2011). Another consideration, is that climate change may increase mean average temperature and alter patterns in annual precipitation. The latter could affect water table depth though this should not be problematic since it is the independent variable in equations 1 and 2. GHG fluxes can vary strongly between years, in part due to fluctuations in temperature. Although fluxes might increase in a warming climate (Couwenberg et al. 2011, and references therein), this applies equally to both the baseline and project case. Hence, the relative difference between the two should be relatively muted. Nevertheless, consideration should be given to re-calibrating equations 1 and 2 if changes in annual temperature and precipitation prove to be substantial.

Annual peat GHG emissions in the baseline are estimated using equations 1 and 2 from a projected decline in mean annual water table depth due to drainage. The latter should be supported and estimated from local, documented practices.

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data from which the GHG flux data are derived. If there is sufficient similarity, then on-site vegetation itself can be used as a proxy for GHG emissions; this exercise is useful for large projects with range of vegetation types. It is not included in this methodology because the area comprising most Option 1 AFCP projects is small enough that it encompasses only a single vegetation community.

Calculating project emissions

Project GHG emissions from the peat component are estimated from equations 1 and 2 assuming a constant mean annual water table depth, as measured prior to the first carbon credit calculation.

The GHG balance of the vegetative component over the project lifespan will be calculated as per GCC AFCP guidelines[4].

Peat depletion time (PDT)

A final consideration is to ensure, in the case of the baseline, peat stores are sufficient that oxidation does not result in total depletion within the project lifespan. In temperate peatlands, peat is depleted at a rate of about 0.4 cm year^{-1} for each 10 cm of additional drainage depth (references in Couwenberg et al. 2010). So, for example, a 30 cm drop in the mean annual water table results in an annual subsidence rate of 1.2 cm year^{-1}; over a 20-year project timeline, this would translate into a loss of 24 cm in depth[6]. In principle, then, a peat layer of 20 cm would be totally oxidized in about 17 years (the PDT). A complicating factor is that the deeper peat layers found in the catotelm (the permanently saturated layer) usually have different biochemical properties than surface peat. Deeper layers are more weathered (humic peat) and tend to resist decay even when exposed to oxygen, versus the 'younger' fibric peat characteristic of the acrotelm, which decays relatively quickly. Hence, oxidation rates in the humic peat will be lower and so the entire peat deposit is not likely to decay at a constant rate following drainage. It is proposed therefore that the PDT must exceed the time required for half of the peat deposit present at the project start date to decay, a conservative assumption in terms of the net carbon balance. So, in the example above the average depth of the peat deposit must exceed 48 cm since a 24-cm loss is anticipated over the 20-year project lifespan from a 30-cm drop in the mean annual water table. These calculations can be used to determine the PDT for projects of any duration.

Estimating and accounting for uncertainty

Uncertainty in the estimation of emissions and carbon stock changes (i.e., calculating a precision level and any deduction in credits for lack of precision in baseline and project estimations), is calculated as follows.

Sources of uncertainty:

- Estimation of stocks in carbon pools and changes in carbon stocks
- Assessment of project emissions

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[6] Typically, subsidence rates are very high immediately after drainage as the peat body compresses mechanically due to a decline in the supporting pore water pressure (Oleszczuk et al. 2008). These values exclude this period.

Guidance on uncertainty:

Where an uncertainty value is not known or cannot be simply calculated, the project proponent must justify that it is using a conservative number and an uncertainty of 0% may be used for this component. However, a mandatory default uncertainty deduction of 1.5% is subtracted from the total project emission reductions to account for unplanned losses from anthropogenic sources.

Total uncertainty associated with project activity is calculated as (adapted from Emmer and Couwenberg 2017)**:**

$$\mathrm{Uncertain}_{Total} = \frac{\sqrt{(Uncertain_{BSL} \times GHG_{BSL})^2 + (Uncertain_{WPS} \times GHG_{WPS})^2}}{GHG_{BSL} + GHG_{WPS}} \tag{3}$$

Where,
$Uncertain_{Total}$ is the total uncertainty for project activities; decimal %
$Uncertain_{BSL}$ is the total uncertainty in the baseline scenario; decimal %
$Uncertain_{WPS}$ is the total uncertainty in the project scenario; decimal %
GHG_{BSL} is the net CO_2 equivalent emissions in the baseline scenario up to year t; t CO_2e
GHG_{WPS} is the net CO_2 equivalent emissions in the project scenario up to year t; t CO_2e

To account for uncertainty in the estimation of emissions and carbon stock changes, a precision threshold target of a 90% or 95% confidence interval equal to or less than 20% or 30%, respectively, of the recorded value is required. Where this precision level is met no deduction is required for uncertainty. Where exceeded, the deduction is equal to the amount that the uncertainty exceeds the allowable level.

$NER_{RDP,t}$ (t CO_2e) is the total net CO_2 equivalent emission reductions from the project up year, *t.* It is adjusted for uncertainty, as follows:

$$adjusted\_\ NER_{RDP,t} = NER_{RDP,t} - NER\_ERR_{RDP,t}$$

and

$$NER\_ERR_{RDP,t} = NER_{RDP,t} * \max(0, Uncertain_{Total} - allowable\_uncert) + 0.015$$

where,
$NER\_ERR_{RDP,t}$ is the net uncertainty error for project activities at time *t*; (t CO_2e)
$adjusted\_\ NER_{RDP,t}$ *is the* cumulative total net GHG emission reductions at time *t* adjusted to account for uncertainty; t CO_2e,
$NER_{RDP,t}$ *is as defined above*,
allowable_uncert is the allowable uncertainty; 20% or 30% at a 90% or 95% confidence level,

respectively; %

Required conditions:

- Levels of uncertainty must be known for all aspects of baseline and project implementation and monitoring. Uncertainty will generally be known as the 90% or 95% confidence interval expressed as a percentage of the mean.
- Where uncertainty is not known it must be demonstrated that the value used is conservative.
- Calculation of project uncertainty is, in general, additive. One exception is the estimation of CO_2 and CH_4 emissions (equations 1 and 2). These GHGs have opposite responses to changes to mean annual water table depth (see Couwenberg et al. 2011) and so, in this case, the largest error term associated with a given GHG, is used.

Calculation coefficients

1 tonne C = 3.67 t CO_2e
GWP potentials:
CO_2 = 1
100-year GWP of CH_4 = 28 (IPCC, 2014)[7].

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[7] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

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