DARKWOODS FOREST CARBON PROJECT

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For: Nature Conservancy of Canada

www.natureconservancy.ca

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1 PROJECT DETAILS

1.1 Summary Description of the Project

The Darkwoods Forest Carbon Project creates climate, community and biodiversity benefits through the acquisition and management of a 54,870 ha (135,587 acre) commercial timberland, located near Creston, British Columbia, Canada, for ecological conservation purposes in perpetuity. The project avoids GHG emissions from logging in the without-project baseline scenario, retains and sequesters significant carbon stocks, retains substantial net benefits for the local communities, and provides exceptional biodiversity benefits from the conservation and management of large-scale fully functional natural ecosystems and critical habitat for key endangered species.

The Darkwoods Forest Carbon Project achieves net GHG emission reductions and removals through the avoidance of emissions due to logging in the baseline scenario, and by increasing carbon stored by biomass growth in the retained forests on the project area in the project scenario.

Prior to the project, the Darkwoods property was being sold privately by the previous owner based on a sales price from a formal property and timber valuation/appraisal, which valued the property based on a management regime similar to the baseline scenario. The most plausible baseline scenario is a market-driven acquirer who implements an approximately 15 year depletion of current mature timber stocks to provide a reasonable internal rate of return on investment. Under the baseline scenario, a 100 year uneven harvest schedule is implemented with the typical regional practice of clearcut logging with minimum legal requirements for private forestlands in B.C. and comparable regional practices.

The project scenario is conservation management activities, wherein NCC undertakes the carbon project and ecosystem protection and enhancement activities. The project scenario periodically involves a low level of timber removal as part of conservation management activities for ecosystem/habitat enhancement, risk management, and other conservation objectives.

The project has been successfully implemented as planned since the start date in 2008. The project has been verified for emission reductions from 2008-2016, with 2017-2019 pending verification simultaneously with the re-validation of this document. This new version of the Darkwoods Project Design Document has been created to comply with the VCS 10 year baseline re-validation requirement, and to update the project documentation for various improvements and changes to forest inventories and carbon modeling techniques made over the first 10 years of the project.

The project has also been validated and verified to the Climate, Community and Biodiversity Standard (CCB), and further details of the projects impacts on community and biodiversity are available within the adjoining CCB PD and various CCB/VCS Monitoring Reports.

After re-assessment, there have been no changes to the baseline scenario conditions, and hence the baseline scenario projections have been maintained. The outlook for the baseline scenario over the next 10 years is similar to the original ex-ante projections, with the exception that new forest inventory likely extends the available forest standing stocks beyond the original expected 15 years (to ~2028) before dropping to lower harvest rates as expected. No other project background or assessment has materially changed in Section 1, including no change to the applicable legal requirements on the project area.

The PD re-validation also requires modification to become compliant with the latest version of the VM0012 methodology (now v1.2). This has required changes to the calculation of Harvested Wood Products carbon accounting which is now reflected in this PD version. The project has modified the leakage method used starting in 2017 to the VCS Leakage Method outlined in VM0012 (see the 2017-2019 Monitoring Report for additional details).

A new forest inventory was created for the property in 2011. Further details of the transition to the new inventory are outlined in the 2011-12 Monitoring Report. A change was made to improve the forest and carbon modeling in the 2017-2019 monitoring period which is now reflected in this updated PD version.

The Darkwoods IFM-LtPF carbon project is projected to generate approximately 14.7 million tCO_2e emissions reductions over 100 years on an ex-ante basis. Annual average net emission reductions are variable and are projected to average between 10,000 and 440,000 tCO_2e.

1.2 Sectoral Scope and Project Type

Sector 14 - AFOLU

Improved Forest Management (IFM)

Logged Forest to Protected Forest (LtPF)

This is not a grouped project.

1.3 Project Eligibility

Eligible IFM activities are those that increase carbon sequestration and/or reduce GHG emissions on forest lands managed for wood products such as sawtimber, pulpwood and fuelwood by increasing biomass carbon stocks through improving forest management practices. The baseline and project scenarios for the project area shall qualify as forests remaining as forests, such as set out in the IPCC 2006 Guidelines on National GHG

Inventories, and the project area shall be designated, sanctioned or approved for wood product management by a national or local regulatory body (e.g., as logging concessions or plantations)

The project meets VCS IFM eligibility requirements:

- The project increases carbon sequestration and/or reduces GHG emissions on forest lands managed for wood products by increasing biomass carbon stocks through improved forest management practices.
- The baseline and the project scenarios both involve activities where forests remain forests. Forest areas are retained as forest after harvest, with no material land conversion other than for forest roads required to support forest management.
- As fee simple private lands, the project area is approved for wood product management. The project voluntarily participates under the British Columbia Private Managed Lands Act.

The project meets the VCS LtPF eligibility has by converting logged forest to conservation forests.

1.4 Project Design

The project is non-grouped and is located on a single project area and can include multiple project activity instances, including limited timber harvesting and other conservation-based forest management activities.

1.4.1 Eligibility Criteria

The project is not a grouped project

1.5 Project Proponent

Organization name	Nature Conservancy of Canada
Contact person	Rob Wilson...
Title	Director, Carbon Finance
Address	Suite 400 - 36 Eglinton Avenue West Toronto, Ontario, Canada. M4R 1A1
Telephone	+1 416 932 0050
Email	rob.wilson@natureconservancy.ca

1.6 Other Entities Involved in the Project

Organization name	RainCloud Forests
Role in the project	Project Implementation Partner
Contact person	Mike Vitt
Title	Principal
Address	3516 Skylark Loop, Bellingham, WA, USA. 98226
Telephone	+1 206 307 7096
Email	mike.vitt@raincloudforests.com

1.7 Ownership

NCC owns the Darkwoods property (the entire project area) on a fee simple basis. Title documentation is registered with the British Columbia Land Title Office (www.ltsa.ca).

Table 1 - Legal Descriptions and Parcel Identifiers of Darkwoods Parcels

PID #	Description
PID 007-608-349	Sublot 1, District Lot 2381, Kootenay District, Plan X74, except (1) Plans 1760 and NEP77791 and (2) Part in Lot 15184 known as “Tramline” MC
PID 007-608-594	Sublot 7, District Lot 2381, Kootenay District, Plan X74
PID 007-608-446	District Lot 887, Kootenay District, except part included in Plan 1760
PID 026-235-927	District Lot 15184, Kootenay District

1.8 Project Start Date

Project Start Date: 01 April 2008.

The project start date is the date that NCC completed the acquisition of the Darkwoods property.

1.9 Project Crediting Period

Project Start Date: 01 April 2008

Project End Date: 31 March 2109

Crediting Period: 100 years

1.10 Project Scale and Estimated GHG Emission Reductions or Removals

Project Scale	
Project	X
Large project	

Year	Estimated Annualized GHG emission reductions or removals (tCO_2e)
2008	**317,823**[1]
2009	**331,727**
2010	**439,461**
2011	**435,748**
2012	**427,496**
2013	**371,602**
2014	**405,719**
2015	**367,248**
2016	**414,790**
2017	**263,116**

[1] 2008-2016 net emission reductions are reported here on a verified ex-post basis. 2017-2019 are reported on an ex-post basis under verification. 2020-2028 are reported as ex-ante projections. The remaining years from 2028-2109 are reported as annualized ex-ante projections averaged over 5 year increments.

2018	**231,998**
2019	**315,986**
2020	452,612[2]
2021	413,921
2022	430,528
2023	440,911
2024	290,837
2025	131,601
2026	126,403
2027	243,925
2028	134,467
2029-2033	127,468
2034-2038	116,801
2039-2043	158,659
2044-2048	97,842
2049-2053	81,649
2054-2058	117,388
2059-2063	119,179
2064-2068	90,160
2069-2073	74,324
2074-2078	41,217
2079-2083	10,230
2084-2088	75,355

[2] Future ex-ante projections are reported based on the prior version VCS Project Description (v1.1), which are consistent with the long term emission reduction outcomes expected by the project. Updated inventory and modeling techniques may result in variation on an annual ex-post basis at future verifications, but the overall ex-ante outlook is representative of the net ER expected by the project.

2089-2093	139,373
2094-2098	107,151
2099-2103	113,304
2104-2108	83,095

1.11 Description of the Project Activity

The Darkwoods project will create net GHG emission reductions and sequester additional carbon in biomass by avoiding logging operations in the baseline scenario. Project activities are designed to meet the objectives of the latest Darkwoods Property Management Plan (PMP), or the equivalent future conservation and property management planning processes developed by NCC for Darkwoods. The currently effective PMP for Darkwoods is for the period of 2017-2021 (NCC, 2016), and these plans are currently updated on a 5 year basis. The current PMP has seven biodiversity targets as outlined in Table 2.

Project activities primarily include forest conservation activities that do not materially affect carbon stocks. Project activities that impact carbon stocks include limited limited timber harvesting for long term conservation purposes (and to support community impact mitigation - see the project's CCB Project Description and Monitoring Reports). Future project activities may include new conservation-based management activities including limited timber harvesting, thinning, fire fuel reductions, or potentially prescribed burning. These activities will target improvements in biodiversity effectiveness, ecosystem services enhancement, long term habitat development/support, fire and forest health risk mitigation, and/or to support other conservation objectives developed by NCC.

The project is not located in a jurisdiction covered by a REDD+ program.

Table 2. 2017-2021 Darkwoods Property Management Plan biodiversity targets (summarized, see Table 7 in the Darkwoods Property Management Plan 2016).

Biodiversity Target	Ecological Justification	Size Impact	Property Condition	Landscape Context	Viability Rank
Carbon Sequestration	Mitigating the impacts of climate change	Very Good	N/A	Good	Very Good
Fire Maintained Ecosystems	ICHxw and ICHdw ecosystem are rare, degraded, support many species at risk	Very Good	Good	Fair	Good
Hydroriparian Ecosystems / Wetlands	Rare, diverse ecosystems. Support key fish populations	Very Good	Good	Very Good	Good
Mid-elevation Forests	Old Growth Interior Cedar-Hemlock.	Very Good	Good	Good	Good
Whitebark Pine Ecosystems	Keystone species in high elevation forests. Endangered.	Good	Poor	Good	Fair
Woodland Caribou Habitat	Critical habitat, highly endangered trans=border herd.	Poor	Poor	Fair	Poor
Grizzly Bear	Key habitat for important sub-population. Umbrella species	Good	Good	Good	Good

1.12 Project Location

The Darkwoods property is a 54,870 ha (135,587 acre) contiguous parcel of fee simple private property in south eastern British Columbia just north east of the municipality of

Creston[3]. The Darkwoods property is bounded by Kootenay Lake on the east and various crown and private land on the other property boundaries. There is a significant in-holding in the center of the property that was acquired by NCC in 2018-19 but is currently not part of the project. The boundaries are surveyed with the following legal and land description for the parcels described in Table 1.

The project area from the prior version of the PD has been updated from GIS data from 54,792 ha previously reported to 54,870.4 ha, a change of 78.4 ha (0.14%). This is a de minimis change. This new area matches the KML files provided as part of findings responses from the 2013-2016 monitoring period.

[3] Property centroid: UTM Zone 11 (505983, 5458692).

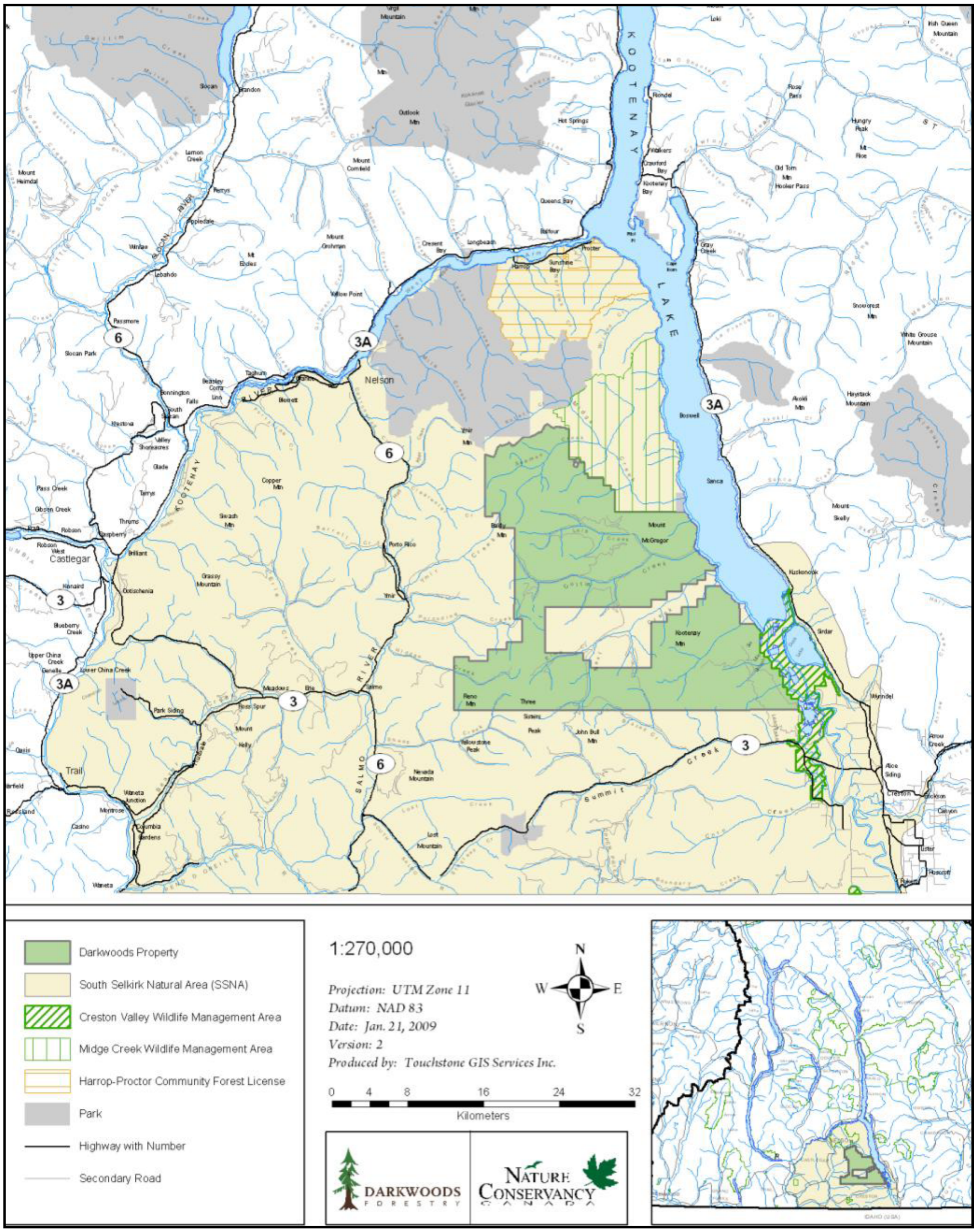


Figure 1. Darkwoods Property Boundary and Project Area Overview Map

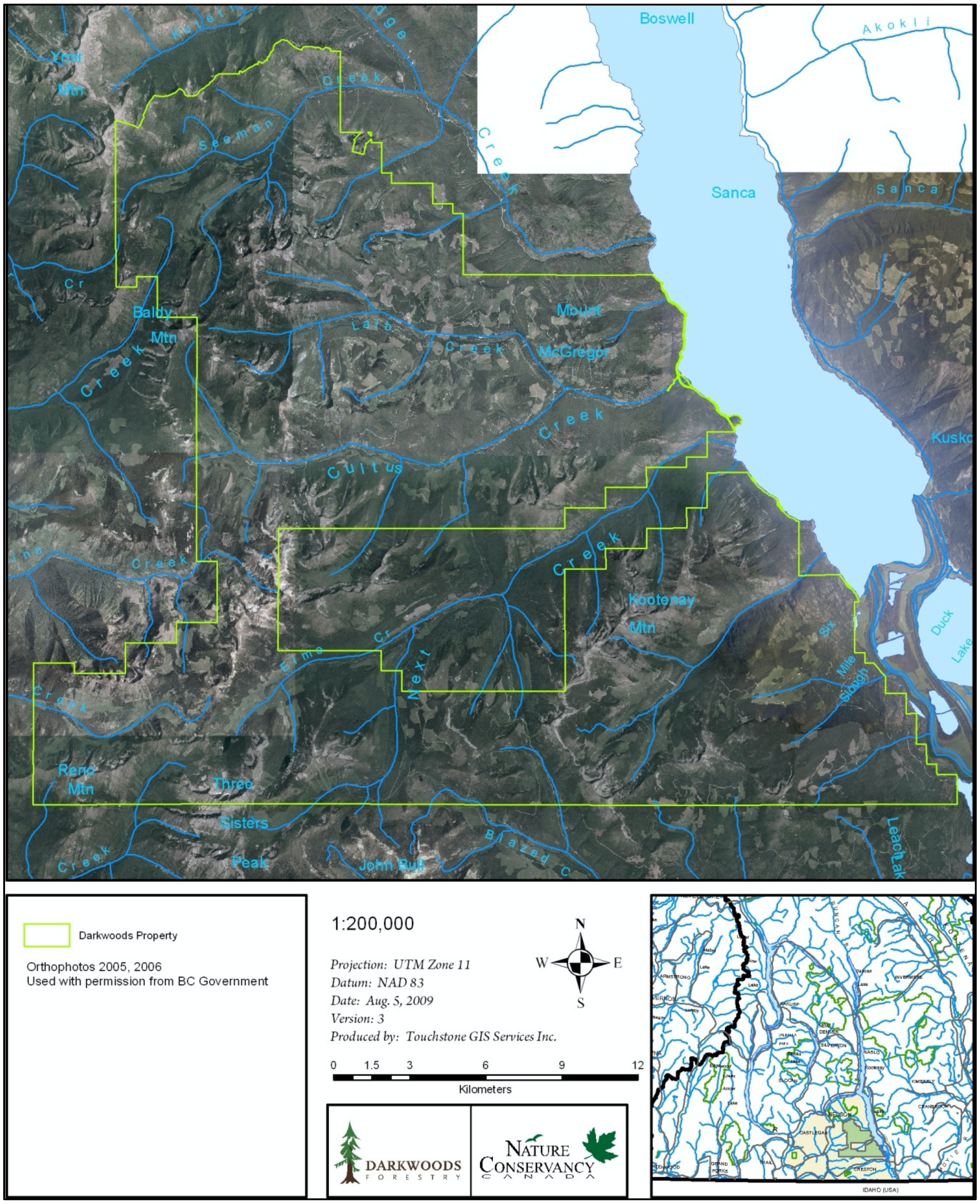


Figure 2. Darkwoods property ortho mosiac

1.13 Conditions Prior to Project Initiation

Prior to the NCC acquisition, the Darkwoods property was been owned and managed by the Pluto Darkwoods Corporation on behalf of a His Royal Highness Duke Carl Herzog von Wurttemberg (a German aristocrat) since 1967. The previous management has been focused on sustainable forest management with a moderate harvest level (averaging approximately 57,000 m^3/year) and strong ecological and conservation management principles. For example, despite no legal requirement on private land and beyond even crown land regulations, the Pluto Darkwoods Corporation retained approximately an additional 1/3 of the merchantable timber areas on the property in generally protected condition.

The Pluto Darkwoods Corporation decided to divest the Darkwoods asset, apparently to re-deploy the asset capital and due to the operations not producing reasonable returns at the reduced harvest levels. The history of conservation-based management on the property created retained critical biodiversity and habitat areas of interest to NCC; however, this previous management also resulted in a large component of mature growing stock which provides an important immediate revenue opportunity for market driven acquirers. In addition, the property sits adjacent and overlooking Kootenay Lake, with substantial future real estate development potential that was attractive to alternative investors.

The property was offered for a sealed bid sale, first to a selected group of bidders, of which NCC was one. NCC viewed the Darkwoods property as under immediate threat of liquidation logging and other industrial logging practices and/or extensive real estate development. Recent liquidation logging activities on a large adjacent property and other regional evidence of private forestland liquidation reinforced this threat assessment.

In B.C., private land is lightly regulated with minimal land protection requirements and regulations. Private rural residential land has limited regulatory oversight other than local land use zoning, when applicable. Private timberland in B.C. can be voluntarily registered as Private Managed Forest Land under the Private Managed Forest Land Act in B.C., which provides a lower land tax rates in exchange for maintaining the forest land as forested. The act requires only very basic riparian and minimal reforestation (significantly lower than what is required on adjacent crown/public lands); however there are no other constraints on harvest levels or other minimum practices. Liquidation logging with little regard for basic environmental protections or sustainable timber production is legal and not uncommon in B.C. on private land. The original Pluto Darkwoods management was not representative of either the legal requirements or common practice on comparable private lands.

Project Site Background (adapted from (NCC, 2010)**):**

Forest harvesting, wild fire and forest pathogens have disturbed the property area over the past 100 years. Still, the current and long-term biodiversity potential is very high. To date, 200 animal and 219 plant species have been confirmed on the property.

Physical description: The property is located near the southern extent in BC of the Selkirk mountain range, which is locally bounded to the east by Kootenay Lake and to the west by the Salmo River valley. Elevations range from approximately 450 m in the Creston Valley to over 2400 m.

Biological description: Darkwoods is located in the Southern Interior Mountains ecoprovice, Northern Columbia Mountains ecoregion, and the Southern Columbia Mountains ecosection. Biogeoclimatic subzones include the Engelmann-Subalpine Spruce (ESSF) dry-mild (dm) and wet-cold (wc) subzones, as well as the Interior Cedar-Hemlock (ICH) dry-warm (dw) and moist-warm (mw) subzones.

IUCN red-list species: grizzly bear (*Ursus arctos*)(Threatened), wolverine (*Gulo gulo*)(Near Threatened),and bull trout(*Salvelinus confluentus*)(Vulnerable).

Other notable species: In total, 19 Globally, Nationally, and/or Provincially significant species-at-risk are predicted to occur on the property, 15 of which have been confirmed (Steeger and Machmer 2009). Darkwoods likely provides significant habitat for at least 8 of these species-at-risk, including grizzly bear (Special Concern; blue list), mountain caribou (*Rangifer tarandus*) (Threatened; Red list), Olive-sided Flycatcher (*Contopus cooperi*) (Threatened; Blue list), Peregrine Falcon (*Falco peregrinus*) (Special Concern; Red list), western toad (*Bufo boreas*) (Special Concern; Yellow list), wolverine (Special Concern; Blue list) and bull trout (Blue list).

Legal status: Darkwoods is private land, owned in fee simple by the Nature Conservancy of Canada, subject to the encumbrances registered on title and the terms of the original Crown Grant. The management and disposition of the property is subject to NCC"s Conservation Policy Framework as approved by its board of directors. Furthermore, the property purchase involved the Ecological Gifts Program, therefore Environment Canada must approve any "Changes in Use" as defined by Environment Canada. The land is also voluntarily registered as managed forest land for assessment purposes, and as such NCC has obligations as a managed forest owner under the Private Managed Forest Land Act.

Historical description: The property was originally a crown land grant to the Nelson & Fort Sheppard Railway in 1897. It was held by various private interests until purchased by Nature Conservancy Canada in 2008 from the Pluto-Darkwoods Corporation, the latter of which had owned the property for the previous 40 years. The principle land use has been forestry.

Cultural description: Darkwoods is within the traditional territory of the Ktunaxa First Nation. There has been a tradition of outdoor recreation on the property, including fishing, snowmobiling, skiing, and summer vacations at Tye.

Access information: Permitted public access is provided through the Blazed Summit Forest Service Road or the Porcupine Creek Forest Service Road from the west near Salmo. Other access points include Wildhorse, Oscar, Hidden, Sheep, Nugget, Topaz and Newington roads. The residential Tye site can be reached by boat via Kootenay Lake. Other access to the property is often arranged by helicopter.

Regional Biogeoclimatic Overview:

The following is an overview of the sub-regional bioclimatic conditions that relate to the project site (B.C. Ministry of Forests, 2008).

The Kootenay Lake Timber Supply Area (TSA) includes both moist and wet climatic regions, and is commonly referred to as part of the Interior Wet Belt. The moist climatic region covers most of the TSA, except for a wet region north of the Purcell Wilderness Conservancy (well to the north of the Darkwoods property). Varied ecological features and species diversity contributes to the high biodiversity values in this TSA.

Three biogeoclimatic zones and four ecosections occur in the Kootenay Lake TSA. The Interior Cedar Hemlock (ICH) zone occupies valley bottoms and lower slopes to about 1400 meters. Four different subzones of the ICH occur in this TSA, reflecting differences in precipitation. They range from a drier subzone around the south end of Kootenay Lake where annual precipitation averages 70 cm to a wetter subzone in the Duncan Valley where annual precipitation averages 120 cm. In general, the ICH zone has wet, cool winters and warm, dry summers, and is the most productive forest zone in the interior of BC. The ICH has a high diversity of tree species including Western red cedar, Western hemlock, Grand fir, Engelmann spruce, Subalpine fir, Western larch, Douglas-fir, Western white pine, Western yew, Ponderosa pine and Lodgepole pine. The Engelmann Spruce-Subalpine Fir (ESSF) zone is the uppermost forested zone in the Kootenay Lake TSA, typically occurring at elevations between 1400 and 2500 meters (i.e., above the ICH and below the Interior Mountain-heather Alpine zone). The ESSF zone has a relatively cold, moist and snowy continental climate. Growing seasons are cool and short, while winters are long and cold. Engelmann spruce and Subalpine fir are the dominant climax tree species, while Alpine larch and Whitebark pine also occur. At the lower elevations of this zone, Lodgepole pine, Douglas-fir, Western hemlock and Western red cedar can be found. The Interior Mountain-heather Alpine (IMA) zone occurs at elevations greater than 2250 meters, above the ESSF zone. The climate is cold, windy and snowy with a short, cool growing season. By definition this area is largely treeless — consisting of rock, ice and snow. Shrubs, herbs, mosses and lichens are a common component in vegetated areas.

The diverse forests of the Kootenay Lake TSA support an abundance and wide variety of wildlife species. Large mammals include black bear, grizzly bear, moose, mule deer, white-tailed deer, cougars, elk, mountain goat, bighorn sheep and caribou. Mountain caribou require older forests for forage and security cover, as well as large unfragmented forests for seasonal migrations. Seventy percent of the bird species known to occur in BC and 62% of bird species that breed in the province are known to exist in the Kootenay Lake area. More than 20 varieties of birds are area year-round residents of the TSA including golden eagles, grouse, woodpeckers, jays, magpies, ravens and English sparrows. The area also contains one of the highest breeding concentrations of ospreys in the world (B.C. Ministry of Forests, 2008).

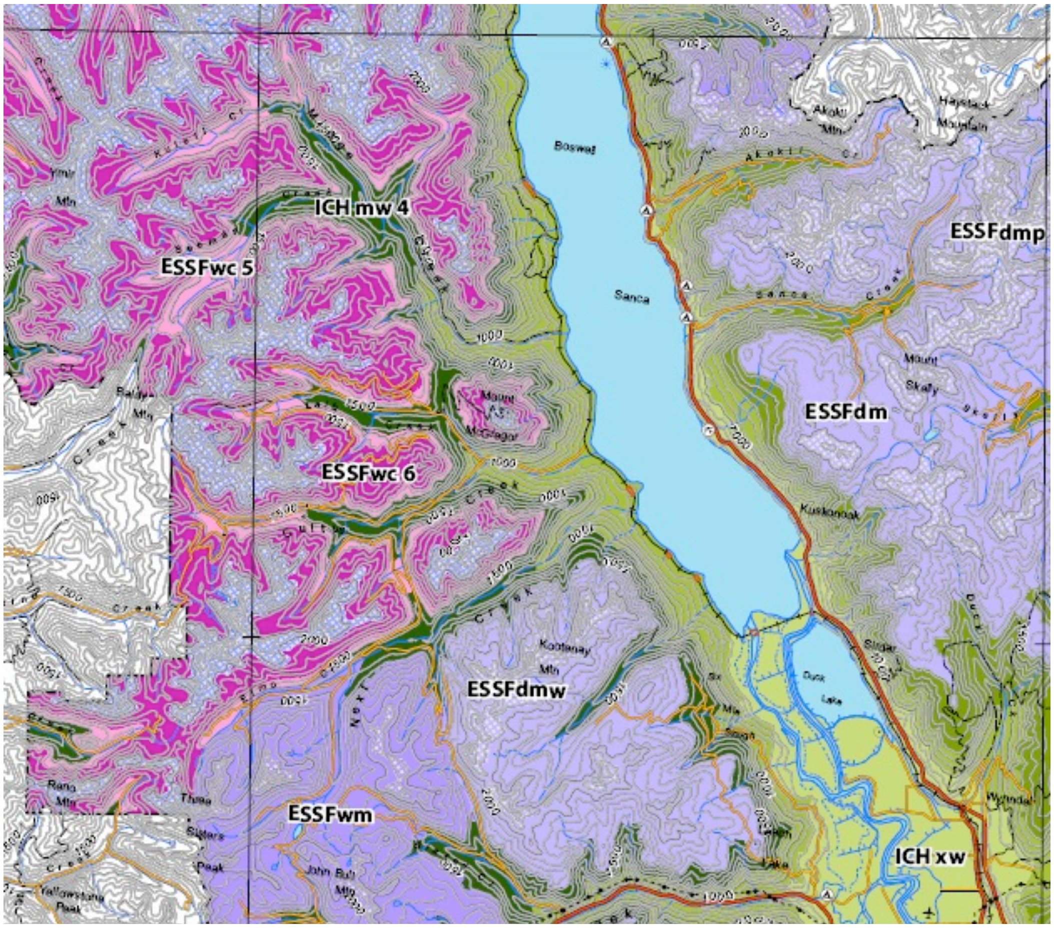


Figure 3. Darkwoods Area Biogeoclimatic Subzone/Variant Field Map (http://www.for.gov.bc.ca/HRE/becweb/)

Current State of the Property:

The Darkwoods property has a diverse mix of forest types, topography, age class, and forest conditions well distributed across the landbase (Figure 3, Figure 4, and Figure 5).

Approximately 68% of the property (37,250 ha) is considered operable for timber harvesting. Within this operable area, approximately 9,000 ha are in managed/reforested stands <40 years old, which reasonably reflects the total area harvested and reforested during modern silvicultural practices. The balance of the operable area reflects natural and older harvesting (>40 years ago) which are reasonably assumed to have been regenerated naturally, and exhibit (or have started to recover to) natural forest conditions and ecosystem function.

The property is well-roaded, with main haul routes located into each drainage area, as shown in Figure 4. A significant number of roads and stream crossings have been deactivated, stabilized, or fully reclaimed by NCC since the start of the project to reduce access pressure and improve biodiversity outcomes. Main access routes are maintained to support general access and support fire and forest health mitigation.

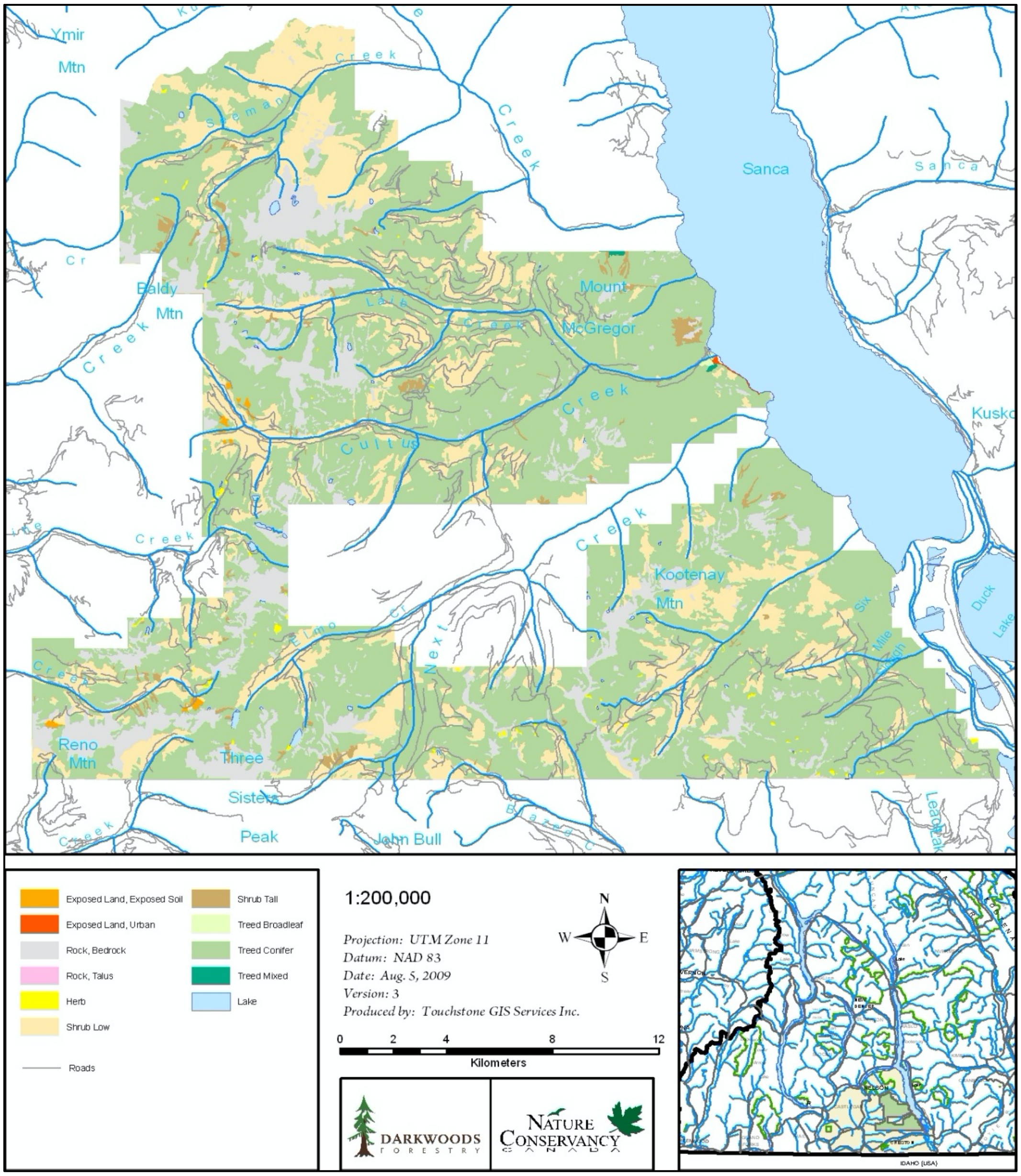
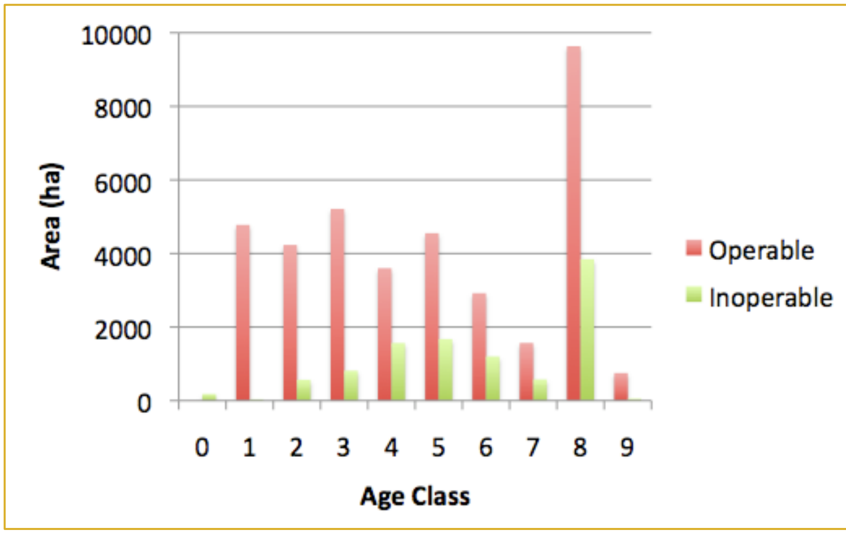


Figure 4. Darkwoods Land Cover Map



Age Class	Stand Age (yr)
1	1 - 20
2	21 - 40
3	41 - 60
4	61 - 80
5	81 - 100
6	101 - 120
7	121 - 140
8	141 - 250
9	251 +

Figure 5. Darkwoods Forest Area by Age Class and Operability (2009).

1.14 Compliance with Laws, Statutes and Other Regulatory Frameworks

This forest carbon project is designed to be compliant with Canadian and British Columbian laws in both the baseline and forest carbon project scenarios.

The Darkwoods carbon project is focused on conserving forest ecosystems and habitat, and is generally inherently compliant with provincial, federal, and international laws and regulations simply because of the limited level of land use activity. However, Darkwoods is managed by experienced forestry managers who ensure compliance with relevant laws and regulations, including the advice and use of B.C. Registered Professional Foresters and B.C. Registered Professional Biologists when required.

The project has projected the baseline scenario to be fully compliant with applicable laws and regulations on private lands in B.C. Any project scenarios activities such as habitat management, restoration, or salvage work will be undertaken with the advice or oversight of a B.C. Registered Professional Forester (or equivalent professional designation), and be undertaken in compliance with any relevant laws and regulations.

The primary set of legislation and regulation is the *Private Managed Forest Land Act*, however, as noted the baseline scenario projects opting out of the Private Managed Forests registration, which makes this legislation non-applicable in the baseline. The project scenario is subject to the *Private Managed Forest Land Act*. Generally, the remainder of the legislation outlined below has no or *de minimis* operational impact on the baseline or project scenario projections. .

An overview of the most relevant Provincial and Federal laws and regulations which might apply in certain circumstances to the Darkwoods property baseline or project scenario (source, and further details: (FSC Canada, 2005)):

Provincial Legislation:

Statute: *Private Managed Forest Land Act*, S.B.C. 2003, c. 80.
Comments: Sets out the legal framework for forest management on untenured private managed forest land.
Regulations: *Private Managed Forest Land Council Matters Regulation*, B.C. Reg. 372/2004. *Private Managed Forest Land Council Regulation,* B.C. Reg. 336/2004. *Private Managed Forest Land Regulation,* B.C. Reg. 371/2004.

Statute: *Foresters Act*, S.B.C. 2003, c. 19.
Comments: Regulates the forestry profession including registration, certification and discipline. Provides for the creation and mandate of the Association of British Columbia Forest Professionals.

Statute: *Water Act*, R.S.B.C. 1996, c. 483.
Comments: Among other things, applies to persons making changes in or about streams. See provisions in the *Water Regulation* that apply to forestry operations, particularly 38(2) 41 and 42.
Regulations: *Groundwater Protection Regulation,* B.C. Reg. 299/2004. *Water Regulation*, B.C. Reg. 204/88.

Statute: *Wildfire Act*, S.B.C. 2004, c. 31.
Comments: Regulates the use of open fires in and near forest land. Outlines the government's rights and duties in case of a wildfire.
Regulations: Wildfire Regulation, *B.C.* Reg. 38/2005.

Federal Legislation:

Statute: *Fisheries Act,* R.S.C. 1985, c. F-14.
Comments: Among other things, provides that no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat, and prohibits depositing deleterious substances of any type in water frequented by fish. Provides for authorizations to alter fish habitat.
Regulations: *Fishery (General) Regulations*, SOR/93-53.

Statute: *Migratory Birds Convention Act, 1994,* S.C. 1994, c. 22.
Regulations: Migratory Birds Regulations, C.R.C., c. 1035.
Migratory Birds Sanctuary Regulations, C.R.C., c. 1036.

Statute: *Navigable Waters Protection Act*, R.S.C. 1985, c. N-22.
Comments: Among other things, applies to dumping of fill and to structures or bridges on navigable waters.
Regulations: Navigable Waters Bridges Regulations, C.R.C., c. 1231.
Navigable Waters Works Regulations, *C.R.C., c. 1232.*

International Agreements:

An overview of key international agreements and how or when they may be applicable can be found in (FSC Canada, 2005). No specific agreement is material to the baseline or project scenarios.

1.15 Participation under Other GHG Programs

1.15.1 Projects Registered (or seeking registration) under Other GHG Program(s)

The project does not participate in any other GHG programs. The project is additionally certified under the Climate, Community, and Biodiversity Standards, which is managed jointly under Verra with the VCS project. CCB does not create any competing claims on GHG emission reductions.

The project is seeking certification under the SDVISta Standard, which is also managed by Verra as a joint VCS – CCB – SDVISta project. SDVISta does not create any competing claims on GHG emission reductions.

1.15.2 Projects Rejected by Other GHG Programs

The project has not be rejected by any other GHG Program.

1.16 Other Forms of Credit

1.16.1 Emissions Trading Programs and Other Binding Limits

Darkwoods has not, nor intends to generate any other form of GHG-related environmental credit for GHG emissions claimed under this VCS project.

1.16.2 Other Forms of Environmental Credit

Darkwoods has not, nor intends to generate any other form of GHG-related environmental credit for GHG emissions claimed under this VCS project.

NCC may decide to pursue other ecosystem services credits (such as water as an asset under SDVISta) if or when such units become available, however these other environmental credits will not affect the GHG credits and the VCS project.

1.17 Additional Information Relevant to the Project

1.17.1 Leakage Management

NCC does not currently undertake commercial timber harvesting on any other property they own or manage, and hence does not create activity shifting leakage risks. However, future property acquisitions or management plans may include timber harvesting, in which case NCC will monitor and report on activity shifting leakage risks and mitigation when appropriate in future verification periods.

Darkwoods does not employ plans specifically designed for market leakage management; however, the project activities do inherently include a level of leakage mitigation by periodically providing a low level of timber production to the market which offsets a portion of the avoided harvesting. Although the plans to undertake active conservation management activities in the project are designed and driven by objectives for ecological maintenance, protection, and improvement; an ancillary part of the rationale is also to provide some level of community engagement and indirectly offset a portion of the leakage risk.

1.17.2 Commercially Sensitive Information

None of the contents of this PDD are considered confidential. However, elements of reference materials and supplemental evidence materials, including acquisition details, financial modeling and information; certain NCC financial information and business plans; and carbon sales contract details that have been provided to validators and verifiers outside this PDD document may be marked as confidential. Other confidential supporting information may be identified during validation or verifications at NCC's discretion.

1.17.3 Sustainable Development

Darkwoods does not directly contribute to any national sustainable development programs in Canada.

1.17.4 Further Information

No further information is relevant.

2 SAFEGUARDS

2.1 No Net Harm

Darkwoods is validated and verified under the CCB standard. The Darkwoods joint VCS/CCB PD outlines net impacts to community and biodiversity and demonstrates the project creates no net harm to communities, along with substantial net benefits to biodiversity.

2.2 Local Stakeholder Consultation

Darkwoods is an isolated, access controlled private property, and there are no stakeholders living on or reliant upon the project area for their well-being. As detailed in the Darkwoods CCB PD, the local communities are highly diversified and tend to be interested in environmental protection and quality of life features created by the natural beauty and characteristics of the area. The majority of stakeholders directly interested in Darkwoods are related to periodic environmental research, backcountry recreation, and various consulting and contracting engagements. Generally the Darkwoods property and project generally are well aligned to the interested community, and NCC generally has a positive relationship with the community at large.

NCC has an open and regular engagement policy with interested stakeholders related to the Darkwoods project and other NCC initiatives in the region. NCC is publicly known throughout the region and across Canada, and any person wanting to comment can do so through phone, social media, website contacts, or direct interaction at the local NCC offices.

NCC undertook extensive stakeholder engagement during the Darkwoods acquisition process prior to gather input prior to the project start. These included targeted meetings with all relevant stakeholders, including local government, local industry, local recreational use groups, and general public meetings in all local communities. Examples of these pre-project validation meetings are outlined in Table 3.

Table 3. Non-exhaustive list of stakeholder engagements prior to project initiation

Timeline	Stakeholders Met	Comments
Aug 2008	Technical Advisory Committee Members Outdoor clubs Regional District of Central Kootenay (RDCK) Ministry of Tourism, Ministry of Mines, Ministry of Environment Ministry of Forest and Range	
Sept 2008	Regional District of Central Kootenay (Sept. 20) Rod and Gun Clubs of Creston, Trail, Nelson and the West Arm Local ENGO's and researchers Snowmobile Clubs of Creston and Fruitvale Mining Association of BC Nelson Chamber of Mines	
Sept 2008	Open House Information Sessions: September 22, 2008 Creston – 65 people attended Sept. 23/08 in Salmo – 35 people attended Sept 24/08 in Nelson – 45 people attended	Advertised in the local media and through the use of PSAs. Direct invites to relevant partners, stakeholder, and regional NCC donors Open house format: open meet and greet. NCC display materials, Darkwoods maps and hand-outs. Minimum of 4 NCC people at each event. Guests were also encouraged to fill in a comment form
Oct 2008	Public meeting sponsored by Wildsight (local NGO) in Creston - 60 people attending Technical Advisory Team meeting Association of British Columbia Snowmobile Clubs (ABCSC) Ministry of Environment (MoE) Fish and Wildlife Compensation Program (FWCP) Partnership opportunity meeting with Selkirk College Sinixt Nation Meteorological meeting with Alistar Frasier	

	Ministry of Forest and Range on a number of issues:	
Apr 2009	FWCP, Selkirk College, MoE, MoF, BC Tourism, ILMB and RDCK	
Dec 2009	Selkirk College. MoE, MoF, Ministry of Mines, BC Tourism, ILMB and FWCP BC Wildlife Federation	
July 2010	Met with Tye residents Ktunaxa Nation Council Mineral tenure holders and the government agent RCMP	
Sept 2010	Open Houses in Creston, Nelson, Salmo	

The outcomes of these wide meetings were integrated into NCC planning and decision making throughout the acquisition process. An example of the impact of those consultations prior to the project start period was a decision to ramp down harvesting operations on Darkwoods after NCC took ownership in order to mitigate the impacts to the few local contractors active on the property under the prior owners. The ramp down provided an opportunity for those operators to adjust, and was based on feedback from local stakeholders prior to the acquisition. Further, NCC engaged plans to complete road deactivations to provide further transitional work to impacted contractors.

NCC has continued an extensive ongoing stakeholder engagement and public communication process throughout project implementation as documented in the CCB PD and each VCS and CCB/VCS Monitoring Report.

In particular, NCC has maintained webpages specific to Darkwoods and the Darkwoods Carbon Project (http://www.natureconservancy.ca/en/where-we-work/british-columbia/featured-projects/darkwoods/dw_carbon.html), where project updates and public comment periods can be publicized and distributed. The stakeholders in the project area are fully modern and virtually the entire population has daily online access and extensively uses internet resources (along with direct phone contact).

NCC also maintains an active social media presence on Twitter, Facebook, and other popular forums where interested community members and stakeholders can gather information and provide direct feedback with comments or concerns. NCC maintains public communications staff which leads and manages communication nationally and regionally; and community engagement is a key part of local staff at Darkwoods on an ongoing basis.

Since project implementation, stakeholder meetings have been documented in each joint VCS/CCB Monitoring Report and this outlines an ongoing pattern of stakeholder engagement on an annual basis for the most interested groups; along with periodic general public information sessions.

These meetings have influenced the project area in multiple ways, from reviewing and developing recreational access agreements; to project area research planning and review; to general public outreach and education. Examples of stakeholder related engagements in the most recent 2017-2019 monitoring period can be found in

Table 4. Darkwoods public access permit monitoring results (2017-19)

Year	# Public Access Permits
2017	29
2018	40
2019	53

Table 5. Recreational groups engaged with NCC (2013-2019)

Recreational Groups	Years
Kootenay Mountaineering Club	2013-2019
Beaver Mountain Snowmobile Association	2013-2017
Kokanee Snowmobile Club	2013-2017
Nelson Snowgoers Club	2013-2017
Creston Rod and Gun Club	2013-2019
Association of BC Snowmobile Clubs	2013-2016
West Kootenay Naturalist Club	2013
West Kootenay Camera Club	2013
Selkirk Rock and Mineral Club	2015
Western Canada Bryophyte and Lichen Interest Group	2014
Nelson Camera and Naturalist Club	2013
Climbers Association	2013

Selkirk Caribou Intl Working Group	2017
Whitebark Pine Ecosystem Foundation of Canada	2018
Gerex Mining	2018

Table 6. Scientific researchers engaged on Darkwoods during recent monitoring periods (partial list)

Scientific Researchers	Topic	Years
Michael Proctor	Grizzly Bears	2013-2019
Adrian Leslie	Whitebark pine	2013-2019
Marc-Andre Beaucher	Nighthawks	2015-2017
Grant McHutchen	Grizzly Bears	2013-2016
Masse Environmental Consultants	Bull Trout Redd Surveys	2015
Stefan Himmer	Huckleberries	2015
Gerry Nellestijn	Bull Trout	2016
Olivia Lee	Bryophytes and Lichen	2014
Leo DeGroot	Caribou	2013-2019
Highlander Forestry	FLNRO subcontractors	2014
Cori Lauson	Bats	2014
Jeremy deWaard	Anthropods	2014
Pam Dykstra	FLNRO subcontractors	2013
Olivia Lee	botany	2014
Steve Ardnt	kokanee and Bull Trout	2013-2019
BC Conservation Data Centre	red and blue listed species	2016-2017
BC Conservation Data Centre	Western Screech Owls	2017
Beacon Botanical	Plants at risk inventory	2017
Ministry of Forests, Lands and Natural Resource Operations	Caribou maternal penning project	2017
Erik Leslie	Assessment of Mosquito area LRC	2018
Tyson Ehlers	Macrofungi survey	2018-2019

Living Lakes Canada	Water quality	2019
Central Kootenay Invasive Species Society	Invasive plants	2018-2019
Samantha Mertens (SFU)	Caribou habitat restoration	2018
Carmen Scott (Selkirk College)	Lynx and Snowshoe hares	2018
Emily Chow (FLNRORD)	Caribou	2019

Further details on the project's communication with stakeholders and net impacts on communities can be found in the Darkwoods CCB PD.

During this monitoring period NCC has maintained and implemented "The Nature Conservancy of Canada Policy: Human Resources Policy (2012)" and the "NCC Darkwoods Occupational Health & Safety Program (2012)", along with all applicable Federal and Provincial Laws, which support Anti-Discrimination, Worker Training, Equal Work Opportunities, Workers Rights, Occupational Safety, and a Feedback and Grievance Redress Procedure, as outlined by the project PD (Sections 2.2.5-2.2.11). No related incidents or actions relevant to the project have occurred during this monitoring period.

2.3 Environmental Impact

There are no regulatory environmental impact studies related to the project area.

More generally there are no known environmental impacts to assess for the retention of natural forest. This carbon project enhances biodiversity, water, and other environmental attributes by retaining and protecting the existing forest in an intact, fully functioning ecosystem. Further details of biodiversity impacts can be found in the Darkwoods CCB PD and Monitoring Reports.

2.4 Public Comments

Stakeholders in the project zone are fully modern with virtually the entire population with daily online access and extensive usage of internet resources. Therefore, NCC places a prominent posting on the Darkwoods website with a link to the VCS/CCBA comment website during each public comment or audit period relevant to the project under VCS or CCB. Project documentation is available on the internet via links to the Verra website, and NCC will provide documentations upon request to interested stakeholders. No comments were received.

Generally, stakeholders in the Darkwoods area are very interested in general environmental news, biodiversity, backcountry recreation, and research results from Darkwoods, including as it relates to carbon sequestration; but the carbon project documentation and process itself has not typically generate specific interest or questions over the 10 years of implementation. Since the initial acquisition at the project start NCC has not discovered any new stakeholders with specific interest in carbon project materials or processes. Various monitoring period audits have also found similar. NCC, however, continues extensive stakeholder engagement as outline in Section 2.2 above to continue ongoing communication on items of immediate interest to each group, along with periodic public meetings related to happenings on Darkwoods of interest, which are well attended.

2.5 AFOLU-Specific Safeguards

As outlined in Section 2.2 and 2.4 above, and as detailed in the Darkwoods CCB PD, Darkwoods has an extensive stakeholder engagement process. As noted, the project has no stakeholders living on, or dependent on the project area for their well-being. As outlined in the CCB PD, the project has no direct risks to local stakeholder resources or property rights; and the project provides an overall net benefit to communities.

3 APPLICATION OF METHODOLOGY

3.1 Title and Reference of Methodology

Methodology: VM0012 - Improved Forest Management in Temperate and Boreal Forests (LtPF), v1.2

Tool Applied: VCS AFOLU Non-Permanence Risk Tool v.4.0

Tool Applied: VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities, v3.0

Also note the project is validated and verified to CCB Standards Edition 2.

3.2 Applicability of Methodology

As shown in Table 7, Darkwoods is compliant with the applicability criteria of VM0012.

Table 7. Compliance with Methodology Applicability Criteria

Summarized Applicability Criteria	Darkwoods Fit
Meets either current VCS IFM-LtPF criteria	Darkwoods is protecting forests otherwise being logged Darkwoods is forest remaining forest.

Projects located in FAO Temperate and Boreal Ecological Zones; and have Tier III inventory data available.	Darkwoods is located in the Temperate Ecological Zone. Darkwoods utilizes detailed site level inventory meeting Tier III criteria.
Projects on fee simple private ownership	Darkwoods is entirely fee simple title owned by NCC.
Projects with starting avg. annual illegal, unplanned, and fuelwood removals are <5% of annual harvest (tCO_2e);	Darkwoods has no illegal or unplanned harvesting, and *de minimis* fuelwood removals.
Projects without managed peatland forests	Darkwoods does not contain managed peatland forests.
Projects where % wetlands are not expected to change as part of project activities	Darkwoods will not materially alter the % of wetlands on the project area.
Projects that can demonstrate that no activity shifting leakage occurs to other proponent lands at the start of the project.	NCC can demonstrate baseline activities are not being shifted to other conservation land holdings.
Projects which do not include non *de minimis* application of organic or inorganic fertilizer in the project scenario.	Darkwoods does not include any application of fertilizer in the project scenario.

3.3 Project Boundary

The Darkwoods Carbon Project is bounded by the entire legal land description included in Table 1 and shown in Figure 1, within which the project considers the following GHG sources, sinks and reservoirs shown in Table 8:

Table 8. Selection of Carbon Pools (for both baseline and project scenario).

Carbon Pool	Selected?	Justification/Explanation	Scenario Carbon Flows:
Above Ground Tree Biomass (Live)	Yes	Live Above-Ground Biomass. Required by VCS. Major carbon pool subject to changes from the baseline to the project scenario.	Reservoir – biomass in un-harvested forest biomass Sink – Biomass re-growth after harvest disturbance Sink – Biomass accumulation in growing retained forest Source – Carbon flows resulting from timber harvest removals and adjacent biomass impacts during

			operations (shifted to other carbon pools) Source – emissions from mortality and decay in remaining forests
Above-Ground Non-Tree Biomass (Live)	No	Live Above-Ground Biomass. Excluded by VCS. Minor carbon pool subject to changes from the baseline to the project scenario	Sources and sinks are *de minimis*
Below Ground Biomass Pool (Live and Dead)	Yes	Live and Dead Below-Ground Biomass. Required by VCS. Major carbon pool subject to changes from the baseline to the project scenario.	Reservoir – biomass in retained forest. Sink – Biomass accumulation in avoided harvest stands Sink – Biomass accumulation in growing stands Sink – Biomass re-growth after forest management activities Source – Carbon flows resulting from forest management harvesting removals (shifted to other carbon pools) Source – emissions from mortality and decay in remaining forests (shifted to other carbon pools)
Dead Wood Pool	Yes	Dead Above-Ground Biomass. Required by VCS. Minor carbon pool subject to changes from the baseline to the project scenario.	Sink – dead snags, coarse branches, and stems before and after forest management activities Source – decay of deadwood pool
Litter Pool	No	Dead Above Ground Biomass. Excluded by VCS for AFOLU projects. Minor carbon pool subject to changes from the baseline to the project scenario –	Litter is a short-lived transition pool, and differences between the project and baseline are *de minimis* over time

		generally considered as a transitional pool only.	
Soil Carbon Pool	No	Dead Below-Ground Carbon. Optional in VCS AFOLU IFM projects, but excluded in this methodology. As a conservative approach, changes to soil carbon from harvesting are assumed to be *de minimis*. Monitoring is difficult.	Soil carbon is a reservoir of long-lived carbon storage which is likely unaffected by timber harvesting.
Wood Products Pool	Yes	Required by VCS. All baseline scenarios involve logging.	Sink – carbon in permanent storage in harvested wood products Source – emissions from decaying wood products

Table 9 - Emissions Sources Included/Excluded from the Project Boundary

Emissions Sources	Gas	Included?	Justification/Explanation
Use of Fertilizers	CO_2 CH_4 N_20	No No No	Neither the project nor the baseline scenario include the use of fertilizer, and hence these emission sources are excluded. These exclusion assumptions do not increase the emission reductions in the project.
Combustion of Fossil Fuels by Vehicles / Equipment	CO_2 CH_4 N_2O	Yes No No	Carbon emissions from harvesting equipment, log transport, and primary forest product manufacturing are included in both the baseline and project scenarios. CH4 and N2O emissions from equipment are assumed to be *de minimis*. The exclusion of these combustion gases does not increase the emissions reductions in the project
Burning of Biomass (on site slash burning)	CO_2 CH_4 N_2O	No No No	Emissions from burning of biomass is not included specifically in the baseline or project scenario; however, carbon stock decreases due to burning are accounted as a carbon stock change in both the baseline and project scenario as appropriate. These exclusion assumptions do not increase the emission reductions in the project.

See also the leakage zone shown in Figure 8.

3.4 Baseline Scenario

10-Year Baseline Re-Validation Note:

As per the VCS Standard, the project has re-assessed the baseline scenario conditions at the 10th year of the project. As shown below, the baseline scenario is based on an independent property appraisal from ~2008 which projected a harvest schedule for a market driven buyer based on typical market practices. At the time of acquisition the Darkwoods property was carrying excess mature standings stocks due to the prior owners under-harvesting, which were then projected in the appraisal to be harvested on a conservative, but accelerated harvest schedule to generate typical timberland return on investment. In the appraisal, the harvest was accelerated to 300,000 m^3/year for 15 years.

This baseline scenario harvest level has been modeled by the project in the 10 years since project implementation, and no conditions have changed that would alter this initial appraisal. The concept that a financially driven investor would harvest excess mature and over-mature timber in order to generate cashflow and returns, while returning the forest to a more productive younger growing condition is still typical practice for timberland in North America and across the world. Basic financial assessment and theory shows that the time value of money incentivizes early cashflows over deferred.

Further, the new VRI inventory on Darkwoods in 2011 revealed significantly more volume on the property than originally expected and used in the 2008 appraisal. Therefore, the harvest level of 300,000 m^3/year has not only been maintained in the baseline harvest, but this harvest level can be maintained for 18-19 years rather than the original target of 15 years. This is evidence that the accelerated harvest levels are reasonable – an almost 20 year window of higher harvest is actually reasonably consistent with standard forest financial modeling timeframes (higher actually), and is not dissimilar to B.C. Timber Supply Analysis (TSA) projection approaches for crown timber on larger land bases, where a higher harvest level is maintained for several decades, then stepped down over time to a “Long Run Sustained Yield” (LRSY). Due to smaller scale, the Darkwoods baseline harvest level develops some gaps and inconsistencies after the first 20 years removals as compared to a large scale TSA LRSY, but a harvest level returns and can be sustained over time as the forest regrows.

Most importantly no new data has emerged that would change the plausibility of the baseline scenario: no legal requirements have changed and the baseline harvest could be implemented under current regulations on private land; the timber supply has proven materially above the original timber harvest level projection, which means the baseline harvest is more conservative than intended in the appraisal, and; nothing has changed in financial theory and forest management that would indicate a more valuable alternative would exist at a lower harvest level than the baseline scenario.

Therefore, the project has assessed the baseline scenario as still appropriate on an ongoing basis for the 10 year re-validation.

The following is the original baseline scenario assessment process outlined in the previous validated Darkwoods PD (version 1.8) and following VM0012. No material changes have been made to this assessment text or the supporting materials validated at the original validation:

Baseline Scenario Selection Process:

STEP 1 – Identify Plausible Alternative Baseline Scenarios to the VCS Project Activity

The Darkwoods Carbon Project has identified five (5) plausible baseline scenarios that were evaluated in this baseline selection process, following the VM0012 process and requirements:

1. Continuation of the previous owners practices

   The first potential baseline scenario was the continuation of the previous owner's historical operating practices. As noted, Pluto Darkwoods has a unique history with historical practices that are not typical of any regional comparable market-driven private property entity. This included establishing an annual harvest level of 57,000m^3, far below the sustainable timber capacity of the land; and voluntarily setting aside approximately 1/3 of the operating area.

   Pluto Darkwoods had a unique private ownership structure led by an individual who established atypical management principles, and who had unique financial capabilities. Additionally, the Darkwoods property was acquired over 30 years ago (at a time of significantly lower land valuations in the region), and likely did not face any additional investment capital costs or debt; and hence was not operating under the same financial constraints as a new acquirer.

Table 10. Previous Owner Operations History (Pluto Darkwoods 2004-2008)

Year[4]	Harvest Volume (m^3)	Road Construction (km)
2004	60,895	9.27
2005	63,891	12.47
2006	40,138	13.77
2007	53,734	11.01
2008	50,763	12.7

2. Acquisition by a market driven acquirer baseline logging scenario

   Given the Darkwoods property was being put up for sale, the next plausible baseline was a market-driven buyer(s) acquiring the property to gain financial returns from the timber assets. The key piece of supporting information for this baseline scenario was the formal land and timber valuations undertaken by Pluto Darkwoods (Thrower & Orr-Ewing, 2007). which evaluated the most likely scenarios in order to value the property; and also, by setting a target acquisition price, inherently drove the type of forestry practice that would be necessary to achieve a reasonable investment return on that investment capital. The Darkwoods timber appraisal valuation recognized the excess mature standing stocks and then anticipated 3 potential harvesting scenarios for an expected market buyer of the property:

   a. 10 year mature standing stock depletion rate harvesting regime
   b. 15 year mature standing stock depletion rate harvesting regime
   c. 20 year mature standing stock depletion rate harvesting regime

   For the purposes of this baseline identification process, all three sub-variants are considered together, and selected between in Step 2 below. The selected baseline scenario is further detailed in Section 4.1 below.

3. Acquisition for a sustained yield harvesting regime

   During baseline scenario options modeling, the option to set a long run sustainable yield harvest level was added for consideration. Under this scenario, an acquirer would set an even-flow harvest level for the property over at least one full rotation.

   It is expected that an acquirer under this scenario would most likely undertake something close to the minimum practices required by the B.C. Private Forestlands Act to minimize costs and maximize return on investment.

[4] Pluto Darkwoods operational years consist of the previous 12 months to April 1 of the reported year (i.e. 2004 = Apr.1 2003 – Mar.31 2004).

This scenario would substantially reduce the average timber and carbon stocks over time as the property is brought into a regulated age condition (the eventual goal being to ideally have equal areas of timber in each age class such that there is an even flow of timber through time).

4. Acquisition for conversion to real estate development lands

   Although considered as a baseline scenario based on the real world bidder interest alluded to by Pluto Darkwoods, this scenario was excluded due to not meeting the carbon project eligibility, and the complexity of projecting real estate development over time. Most importantly, it was determined that a timber driven baseline scenario could act as a very conservative proxy for a real estate baseline (i.e. real estate development will very likely emit more carbon per hectare, and therefore it is conservative to consider the emissions related to a timber harvesting scenario instead).

5. Acquisition for conversion to conservation lands

   The project scenario was considered for the purposes of the additionality tests carried out in Section 2.5, where it is found to be additional. This scenario is then excluded from baseline scenario considerations.

The areas in italics in the following are the baseline selection criteria outlined in the methodology.

Each prospective baseline scenario meets the following baseline selection scenario eligibility criteria, except where noted and excluded:

1. *Including activities and areas where forests remaining forests* - this criterion eliminated the potential Baseline Scenario 4 “Acquisition for conversion to real estate development lands”.

2. *Comply with legal requirements for forest management and land use in* the area - all the remaining baseline scenarios would meet the minimum practice requirements of either the BC Private Forestland Act (a voluntary registration) or general rural residential laws and requirements.

3. Demonstrate that the “projected baseline scenario environmental practices equal or exceed those commonly considered a minimum standard among landowners in the area” (Voluntary Carbon Standard, 2008a) - all prospective baseline scenarios could have complied with minimum environmental performance of landowners in the area, most of whom follow the minimal requirements of the B.C. Private Forestlands Act.

This project identified the following 5 baseline scenarios, including the required historical practice and common practice scenarios:

STEP 2 – Selection of a Single Plausible Baseline Scenario for the Project

Project proponents shall select a single plausible baseline scenario for the project using the following steps:

STEP 2a - The Historical Baseline Scenario - based on actual property harvest history must be selected if:

2a.1 The current property owner retains ownership of the property and has at least 5 years historical harvest level data history, and

The Darkwoods property was put up for sale, and hence the owner previous to the carbon project did not retain ownership. NCC has owned the property for less than 3 years. Therefore, Baseline Scenario 1 is excluded, and the project will use a common practice baseline following Step 2b.

All other cases will utilize the Common Practice Baseline Scenario Selection steps below:

STEP 2b - The Common Practice Baseline Scenario – based on previous owner activities:

a. If the current owner has owned the property for less than five years then the project proponent may:
    i. Choose to use the previous owners historical activities or management plan as representative of common practice, in which case the baseline scenario is selected based on the process and criteria in Step 2a; or,
    ii. Choose to select the baseline scenario based on common practice and investment analysis of scenarios as outlined in Step 2c below

NCC has owned the property for less than five years and the Pluto Darkwoods management is not considered common practice for an acquiring entity required to bid for a property that was valued from a much higher level of harvest. It is clear that an acquiring entity could not provide a reasonable return on investment at the acquisition price and Pluto Darkwoods historical harvest levels[5]. Therefore, the project will continue to Step 2c.

STEP 2c - The Common Practice Baseline Scenario – new owner activities:

For recent or pending changes in property ownership without historical scenario data (>5 years) (or otherwise not selecting a historical baseline scenario as per Step 2b); the project proponent will select the baseline scenario(s) based on an assessment of regional common practice[6] supported by financial analysis of achieving typical market returns from forest products.

The project proponent shall select the baseline scenario that:

[5] On a very simple analysis, to provide a positive NPV on a 4% cost of capital (i.e. unrealistic risk free rate), at 50,000m^3/yr, over 30yrs, would require average profit margins in excess of \$25/m^3. Typical B.C. firms might average profit margins of \$5 - \$15 and expect IRR's of 8-12%.

[6] Extrapolation of observed similar activities in the geographical area with similar socio-economic and ecological conditions as the project area occurring in the period beginning ten years prior to the project start date (Voluntary Carbon Standard, 2010a).

1. Generates the most financial attractive return on investment from forest product returns using the assessment process outlined in Step 2 Option II and/or Option III in the *Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities* (Voluntary Carbon Standard, 2010a); and,
2. Can be demonstrated to be regionally common practice and locally operationally implementable, including:
   a. Compliant with the legally required land use and forest management practices in a manner consistent with VCS requirements (see Step 1);
   b. Consistent with local market capacity for the baseline scenario activities and products (i.e. log markets, contractor capacity, etc.);
   c. Consistent with observable and verifiable regional operational practices, including, at minimum:
      1. Harvest types (i.e. clearcut, selective cut, etc.),
      2. Logging and hauling equipment types and capabilities,
      3. Annual harvest levels (i.e. m^3/year, ha/year),
      4. Average minimum harvest age, tree size, and/or stand volume,
      5. Average minimum economic viability (or decision criteria) by stand type,
      6. Average minimum log utilization specifications (on average based on size and/or species), and waste/breakage assumptions,
      7. Average tree retention practices, including hydro-riparian buffers, wildlife trees, and other single or grouped merchantable and un-merchantable tree retention,
      8. Maximum harvest slope or other operability constraints which would limit regional logging equipment,
      9. Reforestation and stand management practices; and
   d. Operationally feasible on the project area using local harvesting and hauling technology, local infrastructure, etc..

The remaining baseline scenarios to be evaluated under Step 2c include:

1. Acquisition by a market driven acquirer baseline logging scenario
2. Acquisition for a sustained yield harvesting regime

First, at an intuitive level, the difference between these two baseline scenarios is the timing and level of harvest. Both scenarios utilize the available commercial timber and carbon stocks in a similar manner when evaluated over a 100-year period, and result in growing stocks within about 20%, and total removed volume within 10% of each other. From a total biomass/carbon impact, these scenarios end up reasonably similar, although there is a shift in the temporal emission reductions.

However, the difference between these scenarios in financial modeling, where discounting and the time value of money weigh heavily is significant (and can be demonstrated to be materially different without complex additional financial modeling). The first 20-30 years of harvesting between the scenarios is materially different, and this materially affects financial returns opportunities. Although further financial analysis was undertaken, it is relatively easy to infer the implications of a reduced harvest level from the timber valuation reports which drove the property valuation at sale – any significantly lower harvest level in the first 30 years than contemplated in the valuation scenarios, assuming the final sales price was close to the asking price, would necessarily have difficulty covering the capital cost of the acquisition and would not achieve the basic return levels used in the valuation appraisal.

In basic financial modeling, the difference between the two remaining scenarios is clear when using the same timber margin data (using detailed Darkwoods analysis from: Thrower & Orr-Ewing, 2007) with the different harvest volumes over the first 30 years[7]:

1. #2 - Acquisition for a market-driven baseline logging scenario:
    a. IRR = 8-12%
2. #3 - Acquisition for a sustained yield harvesting regime:
    a. IRR – 2-6%

At this level of comparative analysis, it is clear that the first baseline scenario is materially superior in financial returns potential. In addition, as noted earlier, the valuation of the Pluto Darkwoods timber asset (which defined the target sales price) is consistent with remaining option #1 (in other words, the property price was aligned with this operating condition).

Therefore, in accordance with Step 2c: based on its ability to "*generate the maximum financial return on investment from timber and non-timber forest product returns*", the **selected most plausible baseline condition is:**

 # 2 - Acquisition for a market-driven baseline logging scenario

To test against the final capacity tests in Step 2c., item 2:

a. This baseline scenario can be implemented in accordance with the legal forest management requirements for private forestland in B.C.
b. There is mill and contractor capacity for the selected scenario in the local region hauling area.
c. The baseline scenario is consistent with regional operational practices, which is observable in comparable properties. Details of baseline scenario practices assumptions are detailed in Section 4.1 and in the original appraisal report (Thrower & Orr-Ewing, 2007). There are regional (and adjacent) examples of similar and higher harvest levels during timberland acquisitions[8].
d. This baseline scenario can be implemented with existing typical local harvesting and hauling equipment under typical clear-cutting practices. This baseline scenario is operationally feasible on the property, with 6 main road access points, and multiple operating areas with various year round opportunities available. This is confirmed by Pluto Darkwoods personnel, and is also documented within the original appraisal report (Thrower & Orr-Ewing, 2007).

Finally, within this selected baseline there are 3 variants identified:

a. 10 year depletion rate harvesting regime

[7] Further analysis details available within the file "Darkwoods Carbon Model – Baseline Valuations", which is available to auditors, but confidential due to previous owner financial information.

[8] Further details on regional comparables are available upon request – they are not listed here for privacy reasons.

i. Projected harvest levels of between 325,000-400,000m3/year for 10 years, followed by a multiple year gap before resuming lower levels of harvesting in future years as younger stands grow to maturity.

b. 15 year depletion rate harvesting regime

i. Projecting harvest levels in at 250,000 – 325,000m3/year for 15 years, followed by a short (1-2 year) potential gap before ongoing lower harvest levels resume.

c. 20 year depletion rate harvesting regime

i. Projecting harvest levels at a lower level of 175,000 – 250,000m3/year for 20 years, followed by a lower level of harvest.

For this project, the middle (15 year) selection was identified as the final selected baseline condition as a reasonably conservative approach – the 20 year scenario would materially affect potential returns; while the 10 year scenario would be the most aggressive.

The details of ex-ante modeling and assumptions related to the selected most plausible baseline are located in section 4.1.

STEP 3 – Additionality Test

The project is additional as per Section 2.5 in a manner consistent with this baseline selection method.

3.5 Additionality[9]

The project uses the Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities (currently v3.0: https://verra.org/methodology/vt0001-tool-for-the-demonstration-and-assessment-of-additionality-in-vcs-agriculture-forestry-and-other-land-use-afolu-project-activities-v3-0/)

This PDD meets the eligibility requirements of this tool by:

1. The project activities are not in violation of any applicable law;

2. The project employs a step-wise method to determine the most baseline scenario, which is consistent with the application of this tool.

Step 1a – Identification of plausible baseline scenarios

1. Continuation of the previous owners practices
2. Acquisition by a market driven acquirer baseline logging scenario
    a. 10 year depletion rate harvesting regime

[9] Note that no changes have been made to the previously validated Additionality section in this PD update version.

   b. 15 year depletion rate harvesting regime (selected baseline scenario)
   c. 20 year depletion rate harvesting regime
3. Acquisition for a sustained yield harvesting regime
4. Acquisition for conversion to real estate development lands
5. Acquisition for conversion to conservation lands (project scenario)

Step 1b – Legal tests

All plausible baseline scenarios could be undertaken within the legal requirements of private forestland or private rural residential land in British Columbia.

Step 1c – Selection of Most Plausible Baseline Scenario

See Section 2.4 for description of the baseline selection process.

The outcome of the selection process is to select the "Acquisition by a market driven acquirer baseline logging scenario, with a 15 year depletion rate harvesting regime".

Step 2 - Investment analysis

In general, the project scenario is less financially attractive then *all* of the alternative baseline scenarios. As a Logged to Protected Forest conservation project, the project scenario for the Darkwoods Forest Carbon project generates no material financial or economic benefits other than VCS related income, and therefore is suitable for Option I – Simple Cost Analysis

Step 2 – Investment Analysis – Option I Simple Cost Analysis

The operating costs of the Darkwoods carbon project specific to the carbon project itself are projected to be C$380,000/year[10] (including verification, issuance and registration, project management, monitoring, and sales costs; not including capital costs, management overhead costs, road costs, conservation activities costs, or taxes).

The primary cost associated with the project scenario is the acquisition cost of the property (C$50 million). Access to this level of capital for a conservation activity with no generation of property revenue is in itself is a Barrier, as outlined under Step 3 below. Beyond the barrier analysis of acquiring the capital, this investment has created significant additional debt expenses that expand the carrying cost of the property dramatically in the project scenario.

In addition, NCC undertakes substantial additional property and conservation management activities (road closures, biodiversity research, inventory, access management, etc.) that require substantially greater cost than projected here. The majority of these costs (which is difficult to isolate) would be attributed to property management costs of the carbon project related to the carbon project implementation, regardless of other biodiversity and conservation objectives underlying NCC's other management activities in the project scenario. In other words any entity acquiring the land strictly for the purpose of carbon offsets with no other interests would face these costs as well. The non-carbon operating

[10] Additional details of cost modeling available upon request.

budget for Darkwoods is currently >$500,000/year. Some grant and other non-commercial revenue are associated with offsetting a portion of these costs.

The project scenario does include a low level of timber harvest periodically as part of conservation management and community engagement that does generate revenue from timber sales. However, the low level of harvest and high cost of expected conservation harvesting is expected to be operationally break-even at best, and often money losing operations. These operational revenue and costs are not detailed further here because it is obvious once capital costs and other property management costs are included that it is impossible for these timber harvests to cover overall costs. However, actual details of current and projected project activity revenue and costs are available upon request.

To summarize, the Darkwoods carbon project and only material commercial revenue and profit opportunity within the carbon project is from the sale of VCU's. Option II and Option III are not considered further because there is no reasonable alternative business model for a private entity to acquire this land for purposes which achieve similar emissions reductions, given the high acquisition cost and lack of revenue options from conservation activities without carbon. Carbon finance provides the only reasonable revenue opportunity to cover project costs, property management costs, and capital costs in the project scenario.

Step 3. Barrier Analysis (supporting information only)

In addition to the Investment Analysis above, there is a clearly related applicable barrier, including:

Step 3a:

1. There are barrier for AFOLU project activities undertaken and operated by private entities:
   - Similar conservation activities have only been implemented with grants or other non-commercial finance terms. In this context similar activities are defined as activities of a similar scale that take place in a comparable environment with respect to regulatory framework and are undertaken in the relevant geographical area.

Step 4. Common Practice Analysis (not required; supporting information only)

Darkwoods is, by far, the largest conservation purchase ever recorded in Canada, and such there are actually no real comparables at this scale. However, smaller scale conservation acquisitions have only been undertaken with non-commercial funding sources.

Darkwoods is also the first IFM-LtPF carbon project proposed in Canada, and the largest forest carbon project considered in Canada to date.

In other words, there are no comparable activities that could be considered common practice and which achieve similar scale or employ similar project activities. Smaller scale conservation acquisitions are only achieved with non-commercial funding and capital sources.

Based on the application of this VCS tool, the Darkwoods Carbon Project is Additional based on Investment Analysis.

3.6 Methodology Deviations

Several methodology deviations have been noted during the implementation of project, and are now included in the PD for all future verification periods:

1. VM0012 v1.2 lists the plot remeasurement period is listed as 5 years. In the 2013-2016 monitoring period a deviation was created because the plot remeasurements were not made within exactly 5 years from installation. A deviation was made to adjust the interpretation of VM0012 to mean within 5 calendar years to allow for field season adjustments in the year of remeasurement. This is a permanent methodology deviation from 2017 forward. This deviation does not materially affect carbon stock accounting.
2. VM0012 requires plot representation for each Analysis Unit. The stratification of the project area resulted in one AU (AU 110) that is very small (<0.01% of the productive forest area on Darkwoods) and does not have a plot. Although future re-stratifications may resolve this issue and avoid overly small AU's, a permanent deviation is being made to allow small AU's (<1% of the property area) to forego plot representation, These areas are still represented by forest inventory and tree data for carbon accounting, and are otherwise small enough to be immaterial to carbon accounting results.
3. The error in VM0012 formula 60b noted in the 2013 verification has been corrected in an errata update to VM0012 v1.2, and hence this deviation is no longer required.
4. The 2011-2013 verification identified a minor deviation was noted to not re-measure or include plot data which are located within the non-productive landbase (i.e. AU 111). This has been verified to have no impact on the calculation of GHG emission reductions. This is a permanent methodology deviation.
5. The 2013-2016 verification noted a minor methodology deviation related to the source of data used to report the volume of harvested wood used to calculate carbon in the harvested wood product pool for the project scenario actual harvest. The project uses the government issued scaling reports to determine project harvest volumes, which is consistent with the newer versions of the VM0012 v1.2 (Section 8.2.10). This methodology deviation is no longer applicable with VM0012 v1.2.

4 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

This update of the Darkwoods VCS PD (v2.0) includes a change in forest and carbon models for the project from the use of the FORECAST and FPS-ATLAS models to the use of the FVS-FFE and FPS models. The project continues to calculate Baseline and Project emissions following the requirements and process in VM0012 v1.2; however there are some changes to certain data handling and assumptions due to improved modeling capability and functionality.

Review of the Change to the Forest and Carbon Modeling Tools and Approach:

During the 2017 monitoring period and effective as of this updated Darkwoods PD v.2.0, the project shifted from the use of the FORECAST and ATLAS models to the use of the USFS Forest Vegetation Simulator (FVS) with the Fire and Fuels Extension (FFE) module (and the Inland Empire (IE) Variant), along with the harvest scheduling model Forest Projection System (FPS). This change to FVS-FFE is being made to move to a more widely accepted and more actively supported models that is built and maintained by the U.S. Forest Service. FVS-FFE is widely used in both forestry applications and in forest carbon project across North America, and hence the Darkwoods project is updating its model usage to a more broadly available and used model.

FVS-FFE and FPS models meet all of the requirements of VM0012 (see below) and is well documented and referenced for use in both the project area and the calculation and tracking of all the required carbon pools in manner consistent with the VCS AFOLU guidelines, VM0012, and the Darkwoods project design. The new models are consistent with the overall project design, but have resulted in the alteration of some data handling and stand modeling in both the baseline and project scenario.

The FVS-FFE tool was selected as a well-known and tested forest growth and yield model with complete carbon pool tracking capabilities, including HWP to meeting updated VM0012 v1.2 requirements. Since the Darkwoods 2011 VRI inventory, stand level tree data has become available, which means FVS-FFE can be used to shifted to stand level modeling, which is then rolled up to AU level carbon tracking and calculations. Carbon is still being tracked at an AU level as before, but now the AU data is directly tied to the actual forest inventory stand data and carbon pools rather than created representative AU stand data. This approach gains substantial accuracy improvements to track the AU data back to actual inventory data, while stand level modeling provides improved tracking of carbon pools, particularly across harvest activities and natural disturbance events.

Further, the stand level inventory-based modeling allows for better flexibility and adaptation to model and track natural disturbances such as fire (which the FFE module in FVS is directly designed to model and track). The project is also now better situated for anticipated future management activities which may increase in diversity and complexity (i.e. selective harvests, fire fuel reduction strategies, habitat management, etc). Further, the project anticipates a need to replace and upgrade the project area VRI inventory with (likely) leading edge LiDAR based forest inventory, and FVS-FFE will be well suited to adapt to new project-wide polygon inventory data as compared to the previous approach.

The plot network is still fully appropriate to test the model and inventory error at the rolled up AU level, and in fact the uncertainty factor result should better reflect the VRI forest inventory. Further, the actual plot tree data carbon content by pool can be calculated in FVS-FFE using the same model parameters and assumptions as the overall project modeled carbon to better reflect inventory/model error rather than potentially including plot carbon calculation differences (previously actual plot data had to be manually converted to stand carbon rather than through the actual FORECAST model doing the AU stands; a tedious process that risked inserting other error).

Importantly, the new FVS-FFE model provides the imbedded capability to track Harvested Wood Product decay pools by product in the manner required by VCS and VM0012 v1.2. HWP tracking has been changed to more complex multi-year decay pools that are difficult to track manually as compared to the previous HWP approach.

The FPS harvest scheduling model is fairly comparable to ATLAS, however it is one of the most widely used forest estate models in North America and is better supported and kept up to date. The usability and support for the ATLAS model was a concern in prior monitoring periods, so FPS is an upgrade for project proponent use.

Changes to the Modeling Process:

Previously, the AU's created from the original 2008 inventory (and then updated to the 2011 inventory) were used with the FORECAST and FPS-ATLAS models. These models are fully described in the prior Darkwoods PD v1.8. The FORECAST model was used to create a series of stand attribute curves for each AU, including creating an average merchantable timber volume and carbon storage by ecosystem pool, by age. The FPS-ATLAS model provided temporal harvest scheduling for the baseline (and ex-ante project harvesting projections) based on inventory polygons. The FORECAST AU inventory data was used by FPS-ATLAS to project harvest schedules in each scenario. Due to 2008 inventory conditions, model limitations, various carbon tracking complexities and simply as the original selected modeling design approach, the project prior to 2017 created these 'representative' stand conditions for each AU in the baseline and project scenario, and then replaced the inventory stand data with presumed AU stand data.

The prior approach and models were effective and were successfully verified in multiple monitoring reports from 2008 to 2016. The project identified several opportunities to improve the carbon modeling reliability and accuracy with new modeling tools and a modified approach. A key limitation of the previous approach was the carbon modeling used 'created' representative AU level data rather than modeling from actual forest inventory tree data. This AU-level stand data became increasingly difficult and complex to modify and track through actual spatial disturbance and forest inventory changes over time (i.e. fires, MPB, etc; each of which required creation of new 'sub-AU's' to track various disturbance assumptions and impacts forward). And the project proponents saw risks the created AU stands could potentially become increasingly 'separated' from actual stand inventory data over time and lose clarity and possibly reduce accuracy in some situations. Further, it increasingly appeared this simplified AU stand curve system would become difficult to use and transition as the project moves forward with new inventories and potentially more complex activities in the future.

Therefore, the project implemented a change to use the USFS model 'Forest Vegetation Simulator' (FVS) with the Fire and Fuels Extension (FFE) for stand and carbon modeling; along with the Forest Projection System (FPS) model to create harvest schedules in the baseline scenario.

Rather than creating representative AU stand attribute curves, the FVS-FFE is now used to model stand level tree and carbon attributes at the stand polygon level from actual inventory tree data, which is then rolled up into average stand conditions for each AU. This new modeling approach directly ties the actual current inventory data to AU level analysis, and creates more precision at the stand level within each AU.

FVS-FFE stand level modeling is a significant improvement in project carbon modeling and tracking. Previously, the AU stand curves transitioned to a new curve upon disturbance, which meant there could be a loss of accuracy in the actual stand carbon content after disturbance (i.e. all new stands started from the same starting carbon pool content – all of the carbon was being tracked, but carbon likely did not transition between carbon pools accurately). With FVS-FFE, each stand's carbon pools are modeled and tracked through disturbance to more accurately represent the starting carbon pool contents of new stands based directly on the previous stand conditions.

Overall, the transition to the new models in Darkwoods presents a significant improvement in carbon modeling capabilities for the project that will be well suited for the next decade of project management.

4.1 Baseline Emissions

Valid Starting Inventory Requirements:

The Darkwoods project meets the valid starting inventory requirements from VM0012:

1. The Darkwoods inventory covers the entire project area
2. A new forest inventory was created in 2011 (Ecora, 2011), and the inventory spatial data has been updated annually
3. The 2011 inventory was developed to the BC Vegetative Resource Inventory (VRI) standards and includes field testing (Ecora, 2011).

The Darkwoods 2011 VRI forest inventory is housed within NCC's Geographic Information System (GIS). The inventory dataset is broken into stand level polygons based on forest cover species, stand tree data, and other stand attributes.

Prior to the 2011 VRI inventory, the Darkwoods project utilized a GIS forest inventory based on the prior owners data. The 2008-2011 monitoring periods were analyzed and assessed against this spatial forest cover dataset (which also met VM0012 requirements at that that time). The 2012 monitoring report documented and verified the transition between the older inventory and the 2011 VRI inventory.

Baseline Scenario Area Stratification:

Step 1 – Stratify to create homogeneous units

The Darkwoods 2011 VRI inventory is stratified into forest stand types polygons based on land cover, species, height, and other stand or land characteristics (Ecora, 2012). To simplify the scale and complexity of the Darkwoods forest inventory the project is further stratified/grouped into relatively homogeneous analysis units (AU's) based on similarities in stand conditions and biomass production. A total of 19 different AU's were created to group the VRI stand inventory polygons into productive and non-productive forest land, and similar naturally originated stands and managed stands for both the baseline and project scenario analysis.

If applicable, each current forested AU stand is also assigned to transition to new future AU's based on either planted or naturally regenerated stand conditions, and inventory stand polygons . The AU stratification and assignment criteria are unchanged from the previous Darkwoods VCS PD v1.8 and are shown in Table 11 and Table 12.

In the previous version of the Darkwoods PD v1.8, further AU's were created to isolate and represent Lodgepole Pine stands moderately to severely impacted by the Mountain Pine Beetle (MPB) outbreak across B.C. from 2003-2004 to ~2010. These Mountain Pine Beetle AU's are still assigned per the AU criteria, but these AU have no additional impact on inventory or carbon stocks. The beetle outbreak mortality was over by ~2010 and the 2011 VRI inventory captured post-beetle timber inventory accurately without further adjustment.

In the 2011-2016 monitoring period various other AU changes were made to sub-stratify AU's in areas disturbed by fire. These sub-AU classifications are also no longer necessary in the new modeling approach where the forest inventory data can be updated for disturbances and disturbed stands modeled within the main AU categories.

Table 11. Assignment criteria for carbon analysis units.

AU	Description[11]	Lead Species	Other Species	Prod. Class	Site Index Range[12]	Age[13]
101	Fd / L*/ Bg/Py_med	Fd / L*/ Bg/ Py	Pl	med	>12 <18	>40
102	Fd / / Bg/ Py_good	Fd / L*/ Bg/ Py	H & C	good	>17	>40
103	B / L* / Fd / S*/ Py / Pw_poor	B / L* / Fd / S*/ Py / Pw	S, Pl	poor	> 7 & <13, > 7 &<14 for S	>40
104	BL_med	BL	S,Pl	med	>=13	>40
105	PL_poor	PL	B, S	poor	<13	>40
106	PL_med	PL	F, S	med	>12	>40
107	CW / HW_med-good	CW / HW	S,F	med-good	all	>40
108	S*_med	S*	Bl, Pl	med	>13 <17	>40
109	S*_good	S*	F, H, C	good	>16	>40
110	E / A_Med	E / A		Med	all	All
111	B / L* / Fd / S*/ Py / Pw_	B / L* / Fd / S*/ Py / Pw			<8	All
201	F / L_med	F / L	Pl	med	13-17	<=40
202	F / L_good	F / L	Pl	good	>17	<=40
203	S/P/B poor	S/P/B	L	poor	<13	<=40
204	S/B Med	S/B	L	med	>12 for Bl, >12 &<17 For S	<=40
206	P_med	P	F, S	med	>7	<=40
207	C / H_med-good	C/H	F, S	med-good	all	<=40
209	S_good	S	F, H, C	good	>16	<=40

[11] F = Douglas-Fir, L = Western Larch, B = Subalpine Fir, S = Hybrid spruce or Engelmann Spruce, P = Lodgepole pine and White bark pine, C = Western red cedar, H = Western hemlock, E = Paper birch, and A = Trembling aspen.

[12] Site Index based on height at breast-height age 50.

[13] The Age field is used to distinguish managed from natural stand types.

888	Non-forest					
	MPB curves					
AU	Description	Lead	MPB Curve	Prod class	SI range	Age
406 a	P_med	Fd/Hw/Py/Lw/Pl	Y	med	>7	<86
406 b	P_med	Fd/Hw/Py/Lw/Pl	Y	med	>7	>85

Table 12. Stand regeneration assumptions and transitions starting 2017 period using FVS-FFE

	Natural Stands									
AU	**Description**	**Sp1**	**Sp2**	**Sp1%**	**Sp2%**	**Density**	**Regen delay**	**Endemic mort**	**Trans1**	**Trans2**
101	Determined by FVS-FFE						4	0.04	201	301
102	Determined by FVS-FFE						3	0.04	202	302
103	Determined by FVS-FFE						6	0.04	203	303
104	Determined by FVS-FFE						4	0.04	204	304
105	Determined by FVS-FFE						3	0.04	206	306
106	Determined by FVS-FFE						3	0.04	206	306
107	Determined by FVS-FFE						3	0.04	207	307
108	Determined by FVS-FFE						6	0.04	204	304
109	Determined by FVS-FFE						5	0.04	209	309
110	Determined by FVS-FFE						2	0.04	110	110
111	Determined by FVS-FFE						6	0.04	111	111
	Managed Stands									
AU	**Description**	**Sp1**	**Sp2**	**Sp1%**	**Sp2%**	**Density**	**Regen delay**	**Endemic mort**	**Trans1**	**Trans2**
201	F / L_med	Fd	Pl	75	25	1500	1	0.04	201	301
202	F / L_good	Fd	Hw	75	25	2000	1	0.04	202	302
203	S/P/B poor	Se	Bl	52.5	47.5	1600	1	0.04	203	303
204	S/P/B Med	Se	Bl	52.5	47.5	1600	1	0.04	204	304
206	P_med	Pl	Se	65	35	2000	1	0.04	206	306
207	C / H_med-good	Sw	Cw	60	40	2000	1	0.04	207	307
209	S_good	Sx	Fd	60	40	2000	1	0.04	209	309
Harvest Without Planting										
AU	**Description**	**Sp1**	**Sp2**	**Sp1%**	**Sp2%**	**Density**	**Regen delay**	**Endemic mort**	**Trans1**	**Trans2**
301	Determined by FVS-FFE						6	0.04	301	301
302	Determined by FVS-FFE						5	0.04	302	302
303	Determined by FVS-FFE						8	0.04	303	303
304	Determined by FVS-FFE						6	0.04	304	304
306	Determined by FVS-FFE						4	0.04	306	306
307	Determined by FVS-FFE						5	0.04	307	307
309	Determined by FVS-FFE						7	0.04	309	309

STEP 2 – Identify areas eligible for specific management activities

The portion of the Darkwoods property area that contribute to carbon stocks and that are subject to scenario management activities; and within which carbon stock changes are tracked for the baseline and project scenario analysis was defined using a series of steps stratify the VRI forest inventory.

The first step in this process was to define the productive landbase. This was determined by using GIS software to identify and remove areas where trees were unable to grow, non-forested areas, buffers around creek channels (assumed averaging 3m each side of the channel), buffers around existing roads (5m buffer each side of centerline), and otherwise unreachable or uneconomic timber, following British Columbia Ministry of Forest and Range Timber Supply Analysis methods.

The non-forest and road buffer areas are assumed to have no carbon stocks for the purpose of the carbon project, and carbon stocks are not analyzed further on these areas.

Within the remaining area carbon stocks are modeled for each year of the project in the both the baseline and the project scenario. Further stratifications and limitations were made to identify the operable area which is subject to project and baseline scenario activities (i.e. timber harvesting) for further analysis. In the case of the baseline scenario the following stand types were excluded from harvesting: 1) stands $\geq$ 160 years old with subalpine fir, red cedar or hemlock as the leading species were conservatively considered 'uneconomical' (the high number of senescent trees in these stands render them uneconomical to harvest); or 2) stands in which the volume was less than 150 m^3 ha^{-1} (stands conservatively assumed to have volumes too low to be harvested economically on Darkwoods)[14]. The resulting remaining landbase available for scenario management activities that affect forest carbon stocks are designated the carbon Timber Harvesting Landbase (THLB).

Note that while the entire productive landbase contributes to carbon stocks in both scenario, the carbon in forests outside the THLB will typically 'net out' when calculating net emission reductions between the scenarios. Comparatively, different activities in the baseline versus project scenario within the THLB will result in very different carbon stocks between the scenarios over time.

The same landbase stratifications and operable landbase were used in both the project and baseline scenarios. However, note for the purposes of the original projections of anticipated ex-ante timber harvesting in the project scenario, an additional manually identified spatial data layer called the "Environmental Protection Area (EPA's)"[15] were excluded from project scenario harvesting options (~ 8,600 ha). These EPA areas were identified by the prior owners and used by NCC to define an area which was used for the purpose of more realistically projecting potential project harvesting areas in the project. This area and project activity locations can be modified as needed as part of ongoing property management planning processes for Darkwoods.

No changes have been made to this spatial identification of the THLB during the transition to new modeling in this Darkwoods PD v2.0.

[14] Collectively, these forested and non-economic polygons with trees are added to AU 111 (along with non-productive stands having a site index less than 8).

[15] EPA's are environmentally important areas (generally containing operable commercial timber) identified by previous owners (Pluto Darkwoods) beyond the legal requirements or common practice, which NCC has adopted with their project management plans. Note, however, that although EPA areas are excluded from ex-ante modeling of future project management harvesting, NCC reserves the right to undertake management activities within the EPA zones.

The identification of these management areas over top of the 2011 VRI inventory is the base for both the Baseline and Project Darkwoods Carbon GIS Inventory datasets, which are then used as a spatially explicit stand datasets for FVS-FFE and FPS stand level modeling for each scenario respectively. Figure 6 shows an overview of the spatial distribution of the operable forest land base (THLB) for the Darkwoods property (uneconomic, stream, and road buffer exclusions are not shown). Approximately 30,330 ha of the project area is considered operable at the current time.

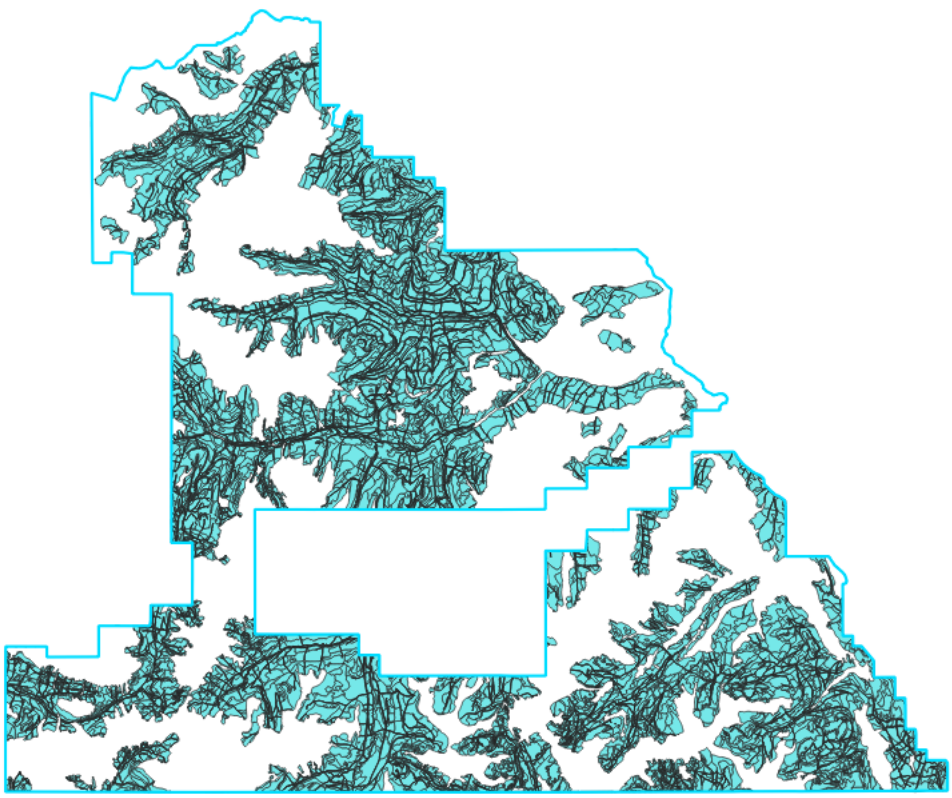


Figure 6 - Darkwoods Timber Operability (THLB) Map[16].

[16] Note that the AU definitions and landbase stratifications may be changed periodically due to improved inventory, data enhancements, or more current operating practices or information. Any changes are to be applied consistently in the baseline and project datasets.

Table 13. Summary of area, actual plots and expected plots by analysis unit.

Analysis Unit	Area (ha)	Actual plots	Expected plots[17]
THLB Area			
101	3,644.1	8	6.1
102	1,766.1	5	3.0
103	12,492.1	15	20.5
104	4,673.3	4	7.0
105	1,296.2	2	2.2
106	1,333.6	4	2.3
107	3,146.3	9	5.2
108	2,126.1	4	3.6
109	1,723.4	3	2.9
110	39.3[18]	0	0.1
201	496.6	1	0.9
202	433.7	1	0.7
203	2,216.5	2	4.2
204	3,160.4	6	6.1
206	1,127.3	2	1.9
207	252.4	1	0.5
209	2,032.9	3	3.8
406a	193.5	1	0.3
406b	433.1	1	0.7
Sub-total	**42,831.1**		
Non-THLB Area			
111	9,055.9	0	0.0
888	2,983.4	0	0.0
Sub-total	**12,039.3**		
Total	**54,870.4**	**72**	**72**

[17] Expected number of plots is calculated by weighting the total number of installed plots based upon the total productive forest area in analysis unit relative to the total productive forest area.

[18] See the methodology deviation for the lack of plots in this very small AU.

Baseline VRI Inventory Updates for Harvesting.

The transition of the prior forest inventory (2008-2010) to the 2011 VRI is described in detail in the 2011-12 Monitoring Report. The key change during this transition was clipping the baseline harvest areas from 2008-2010 (which were based on the old inventory polygons) to the new 2011 VRI inventory dataset. This created the need for 2 ‘starting’ datasets with the latest VRI 2011 inventory – one for the project scenario reflecting actual property conditions in 2011; and one for the baseline scenario adjusted for the polygons harvested in the baseline scenario in 2008-2011. These 2008-2010 harvest polygons were clipped to the new VRI inventory using GIS tools and the resulting polygons tracked as regenerating stands starting from the year of harvest according to the baseline regeneration assumptions shown in Table 12 in the baseline GIS database.

The project and baseline scenarios are then each tracked in separate spatially explicit MS Access Databases, which are then used for FVS-FFE and FPS modeling, and updated for project and baseline activities respectively over time.

Note that baseline harvest polygons modeled by ATLAS and used in the 2011-2016 monitoring periods were not identified spatially and this spatial data is no longer available to the project. The 2011-2016 baseline harvest has been re-run using FPS and the harvest scheduling processes described below. In all future cases the project will project the baseline harvest polygons selections by year and retain the harvest polygon data and extents by year such that the baseline VRI inventory database can be kept up to date spatially and ‘harvested’ baseline polygons clipped into any future disturbances or forest inventory datasets.

Project harvesting activities overlapped with baseline harvest activities in 2008-2011. Starting in the 2011 VRI inventory, the Baseline VRI Database is updated and tracked separately, and project scenario harvesting updates are not included in this database.

Baseline VRI Inventory Updates for Natural Disturbances

The project has also changed the handling of project area fires to affect both the baseline and project scenario inventory starting in 2017 (and applied for the 2018 fires). In previous monitoring periods (2008-2016), due to technological modeling limitations the natural forest fire impacts were limited to the project scenario and not applied to the baseline. There were only 182.8 ha burned in this prior period. These prior fires are tracked only in the project inventory dataset and not included in the baseline dataset to be consistent with prior treatment.

However, upon further review, this differential treatment of forest carbon stocks and inventory after fire and other disturbances creates complexities and difficulties in tracking carbon stocks in the two scenarios. In prior monitoring periods, the project was having to create a significant list of manual “sub-analysis units” and inventory adjustments which applied differentially to each scenario in excel spreadsheets, which was becoming increasingly difficult to track. Of particular concern is the future complexity/difficulty of tracking these manually created “sub-AU” differences between the project and baseline inventory during pending future updates to the actual forest inventory data (last updated in 2011 and expected in 2020-21). The project complexity will be reduced and accuracy improved by minimizing the manual variance between actual inventory conditions in both scenarios other those areas impacted by modeled activities (i.e. harvesting in the baseline vs. project), and by better streamlining/standardizing modeling process across the scenarios. So, by applying actual natural disturbances consistently to both the baseline and project scenario (adjusted for modeled harvesting) we will be better able to track carbon stocks and emission reduction differences over time.

More conceptually, the project area is subject to infrequent natural lightning strike fires that would have likely occurred in either scenario. The 2018 fires, for example, both started as lightning strikes outside the project area during historically extreme dry conditions, and hence would likely have occurred similarly in the baseline and project scenario. The carbon stock impacts could be different due to modeled harvesting in the baseline scenario (which is reflected in the FVS-FFE modeling of the fires by severity over the polygon inventory conditions in the baseline scenario at that year).

We note that there is the possibility that some fire behavior differences might have occurred based on differences in forest stand inventory (i.e. fuel loading differences) in the baseline and project scenarios for the same fire event. Fire behavior is complex, however we posit that these differences would be difficult to anticipate/model and generally minor in terms of impacts on emissions reductions. First, fires are rare in the project area, which is generally a wet or transitional ecosystem as described in the project Non-Permanence Risk Report. Second, the steep and variable terrain is likely a significant driver of fire extent under extreme conditions, with fuel load playing a lessor role (i.e. in steeper terrain and extreme conditions, fires would likely still have burned over or around young stands/harvest area in the baseline to affect approximately similar area; as compared to flat terrain where fires might be expected to more clearly follow fuel load).

In future periods, unless otherwise noted and justified, natural disturbances will applied against the baseline scenario and project scenario inventory datasets. FVS-FFE has the capability to model natural disturbances against the current inventory condition in either scenario, and then continue tracking expected carbon stock changes in either scenario.

Model Selection and Use

As of 2017 and this Darkwoods PD v2.0, the project has transitioned from the FORECAST and ATLAS models to FVS-FFE and the FPS harvest scheduling model, in conjunction with an MS Access Database and supporting MS Excel spreadsheets.

The USFS Forest Vegetation Simulator (FVS) is a semi-distance-independent individual tree growth and yield model ("semi-" because certain parts of the model localize competition and site variables to a plot (or point) basis within a stand). It treats a stand as the population unit and utilizes standard forest inventory or stand exam data. Local growth rates are used to adjust model growth relationships, which is a distinguishing feature of the model. FVS can portray a wide variety of forest types and stand structures ranging from even-aged to uneven-aged, and single to mixed species in single to multi-story canopies. More information: https://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf.

The FVS Fire and Fuels Extenstion (FFE) is an extension module that extends the FVS model to simulate both fire behavior and fuel dynamics (including snag development, downed and dead dynamics, and other fuel related dynamic processes); and also model and track carbon dynamics by pool, including estimating dead wood decay, belowground carbon pools, and harvest wood carbon pools. More information: https://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/FFEguide.pdf.

The Inland Empire (IE) Variant is a set of FVS equations and calibrations for tree growth, mortality, volume and other stand dynamics that are developed and calibrated for a specific geographic area. The IE Variant is developed in the U.S., however is directly adjacent to the project area (which is <20km from the US border that cuts off the IE Variant map – see Figure 7). The IE Variant is the direct basis for the BC Prognosis Variant which has been developed for use in BC, but is currently being updated[19]. More information: https://www.fs.fed.us/fmsc/ftp/fvs/docs/overviews/FVSie_Overview.pdf.

[19] BC Prognosis is a FVS Variant that was developed from the IE Variant with the intent to create B.C. based variants for FVS usage. BC Prognosis is being created by ESSA (www.essa.com) in Vancouver, BC (one of the developers of FVS for the USFS). The BC Prognosis variant is currently out of date for the latest FVS model interface. Don Robinson the FVS and BC Prognosis expert at Essa recommended the IE Variant as appropriate for the Darkwoods project area in lieu and generally equivalent to BC Prognosis.

Figure 7. Inland Empire Variant location map in comparison to the project location

FVS-FFE with the IE Variant models and tracks stand growth, mortality, snag recruitment and dynamics, dead and down (CWD) recruitment and related above- and below-ground biomass dynamics, all based on the project stand level tree inventory data.

Additional localized model calibrations were made by including polygon centroid lat/long, elevation and average aspect when loading GIS data into FVS-FFE. Polygons were also assigned to a Habitat Code, which is used in FVS-FFE in place of site index. Don Robinson from Essa in Vancouver, BC provided an expert opinion cross-walk table for property level biogeoclimatic classifications and the FVS habitat codes. Further details on the set up and of FVS-FFE and the Darkwoods GIS data can be found in the supporting “Darkwoods Carbon Methods_2019” document.

The Forest Projection System (FPS) model is a stand-alone forest estate management software package which is used to create a harvest schedule for the property area using input volume spatial data from the FVS-FFE model and the project area baseline GIS database. More information on FPS: www.fbrinstitute.org.

The outputs from FVS-FFE are exported to a series of MS Access Databases (collectively the Darkwoods Carbon Database) which compile, track and make additional calculations to summarize and report carbon emission reductions and other VM0012 equation calculations.

The final outputs from the Darkwoods Carbon Database are then summarized and output to an MS Excel spreadsheet (Darkwoods Carbon Model) where calculations for Emissions from Fossil Fuels from Equipment and Manufacturing are made, and then final summarizing the final net emission reductions and VCU’s for the project.

The FVS-FFE and FPS models meets the requirements for model selection as listed in VM0012:

1. FVS-FFE and FPS have been in use and under development for >10 years
2. FVS-FFE and FPS can generate values on <10 year increments
3. FVS-FFE and the IE Variant and FPS include stand dynamics and mortality regimes that are regionally specific and tested.
4. FVS-FFE outputs both biomass and carbon for all of the required carbon pools. The IE variant includes growth and yield and expansion factors that are regionally appropriate.
5. FVS-FFE is well documented and involved in many peer reviewed and published documents. The model is created and used by the United States Forest Service in forest management, carbon applications, and for research purposes. FPS is well documented and used by industry and other entities throughout the western United States and Canada.
6. The model has been parameterized and calibrated for the specific conditions of the project. Project area stand inventory tree data was used in the model; additional site specific calibrations/parameters were based on habitat types, elevation, aspect, and lat/long by polygon. The main calibrations are based on extensive USFS work in development of the IE variant, which is directly geographically adjacent to the project area.
7. FVS-FFE is used and documented extensively to model both harvesting and natural disturbances for the project and baseline scenarios. FVS can model a very wide range of timber harvesting scenarios, including the clearcutting currently in use in this project. The FFE module is specifically designed to model fire, which has been the primary natural disturbance type.
8. FVS-FFE is a stand-based model that also models all carbon pools with the FFE module. Further, FVS-FFE models Harvested Wood Product pools as required by VCS. The FPS harvest scheduling model is also well documented and established, and uses the FVS-FFE inputs.
9. As noted in VM0012, FVS itself was designed as a timber growth and yield model. However, the FFE module adds carbon pool level processes well suited for carbon modeling in this project.

Calculating the Baseline Carbon Balance

The carbon accounting approach employed for the Darkwoods carbon project utilizes the Darkwoods VRI forest inventory data (broken into a Project and Baseline datasets and stratifications, as noted above) and the biomass modeling and tracking output from a regionally calibrated stand-level model, FVS-FFE (IE Variant), in conjunction with a forest-level harvest scheduling model, FPS.

FVS-FFE is used to calculate stand level biomass and carbon content by carbon pool for each stand in the Darkwoods VRI forest inventory GIS database[20]. FVS-FFE then simulates stand level temporal changes in carbon storage of different ecosystem pools for each stand, including modeling forest growth, mortality and all related stand dynamics by carbon pool (including as related to natural disturbances), along with calculating and tracking volume removals from baseline harvesting in all applicable harvested wood product pools.

The stand-level output from FVS-FFE is then linked to the FPS model, which creates a harvest schedule based on specified polygon selection criteria and baseline harvest target criteria against the current baseline inventory database of available volume. This harvest schedule output is then linked back into FVS-FFE to apply the modeled harvest activities by polygon over time, and then model and track the resulting changes in biomass and carbon content by ecosystem carbon pool and harvest wood product pool.

FVS-FEE regenerates stands after harvest based on the defined regeneration assumptions in Table 12, while continuing to track carbon pool changes after harvest and during regrowth at a stand polygon level.

FVS-FFE is also used to simulate natural disturbances and other inventory changing events in both the baseline and project scenarios, as appropriate. The FFE modules can simulate carbon stock changes by pool at the stand polygon level for various management treatments and natural disturbances, including fire by severity condition using the SimFire option in FVS-FFE based on starting stand tree inventory data for the fire areas. FVS-FFE then continues stand develop and/or regeneration after the natural disturbance event. For example, in a fire event, FVS-FFE can model the field assessed fire severity polygons to ‘burn’ the affected stands in manner approximating the fire severity classification (the BC Ministry of Forests surveys all fires and creates spatial fire severity class maps). FVS-FFE models fire behavior and tree survival/mortality based on fire conditions, species (bark thickness), fuel loading, and other stand conditions. FVS-FFE then models tree mortality, snag recruitment and fall-down after the fire, along with surviving tree growth and the

[20] Additional details about the specific settings and inventory data usage is available In the supporting Darkwoods Carbon Methods_2019 document.

establishment of new regeneration based on original stand conditions and habitat codes. FVS-FFE models and tracks all carbon stock changes related to the fire by carbon pool over time.

FVS-FFE then tracks and reports all necessary carbon pools for the project annually across all polygons of interest in the inventory. Annual outputs by carbon pool are summarized and output to MS Access Database(s) (collectively the Darkwoods Access Database) for further compilation by Analysis Unit and further calculations on the baseline and project balance. Final VCU calculations are made in an excel spreadsheet called the Darkwoods Carbon Model.

Both the baseline and project scenarios use the same model settings and assumptions unless otherwise described, which are tracked against each scenarios spatial GIS inventory dataset each year.

Description of the Baseline Scenario Modeling

The selected baseline scenario applied in FPS assumes baseline logging would have targeted fifteen years of the project at a harvest level of 300,000 m^3 /yr[21]. Then the harvest schedule targets the maximum available merchantable harvest volume each year thereafter, to a maximum of 300,000m^3/ha[22].

The baseline scenario is assumed to be clearcutting (the complete removal of all sound standing trees) to maximize the stumpage margin. Stands are assumed to regenerate naturally (i.e., no reforestation investment) in the baseline scenario to reduce costs and maximize timber investment returns (noting that natural regeneration is not uncommon in Canada due to its low cost and reasonable effectiveness over a slightly delayed regeneration timeline). An overview of the baseline scenario harvest schedule targets is presented in Table 14.

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[21] The reference appraisal document (Thrower & Orr-Ewing, 2007) scenario was 15 years at 250,000 m^3/yr – 350,000 m^3/yr. The project selected the mid-point as the targeted baseline scenario harvest level.

[22] The appraisal and 2008-2011 inventory expected the mature standing stock to be depleted after 15 years. The 2011 VRI inventory demonstrated additional volume in the THLB, so the harvest schedule extends the 300,000 m^3/yr harvest level until stocks are depleted, then harvests to maximum available. As of 2019, the baseline harvest remains at 300,000m^3 until 2028 (so 20 years vs. the expected 15 years).

Table 14 - FPS harvest schedule targets for the Baseline and Project scenarios.

Scenario	Harvest Flow Target Years 1-15	Harvest Flow Target Years 16-100	Minimum Harvest Criterion	Harvest in EPA Area?[23]	Regeneration Method[24]
Baseline	300,000 m^3/yr	Maximum possible	150 m^3/ha	Y	Natural
Project	Actual Ex-ante projections at 10,000 m^3/yr	Actual Ex-ante projections at 10,000 m^3/yr	150 m^3/ha	N	Plant

The baseline (and ex-ante project) scenario harvesting is scheduled only within the Carbon THLB, and hence no harvest polygons are selected in the inoperable areas or identified uneconomic stands. Stream and road buffer areas are also clipped from the inventory polygons and cannot be selected for harvest and do not contribute volume to the harvest schedule, nor carbon stock changes after harvest. The FPS harvest schedule selects stands based on “oldest first”, with a minimum harvest age of 45 years, and a maximum clearcut size of ~50 ha until the target harvest level is achieved. FVS-FFE grows the baseline forest forward after applying the FPS harvest schedule by polygon and year, and hence can project future stand development and harvesting in the baseline throughout the project lifetime.

The 2008-2010 baseline harvest schedule polygons have retained for all future periods (as noted, these early baseline harvest polygons were selected in a prior inventory dataset and clipped to the Baseline 2011 VRI dataset). Also as noted, spatial polygons selected for baseline harvests in the 2011-2016 period are unavailable, and hence the project has re-projected the baseline harvest polygons from 2011 forward using FPS and FVS-FFE modeled stand data[25].

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[23] Environmentally protected areas as defined in Section 4.1

[24] Natural regeneration causes stands to regenerate based upon the 300-series managed stand analysis units after harvesting while planting transitions to the 200-series regeneration assumptions.

[25] This reprojection of the baseline harvest does not affect prior verified monitoring periods, but it creates a spatialized baseline harvest pattern to update the baseline VRI forest inventory layer and track baseline carbon stocks and inventory conditions consistently going forward.

The project scenario inventory dataset is updated annually for project harvesting and natural disturbances, which then becomes part of the GIS inventory dataset used by FVS-FFE to project and track project scenario carbon stocks.

Calculating the Baseline Carbon Balance

Total GHG emissions for the selected Baseline Scenario described in Section 3.4 are calculated using a suite of carbon accounting tools. The pools included in the accounting are described in Section 3.3. The basic equations employed for emissions accounting are based on the IPCC gain-loss method (IPCC, 2006b).

Prior to 2017, and as shown in the prior PD v1.8, the FORECAST model, ATLAS model, and a MS Excel spreadsheet (Darkwoods Forest Carbon Model) were used in combination with the initial (2008) and later updated VRI spatial forest inventory data (2011) to calculate the baseline carbon balance in compliance with VM0012 v.1.0-1.1.

As of 2017 and this new PD v2.0, the project has changed to use the FVS-FFE and FPS models and the 2011 VRI forest inventory data to calculate and track annual changes the total annual carbon balance for the baseline scenario in accordance with VM0012 v1.2.

Summarized, the total annual carbon balance for each inventory polygon within the project Carbon THLB is tracked using the FVS-FFE model. The annual carbon content (tracked for each ecosystem pool) is then summed each year for the landbase in the baseline scenario by FVS; and compiled into AU's in the Darkwoods Carbon Database; and finally summarized across the project area in the Darkwoods Carbon Model spreadsheet (Equations 1-3, 10). The annual change in harvested wood products storage (Equations 2, 18) is calculated and tracked in FVS-FFE using annual simulated baseline harvested wood volume output from the FPS baseline harvest schedule, with supplementary calculations related to the annual change in fossil fuel emissions from harvesting and processing made in the Darkwoods Carbon Model MS Excel spreadsheet.

The calculations of the annual balance changes are made within these carbon accounting tools, following the sequence of equations required by VM0012 v1.2 for the Baseline 2011 VRI forest inventory dataset, updated to year, t.

The total annual carbon balance in year, t, for the baseline scenario is calculated as ($\Delta C_{BSL,t}$, in t C yr^{-1}):

$$\Delta \mathbf{C}_{BSL,t} = \Delta \mathbf{C}_{BSL,P,t} \qquad \textbf{(1)}$$

where:

$\Delta C_{BSL,P,t}$ = annual change in carbon stocks in all pools in the baseline across the project activity area; t C yr^{-1} .

Change in carbon stocks by pool by year is modeled by FVS-FFE by baseline inventory polygon, and summarized by AU and then across the project area for each year. The annual carbon content (tracked by carbon pool) is then summed each year for the project area for the Baseline scenario by FVS, and then the output summarized in the Darkwoods Carbon Model spreadsheet by monitoring year to complete equation 1.

$$\Delta \mathbf{C}_{\mathbf{BSL,P,t}} = \Delta \mathbf{C}_{\mathbf{BSL,LB,t}} + \Delta \mathbf{C}_{\mathbf{BSL,DOM,t}} + \Delta \mathbf{C}_{\mathbf{BSl,HWP,t}} \qquad \mathbf{(2)}$$

where:

$\Delta C_{BSL,LB,t}$ = annual change in carbon stocks in living tree biomass (above- and belowground); t C yr^{-1}

$\Delta C_{BSL,DOM,t}$ = annual change in carbon stocks in dead organic matter; t C yr^{-1}

$\Delta C_{BSl,HWP,t}$ = annual change in carbon stocks associated with harvested wood products, t C yr^{-1}.

FVS models changes in carbon stocks by pool by inventory polygon, which is then compiled and summarized by year, polygon and AU (when necessary) and across the BSL scenario conditions. The FVS stand data (Stand Carbon Report) outputs by pool are imported to the Darkwoods Carbon Database where the data is compiled by AU, polygon and year for the Baseline scenario to complete equation 2.

$$\Delta \mathbf{C}_{\mathbf{BSL,LB,t}} = \Delta \mathbf{C}_{\mathbf{BSL,G,t}} - \Delta \mathbf{C}_{\mathbf{BSL,i,t}} \qquad \mathbf{(3)}$$

where:

$\Delta C_{BSL,G,t}$ = annual increase in tree carbon stock from growth; t C yr^{-1}

$\Delta C_{BSL,L,t}$ = annual decrease in tree carbon stock from a reduction in live biomass; t C yr^{-1}.

If the project area has been stratified, carbon pools are calculated for each polygon, i, and then summed during a given year, t.

FVS-FFE models live tree gains and loss by inventory polygon, by carbon pool, and by year based off of the Baseline 2011 VRI forest inventory stand data and annual baseline activities and stand dynamics. The Darkwoods Database tool compiles and summarizes the FVS-FFE carbon outputs across polygons and baseline scenario conditions, including calculating Equation 3.

Live biomass gain in year, *t*, polygon, *i* ($\Delta C_{BSL,G,i.t}$) is calculated as:

$$\Delta C_{BSL,G,t} = \Sigma(A_{BSL,i} \bullet G_{BSL,i,t}) \bullet CF \quad (4)$$

where:

$A_{BSL,i,}$ = area (ha) of forest land in polygon, *i*;

$G_{BSL,i,t}$ = annual increment rate in tree biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *i*, and;

CF = carbon fraction of dry matter t C t^{-1} d.m. (IPCC default value = 0.5).

$$G_{BSL,i,t} = G_{BSL,AG,i,t} + G_{BSL,BG,i,t} \quad (5a)$$

where:

$G_{BSL,AG,i,t}$ and $G_{BSL,BG,i,t}$ = annual above- and belowground biomass increment rates (t d.m. ha^{-1} yr^{-1});

$$G_{BSL,BG,i,t} = G_{BSL,AG,i,t} \bullet R_i \quad (5b)$$

The total annual live biomass gain for each polygon, *i* within the project landbase is tracked by FVS-FFE for each polygon from the Baseline 2011 VRI forest inventory data, and then summarized for each AU and across the project area for the Baseline scenario by year. FVS-FFE determines the amount of C storage in each inventory polygon by carbon pool, including modeling tree growth based on stand inventory tree data and using algorithms calibrated for forests in the IE Variant and other site specific stand data (i.e. polygon elevation, aspect, area lat/long, habitat type, etc.). Further details of the growth curves, data references, and other parameters used in FVS-FFE for live biomass gain and loss can be found in Dixon (2002). The FVS-FFE Carbon Stand Table provides values in tC/ha which are then converted to total tons by multiplying by the area of the polygon (Equation 4). The amount carbon stored in above and below ground live biomass in each polygon is calculated and tracked annually by FVS-FFE (Equations 5a-b). FVS-FFE models stand regeneration in the baseline scenario after harvest following the criteria in Table 12.

Note that FVS-FFE does not include biomass in bark. This biomass is manually calculated in the Darkwoods Carbon Database by applying an adjustment factor to the FVS-FFE aboveground live tree biomass outputs (which is then treated as live tree biomass for the purpose of these carbon calculations). Details of this bark calculation and data references can be found in the supplemental Darkwoods Carbon Methods_2019 document.

Live biomass loss is calculated as:

$$\Delta C_{BSL,L,t} = \Sigma(LBL_{BSL,NATURALi,t} + LBL_{BSL,FELLINGS,i,t} + LBL_{BSL,OTHER,i,t}) \bullet CF \quad (6)$$

where:

$LBL_{BSL,NATURALi,t}$ = annual loss of live tree biomass due to natural mortality in polygon, *i*; t d.m. yr^{-1}

$LBL_{BSL,FELLINGS,i,t}$ = annual loss of live tree biomass due to commercial felling in polygon, *i*; t d.m. yr^{-1}

$LBL_{BSL,OTHER,i,t}$ = annual loss of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1}

CF = carbon fraction of dry matter; t C t^{-1} d.m. (IPCC default value = 0.5).

$$\mathbf{LBL_{BSL,NATURALi,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,NATURAL,i,t}} \qquad \mathbf{(7)}$$[26]

where

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$LB_{BSL,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{BSL,i,t}$) added as per calculations in equation 5a.

$f_{BSL,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in polygon , *i* (unitless; $0 \leq f_{BSL,NATURALi} \leq 1$), year, *t*.

$$\mathbf{LBL_{FELLINGS,i,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,HARVEST,i,t}} \qquad \mathbf{(8)}$$

where:

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t* (see equation 7 for its calculation).

$f_{BSL,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{BSL,HARVESTIi} \leq 1$), in year, *t*. Data for this variable should be obtained from harvest schedule information. Values may be constrained by (a) the value of $f_{BSL,NATURAL,i,t}$ (i.e.,

[26] Note, for Equation 7, 8, and 9: $(f_{BSL,NATURAL,i,t} + f_{BSL,HARVEST,i,t} + f_{BSL,DAMAGE,i,t}) \leq 1.0$

$f_{BSL,HARVEST,i,t} < 1 - f_{BSL,NATURAL,i,t}$), and/or (b) the area of timber available for commercial harvest.

$$\mathbf{LBL_{BSL,OTHER,i,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,DAMAGE,i,t}} \qquad \mathbf{(9)}$$

where:

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$f_{BSL,DAMAGE,i,t}$ = the proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t* (unitless; $0 \leq f_{BSL,DAMAGE,i,t} \leq 1$).

The total annual live biomass loss for each polygon, *i* within the project Carbon THLB (Equations 6-8) is calculated and tracked using the FVS-FFE model by year, and then summarized for each AU and across the project area for the Baseline scenario by year in the Darkwoods Carbon Database and Darkwoods Carbon Model spreadsheet. Within-stand losses related to natural mortality and stand-self thinning are modeled and tracked within FVS-FFE for each polygon based on polygon tree data from inventory and algorithms calibrated for the IE Variant and other site specific polygon data (i.e. polygon elevation, aspect, lat/long, habitat type, etc.). Live biomass loss through harvesting is represented using the baseline harvest schedule determined by the FPS model and implemented in FVS-FFE by polygon on an annual basis. When this occurs, the polygon has its age reset to 1 and switches to the associated regenerating stand analysis unit. For the baseline, regeneration is modeled by FVS-FEE functions as natural regeneration using the assumptions described in Table 12 and related text.

Live biomass loss due to fire and other natural disturbances (if applicable to the baseline scenario) are modeled using FVS-FFE sub-routines based on ex-post inventory updates for each disturbance by polygon applied to that years modeled baseline forest inventory. FVS-FFE then models live biomass loss and other stand changes and dynamics by fire severity class, by polygon, by carbon pool. Similar live biomass loss processes can be used for other natural disturbance types updated in the baseline forest inventory as needed. FVS-FFE resumes stand growth and development and carbon pool dynamics based on the modeled outcome of the fire on affected polygons on an annual basis.

Live biomass loss due to incidental loss are not modeled in the Darkwoods project. Instead, permanent roads are removed during the landbase stratification process and a 5m buffer added to each side. These road buffer polygons are then classified as non-forest and removed from biomass calculations in the baseline and project scenario. Darkwoods is extensively roaded, and these road buffer exclusions, in combination with the clearcut harvesting areas are assumed to suitably capture the incidental losses due to roads and landings. This is conservative in the baseline scenario, as baseline emissions related to potentially additional road construction to support baseline harvesting are being excluded.

Change in Dead Organic Matter (DOM) ($\Delta C_{BSL,DOM}$; t C yr^{-1}) is calculated as:

$$\Delta C_{BSL,DOM,t} = \Delta C_{BSL,LDW,t} + \Delta C_{BSL,SNAG,t} + \Delta C_{BSL,DBG,t} \quad (10)$$

where:

$\Delta C_{BSL,LDW,t}$ = change in lying dead wood (LDW) carbon stocks in year, t; t C yr^{-1}

$\Delta C_{BSL,SNAG,t}$ = change in snag carbon stock in year, t; t C yr^{-1}

$\Delta C_{BSL,DBG,t}$ = change in dead belowground biomass carbon stock in year, t; t C yr^{-1}.

The change in DOM derived from lying dead wood (LDW) carbon stock in year, t (t C yr^{-1}) is calculated as:

$$\Delta C_{BSL,LDW,t} = \Sigma(LDW_{BSL,IN,i,t} – LDW_{BSL,OUT,i,t}) \bullet CF \quad (11a)$$

$$LDW_{BSL,i,t+1} = LDW_{BSL,i,t} + (LDW_{BSL,IN,i,t} – LDW_{BSL,OUT,i,t}) \quad (11b)$$

where:

$LDW_{BSL,,i,t}$ = The total mass of lying dead wood accumulated in polygon *i* , at time, *t* (t d.m.).

$LDW_{BSL,IN,i,t}$ = annual increase in LDW biomass for polygon *i*, year, *t* (t d.m yr^{-1}). LDW increases occur as a result of natural mortality (typically, blowdown), and as a direct or indirect result of harvesting.

$LDW_{BSL,OUT,i,t}$ = annual loss in LDW biomass through decay, for polygon *i*, year, *t*, (t d.m yr^{-1})

$LDW_{BSL,IN,i,t}$ and $LDW_{BSL,OUT,i,t}$ are summed across polygons.

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$LDW_{BSL,IN,i,t} = (LBL_{BSL,NATURALi,t} - LBL_{BSL,NATURALi,t} \bullet R_i) \bullet f_{BSL,BLOWDOWN,i,t} + ((LBL_{BSL,FELLINGS,i,t} – LBL_{BSL,FELLINGS,i,t} \bullet R_i) + (LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i)) \bullet f_{BSL,BRANCH,i,t} + ((LBL_{BSL,FELLINGS,i,t} – LBL_{BSL,FELLINGS,i,t} \bullet R_i) + (LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i)) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet f_{BSL,BUCKINGLOSS,i,t} + SNAG_{BSL,,i,t} \bullet f_{BSL,SNAGFALLDOWN,i,t} \quad (12)$$

where:

$LBL_{BSL,NATURALi,t}$, $LBL_{BSL,FELLINGS,i,t,}$ and $LBL_{BSL,OTHER,i,t}$ are as calculated in equations 7, 8, and 9, respectively.

R_i is the root:shoot ratio in polygon, *i* (see equation 5b).

$f_{BSL,BLOWDOWN,i,t}$ = the annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i,* year*, t* (unitless; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$).

$f_{BSL,BRANCH,i,t}$ = the annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, *i* (unitless; $0 \leq f_{BSL,BRANCH,i,t} \leq 1$).

$f_{BSL,BUCKINGLOSS,i,t}$ = the annual proportion of the log bole biomass left on site after assessing and/or merchandizing the log bole for quality, in polygon, *i* (unitless; $0 \leq f_{BSL,BUCKINGLOSS,i,t} \leq 1$).

$f_{BSL,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{SNAGFALLDOWN,i,t} \leq 1$).

$$\mathbf{LDW_{BSL,OUT,i,t} = LDW_{BSL,,i,t} \bullet f_{BSL,lwDECAY,i,t}} \qquad \textbf{(13)}$$

where:

$LDW_{BSL,,i,t}$ = the total amount of lying deadwood mass in polygon *i,* year*, t (see equation 11b)*. $f_{BSL,lwDECAY,i,t}$ = the annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t* (unitless; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$).

The change in DOM derived from standing dead wood (snag) carbon stock in year, t (t C yr^{-1}) is calculated as:

$$\mathbf{\Delta C_{BSL,SNAG,t} = \Sigma(SNAG_{BSL,IN,i,t} - SNAG_{BSL,OUT,i,t}) \bullet CF} \qquad \textbf{(14a)}$$

$$\mathbf{SNAG_{BSL,i,t+1} = SNAG_{BSL,i,t} + (SNAG_{BSL,IN,i,t} - SNAG_{BSL,OUT,i,t})} \qquad \textbf{(14b)}$$

where:

$SNAG_{BSL,i,t}$ = The total mass of snags accumulated in polygon *i, at time t (t d.m.).*

$SNAG_{BSL,IN,i,t}$ = annual gain in snag biomass for polygon *i*, year, *t* (t d.m yr^{-1}). Snag biomass develops as a result of natural mortality. In cases where snags are created through management activities, these should be accounted for here.

$SNAG_{BSL,OUT,i,t}$ = annual loss in snag biomass through decay, or falldown (i.e, transfer to the LDW pool)(t d.m yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

Note that $SNAG_{BSL,IN,i,t}$ and $SNAG_{BSL,OUT,i,t}$ are summed across polygons.

$$\mathbf{SNAG_{BSL,IN,i,t} = (LBL_{BSL,NATURALi,t} - LBL_{BSL,NATURALi,t} \bullet R_i) \bullet (1 - f_{BSL,BLOWDOWN,i,t})} \qquad \mathbf{(15)}$$

where:

$LBL_{BSL,NATURALi,t}$ is as calculated in equation 7, and

1 - $f_{BSL,BLOWDOWN,i,t}$ is the proportion of live tree aboveground biomass that dies in polygon, *i*, year, *t*, but remains as standing dead organic matter (i.e., snags) (unitless; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$).

$$\mathbf{SNAG_{BSL,OUT,i,t} = SNAG_{BSL,i,t} \bullet f_{BSL,SWDECAY,i,t} + SNAG_{BSL,i,t} \bullet f_{BSL,SNAGFALLDOWN,i,t}} \qquad \mathbf{(16)}$$

where:

$SNAG_{BSL,i,t}$ = the total amount of snag mass in polygon *i,* year*, t* (see equation 14b).
$f_{BSL,SWDECAY,i,t}$ = the annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t* (unitless; $0 \leq f_{BSL,SWDECAY,i,t} \leq 1$).

$f_{BSL,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{BSL,SNAGFALLDOWN,i,t} \leq 1$).

The annual change in DOM derived from dead belowground biomass ($\Delta C_{BSL,DBG,\ ,t}$; t C yr^{-1}) is calculated for each polygon as:.

$$\mathbf{\Delta C_{BSL,DBG,t} = \Sigma(DBG_{BSL,IN,i,t} - DBG_{BSL,OUT,i,t}) \bullet CF} \qquad \mathbf{(17a)}$$

$$\mathbf{DBG_{BSL,i,t+1} = DBG_{BSL,i,t} + (DBG_{BSL,IN,i,t} - DBG_{BSL,OUT,i,t})} \qquad \mathbf{(17b)}$$

where:

$DGB_{BSL,i,t}$ = The total quantity of dead belowground biomass accumulated in polygon *i,* at time*, t* (t d.m.).

$DBG_{BSL,IN,i,t}$ = annual gain in dead belowground biomass for polygon *i*, year, *t* (t d.m yr^{-1}). Dead belowground biomass develops as a result of mortality through natural causes or through harvesting activities.

$DBG_{BSL,OUT,i,t}$ = annual loss in dead belowground biomass through decay, (t d.m yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$DBG_{BSL,IN,i,t} = [(A_{BSL,i} \bullet LB_{BSL,i,t} \bullet R_i) \bullet (f_{BSL,NATURAL,i,t} + f_{BSL,HARVEST,i,t} + f_{BSL,DAMAGE,i,t})] \quad \textbf{(17c)}$$

where:

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t.* $LB_{BSL,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{BSL,i,t}$) added as per calculations in equation 5 a, b. This value is then multiplied by $A_{BSL,i,}$ the area (ha) of forest land in polygon, *i*.

R_i is the root:shoot ratio in polygon, *i* (see equation 5b).

$f_{BSL,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in polygon, *i* (unitless; $0 \leq f_{NATURALi} \leq 1$), year, *t* (see equation 7),

$f_{BSL,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{HARVESTIi} \leq 1$), year, *t* (see equation 8),

$f_{BSL,DAMAGE,i,t}$ = the proportion of additional biomass removed or road and landing construction in polygon, *i* (unitless; $0 \leq f_{DAMAGE,i,t} \leq 1$), year, *t* (see equation 9)

$$DBG_{BSL,OUT,i,t} = DBG_{BSL,i,t} \bullet f_{BSL,dgbDECAY,i,t} \quad \textbf{(17d)}$$

where:

$DBG_{BSL,i,t}$ = the total quantity of dead belowground in polygon *i,* year*, t* (see equation 17b).

$f_{BSL,dgbDECAY,i,t}$ = the annual proportional loss of dead belowground biomass due to decay, in polygon *i,* year*, t* (unitless; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$).

Dead organic matter dynamics including dead wood and snag creation and decay are simulated and tracked by carbon pool using FVS-FFE for each polygon, by year; and then summarized by AU and the project area as needed within the Darkwoods Carbon Database. Dead organic matter dynamics (i.e. mortality/snag recruitment and decay; lying dead recruitment and decay, etc.) are modeled and tracked within FVS-FFE for each polygon based on polygon tree data from inventory and growth, mortality, and decay algorithms calibrated for the IE Variant and other site specific polygon data (i.e. polygon elevation, aspect, lat/long, habitat type, etc.). FVS-FFE also models dead organic matter dynamics as it relates to harvesting and natural disturbances as noted above. No additional carbon stocks are attributed to a damage function in the baseline scenario at this time – roads and landings are either accounted for in the road buffer exclusions or assumed to be temporary roads captured by harvesting carbon dynamics (this is a conservative assumption as it reduces baseline emissions and increases regrowth area vs roads). Thus, Equations 10-17 are captured within the carbon curves generated by FVS-FFE for each analysis unit and tracked on the landbase.

Harvested Wood Products

The annual change in emissions associated with the production of harvested wood products (HWP) is calculated as:

$$\Delta C_{BSl,HWP,t} = \Delta C_{BSL,STORHWP,t} - \Delta C_{BSL,EMITFOSSIL,t,} \tag{18}$$

Where:

$\Delta C_{BSL,STORHWP,t}$ = the annual change in harvested carbon that remains in storage after conversion to wood products (t C yr^{-1})

$\Delta C_{BSL,EMITFOSSIL,t}$ = the annual change in fossil fuel emissions from harvesting (logging and log transport) and processing of the various wood products.

The annual change in carbon storage in harvested wood products in year *t* ($\Delta C_{BSL,STORHWP,t}$; t C yr^{-1}) is determined based upon the following equation:

$$\Delta C_{BSL,STORHWP,t} = (C_{BSL,STORHWP,t2} - C_{BSL,STORHWP,t1}) / T \tag{19}$$

where:

$C_{BSL,STORHWP,t2}$ = carbon storage in harvested wood products at t=2; t C

$C_{BSL,STORHWP,t1}$ = carbon storage in harvested wood products at t=1; t C

T = number of years between monitoring t1 and t2

t : 1,2,3…t years elapsed since the project start date

$$C_{BSL,TIMBER,h} = \Sigma[(LBL_{BSL,FELLINGS,i,h} - LBL_{BSL,FELLINGS,i,h} \bullet R_i + LBL_{BSL,OTHER,i,h} - LBL_{BSL,OTHER,i,h} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,h}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,h})] \bullet CF \tag{20}$$

where:

$C_{BSL,TIMBER,h}$= carbon contained in timber harvested in period *h* (summed for all harvested polygons, *i*); t C

$LBL_{BSL,FELLINGS,i,h}$ = annual removal of live tree biomass due to commercial felling in polygon, *i*; t d.m. (equation 8)

$LBL_{BSL,OTHER,i,h}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. (equation 9)

R_i is the root:shoot ratio in polygon, *i* (see equation 5b).

1 - $f_{BSL,BRANCH,i,h}$ the proportion of live tree biomass remaining after netting out branch biomass, in polygon *i* (unitless; $0 \le f_{BRANCH,i,t} \le 1$)(see equation 12)

1 - $f_{BSL,BUCKINGLOSS,i,h}$ = the proportion of the log bole remaining after in-woods log processing/bucking for quality, length, etc., in polygon, *i* (unitless; $0 \le f_{BUCKINGLOSS,i,t} \le 1$) (equation 12)

h = harvest period ; yr

$$C_{BSL,MILL,h,k} = (C_{BSL,TIMBER,h,k} \bullet f_{RND,k} \bullet r_{RND,k}) \quad (21)$$

where:

$C_{BSL,MILL,h,k}$ = carbon contained in harvested timber after milling in period h, for product type *k*; t C

$C_{BSL,TIMBER,h,k}$ = carbon contained in timber harvested in period h, for product type *k*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

$f_{RND,k}$ = fraction of growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

$r_{RND,k}$ = ratio of industrial roundwood to growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

For each product type, *k* : the short-lived fraction ($P_{BSL,SLF,k}$), medium-lived fraction ($P_{BSL,MLF,k}$), and long-lived fraction ($P_{BSL,LLF,k}$) are calculated as:

$$P_{BSL,SLF,k} = 1 - P_{3\text{-}year} \quad (22a)$$

$$P_{BSL,LLF,k} = P_{100\text{-}year} \quad (22b)$$

$$P_{BSL,MLF,k} = P_{3\text{-}year} - P_{100\text{-}year}\ , \quad (22c)$$

$$\mathbf{C_{BSL,STORHWP,t,} = \Sigma\ \Sigma\ ((\ C_{BSL,MILL,h,k} \bullet P_{LLF,k}) + [(C_{BSL,MILL,h,k} \bullet P_{MLF,k}) \bullet ((20\text{-}h)\ /\ 20)])} \quad \mathbf{(23)}$$

where:

$C_{BSL,STORHWP,t,}$ = carbon stored in harvested wood products in year *t* summed for all product types *k* and then over all harvest periods *h*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

h = year of harvest (the term (20-h) should not be allowed to drop below 0)

Fossil fuel emissions from equipment and manufacturing:

The annual change in fossil fuel emissions from harvesting and processing of the various wood products ($\Delta C_{BSL,EMITFOSSIL,t}$) are calculated as:

$$\mathbf{\Delta C_{BSL,EMITFOSSIL,t} = C_{BSL,EMITHARVEST,t} + C_{BSL,EMITMANUFACTURE,t} + C_{BSL,EMITTRANSPORT,t}} \quad \mathbf{(24)}$$

where:

$C_{BSL,EMITHARVEST,t}$ is the annual fossil fuel emissions associated with harvesting of raw material (t C yr^{-1})

$C_{BSL,EMITMANUFACTURE,t}$ is the annual fossil fuel emissions associated with the manufacturing of raw material (t C yr^{-1})

$C_{BSL,EMITTRANSPORT,t}$ is the annual fossil fuel emissions associated with the transport of raw material (t C yr^{-1})

$$\mathbf{C_{BSL,EMITHARVEST,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet c_{HARVEST}} \quad \mathbf{(25)}$$

where:

$c_{HARVEST}$ is the carbon emission intensity factor (t C emitted/t C raw material) associated with harvesting; all other terms are as defined in equation 20.

$$\mathbf{C_{BSL,EMITTRANSPORT,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet \Sigma(f_{BSL,TRANSPORTk} \bullet d_{TRANSPORTk} \bullet c_{TRANSPORTk})} \quad \mathbf{(26)}$$

where:

$f_{BSL,TRANSPORTk}$ = the fraction of raw material transported by transportation type, *k*. (unitless; $0 \leq f_{BSL,TRANSPORTk} < 1$).

$d_{TRANSPORTk}$ = the distance transported by transportation type, *k*. (km);

$c_{TRANSPORTk}$ is the carbon emission intensity factor (kg C emitted/t C raw material) associated with transportation type, k ; all other terms are as defined in equation 20.

$$\mathbf{C_{BSL,EMITMANUFACTURE,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet \Sigma(f_{BSL,PRODUCTk} \bullet c_{MANUFACTUREk}) \bullet CF} \quad \mathbf{(27)}$$

Where:

$c_{MANUFACTUREk}$ is the carbon emission intensity factor (t C emitted/t C raw material) associated with manufacture of product type, *k*; all other terms are as defined in equation 20.

FVS-FFE models the transition of carbon removed from each polygon during harvest into various harvested wood products pools in the Harvested Products Report. FVS natively calculates and tracks harvested wood products pools following the VCS reference "Section 1605b" (Smith, et al. 2006) documentation methods as required by VCS and VM0012 v1.2, including the modeling of HWP pool decay by product type, by short, medium, and long term HWP pool, and by year (Equation 22a-23). See Rebain, 2010 for additional details on the function of FFE and the Harvested Wood Products Report. Note that in addition to tracking carbon in removed forest products (products in-use), FVS-FFE also outputs and tracks carbon storage and emissions for a portion of the removed product in a landfill pool. Although VCS provides optional guidance to combine treat this pool as HWP products in use, the landfill pool amounts are minimal and the complexity to add these back to the HWP by product type is very high (and not possible within FVS-FFE itself). Therefore the landfill pool is retained in FVS-FFE outputs, but not used by the project, which is consistent with the HWP tracking equations in VM0012 and requirements of VCS. The exclusion of landfill emissions is conservative (a small amount of removed carbon is retained in the landfill pool and not emitted with HWP decay functions) and does not result in more emission reductions in the project.

Fossil fuel emissions from equipment and manufacturing calculations are made separately in the Darkwoods Carbon Model; worksheet: Summary Tables and Figures, using output data from the Harvested Wood Report in FVS-FFE and scheduled harvest volumes from FPS, by year. Key assumptions used for the Darkwoods project in the Darkwoods Carbon Model spreadsheet follow the PD recommendations and are shown in Table 15.

Table 15. Carbon emission intensity factors for harvesting, the manufacture of various product categories, k, and various transportation categories, k.

Activity	Value	Reference
Harvesting ($c_{HARVEST}$) (t C emitted/t C raw material)		
Clearcut harvest	0.016	(Zhang, et al., 2010)
Manufacturing ($c_{MANUFACTUREk}$) (t C emitted/t C raw material)		
Sawnwood	0.04	(Pingoud & Lehtila, 2002) – Calculated from Table I & III
Veneer, plywood and structural panels	0.06	(Pingoud & Lehtila, 2002) – Calculated from Table I & III
Non-structural panels	0.12	(Pingoud & Lehtila, 2002) – Calculated from Table I & III
Paper		(Pingoud & Lehtila, 2002) – Calculated from Table I & III
Mechanical pulping	0.48	(Pingoud & Lehtila, 2002) – Calculated from Table I & III
Chemical pulping	0.13	(Pingoud & Lehtila, 2002) – Calculated from Table I & III
Transportation		
$f_{BSL,TRANSPORTm}$ (unitless)		
Truck	1.0	Darkwoods historical data
Rail	0.0	Darkwoods historical data
$d_{TRANSPORTm}$ (km)		
Truck	50	Darkwoods historical data.
Rail	0.0	Darkwoods historical data.
$c_{TRANSPORTm}$ (t C emitted/t C raw material./km)		
Truck	$7.0*10^{-5}$	(Heath, et al., 2010) From Supporting Information Table S16
Rail	$8.2*10^{-6}$	(Heath, et al., 2010) From Supporting Information Table S16

Baseline Emissions Summary:

Summarized, baseline stand-level inventory is grown from the original 2011 VRI inventory while implementing baseline harvesting activities each year. FVS-FFE models and tracks all carbon pools while incorporating the FPS generated baseline harvest schedule and the fires or other natural disturbances. Forests are regrown after harvest and regenerate after fire using the natural regeneration functions in the FVS model using the assumptions shown in Table 12.

The annual emissions calculated for the baseline scenario to date regime is shown in Table 16. Note that the calculations from 2008-2016 are verified under the prior modeling approach, but are generally similar to the comparable results from the new modeling. Of further note is the material increase in carbon stored in the HWP products categories as compared to the 2008-2016 period, due to the changes in HWP tracking VM0012 v1.2 (which moved from the “100 yr method” which tracked only permanently stored HWP carbon in each year; to the 1605b method which tracks HWP by product category on various emission decay curves). The baseline harvesting now stores significant amounts of carbon in wood products on a temporary basis (i.e. decades).

Table 16. Annual emissions/reductions for the baseline scenario calculated for 2017-2019.

Year	Ann. Baseline (Emissions) Reductions (tCO2e)	Volume Harvested (m^3)	Baseline Storage HWP (tC)	Baseline Storage Waste Products (tC)	Baseline (Emissions) Equipment & Production (tC)
2008	(316,806)	309,878	3,952	1,273	(3,968)
2009	(281,998)	301,109	3,840	1,237	(3,855)
2010	(460,747)	302,970	3,864	1,245	(3,879)
2011	(297,264)	300,572	4,009	1,154	(3,826)
2012	(300,470)	300,707	4,010	1,154	(3,828)
2013	(241,227)	301,285	3,843	1,238	(3,858)
2014	(285,826)	300,673	3,835	1,235	(3,850)
2015	(316,975)	301,390	3,844	1,238	(3,859)
2016	(257,335)	307,123	3,917	1,262	(3,932)
2017	(263,116)	300,696	40,298	0	(4,155)
2018	(231,998)	300,668	38,365	1,083	(4,222)
2019	(315,986)	300,923	38,143	2,066	(4,453)

4.2 Project Emissions

Net project emissions have been calculated by repeating the procedures used in the baseline emissions calculations in Section 4.1.

Project activities meet the VM0012 v1.2 for low level management activities:

1. The net GHG emissions from project activities are being modeled and accounted for in the project scenario in the same manner as the baseline scenario.
2. Project activities do not remove more than 20% of the harvesting volume projected in the baseline scenario. See Table 17.
3. Project activities have a conservation benefit and are a. consistent with the principles of managing for biodiversity, ecosystem function, and carbon retention; and b. related to restoration, ecological management, or emission risk reduction.

The harvesting in the project scenario has been low level harvesting that ramped down after the initial acquisition to support the local community. The harvests were made outside of the more critical habitat zones (i.e. outside the EPA area), and were undertaken to create long term habitat diversification and in support of other ecological goals. The harvests from 2008-2010 were focused on MPB risk reduction and salvage. Future harvests may be undertaken for a variety of habitat management or creation objectives, and likely may shift towards fire risk mitigation.

Table 17. Comparison of Project vs. Baseline harvest levels and projections

Year	Project Volume Harvested (m^3)	Project Volume Harvested (m^3)
2008	60,645	309,878
2009	41,418	301,109
2010	32,472	302,970
2011	11,914	300,572
2012	14,152	300,707
2013	261	301,285

2014	0	300,673
2015	12,077	301,390
2016	5,486	307,123
2017	0	300,696
2108	0	300,668
2019	0	300,923
2020-2028+	~10,000/yr	~300,000/yr

Project Scenario Area Stratification

The same Darkwoods inventory data and stratification methods were used for the project scenario as described for the baseline scenario in Section 4.1. The analysis units described in Table 11 were also employed for the project scenario.

The same criteria and methods for determining the operable timber harvesting land base were used for the project scenario as described for the baseline scenario in Section 4.1; with the exception that the areas spatially defined as environmentally protected areas (EPAs) by the previous land owners were excluded from project harvesting activities in the project scenario on a voluntary basis by NCC whenever projecting forward looking ex-ante harvesting.

Determining Actual Onsite Carbon Stocks

For the project scenario the GIS database are annually updated for spatial changes due to harvesting activities or natural disturbances (at minimum >4ha), as per Section 5 monitoring. Any harvested areas are mapped by GPS or remote sensing and stand age reset. Timber stand data replaced with reforestation data when complete. Any natural disturbance areas >4ha are mapped and the GIS datasets adjusted, and any impact classification data (i.e. fire severity classification; pest severity classification) added to the GIS inventory. Updates to the inventory database are dated to track changes by project year.

The GIS spatial inventory is kept up to date annually by NCC staff, including all stand polygon and inventory changes. Stand growth and yield data Is not modeled or updated in the GIS inventory by NCC.

For clarity note that the carbon plots discussed in Section 5 are used for monitoring the accuracy of the Darkwoods inventory at the AU level, and do not contribute directly to forest inventory data.

Forest growth and stand and carbon pool dynamics are modeled by year at each verification using the relavent years updated forest inventory GIS dataset. Currently, the base timber inventory is the 2011 VRI forest inventory which is updated annually for project activities and disturbances. Any disturbances applicable to the baseline scenario are added to the baseline forest inventory dataset in the same manner as the project GIS dataset.

As of 2017, the FVS-FFE model and IE Variant are now used to project 2011 VRI stand inventory data forward by polygon, and adjust for all project harvesting and natural disturbances recorded in project GIS database by year. As detailed in Section 4.1 above, the FVS-FFE models and tracks stand growth and yield, mortality and stand dynamics, harvest activities and natural disturbances, along with all of the related carbon pool dynamics over time, including for HWP.

At each verification, the project will review the version of FVS, FFE, and the IE Variant and update to the latest versions when appropriate (i.e. when it is expected to improve the carbon project results or accuracy). The project will also review the assumptions, model settings/parameters, and the input data format/content to see if additional calibrations are possible that would improve the accuracy of carbon stock tracking on the project. If any changes to model parameters or data calibrations are made, then these adjustments must be applied to the baseline scenario modeling as well.

Periodically, and likely every 10 years, the project will look to update the overall VRI inventory for the property with new forest stand data. Any assumptions or adjustments needed to transition between the existing and new forest data must be documented at the next verification and applied to both the project and baseline scenario in a manner that captures the previous baseline and project activities appropriately. The FVS-FFE carbon modeling can also be transitioned to the new inventory data and re-parameterized and calibrated as appropriate in both scenarios.

Any changes to modeling parameters or assumptions will also be applied to the calculation of carbon stocks on the monitoring carbon plots when the project re-calculates the error terms used in the calculation of the Uncertainty Factor at each verification.

PROJECT EMISSIONS EQUATIONS:

Actual (ex post) annual net carbon stocks are calculated using the equations in this section using the same sutie of carbon accounting tools used in the baseline scenario equations above. Summarized, the total annual carbon balance for each inventory polygon within the project carbon THLB landbase is tracked using the FVS-FFE model in the same manner as in the baseline scenario above. The annual carbon content (tracked for each ecosystem pool) is then summed each year for the whole landbase for the project scenario by FVS-FFE; and compiled into AU’s in the Darkwoods Carbon Database; and finally summarized across the project area in the Darkwoods Carbon Model spreadsheet. The annual change in harvested wood products storage is calculated and tracked in FVS-FFE using annual simulated baseline harvested wood volume output from the FPS baseline harvest schedule, with supplementary calculations related to the annual change in fossil fuel emissions from harvesting and processing made in the Darkwoods Carbon Model MS Excel spreadsheet.

The calculations of the annual balance changes are made within these carbon accounting tools, following the sequence of equations required by VM0012 v1.2 for the Project 2011 VRI forest inventory dataset, updated to year, t.

$$\mathbf{C_{ACTUAL,i,t} = C_{LB,i,t} + C_{DOM,i,t}} \quad \textbf{(28a)}$$

where:

$C_{ACTUAL,i,t}$ = carbon stocks in all selected carbon pools in polygon, *i*, year, *t*; t C

$C_{LB,i,t}$ = carbon stocks in living tree biomass in polygon, *i*, year, *t*; t C

$C_{DOM,i,t}$ = carbon stocks in dead organic matter in year, *t*; t C

Live biomass

$$\mathbf{B_{TOTAL,i,t} = (B_{AG,i,t} + B_{BG,i,t})} \quad \textbf{(28b)}$$

$$\mathbf{C_{LB,i,t} = (B_{TOTAL,i,t}) \bullet CF} \quad \textbf{(28c)}$$

where:

$B_{AG,i,t}$ = aboveground tree biomass (t d.m. ha^{-1}) measured in polygon, *i,* year, *t*

$B_{BG,i,t}$ = belowground tree biomass (t d.m. ha^{-1}) measured in polygon, *i,* year, *t*.

$B_{TOTAL,i,t}$ = total tree biomass (t d.m. ha^{-1}) measured in polygon, *i,* year, *t*

$$\mathbf{B_{BG,i,t} = B_{AG,i,t} \bullet R_i} \quad \textbf{(28d)}$$

CF = carbon fraction of dry matter (IPCC default value = 0.5)

Dead organic matter

Carbon stored in dead organic matter pools in measured polygon, *i*, year *t*, ($C_{DOM,i,t}$) is calculated as the sum of that stored in lying dead wood and standing snags.

$$C_{DOM,i,t} = (DOM_{LDW,i,t} + DOM_{SNAG,i,t}) \bullet CF \qquad (28e)$$

where:

$DOM_{LDW,i,t}$ = average mass of dead organic matter contained in lying dead wood (t d.m. ha^{-1}) in measured in polygon, *i,* year, *t*

$DOM_{SNAG,i,t}$ = average mass of dead organic matter contained in standing snags (t d.m. ha^{-1}) in measured in polygon, *i,* year, *t*

The average quantity of dead organic matter contained in lying dead wood for measured polygon, *i,* in year, *t* ($DOM_{LDW,i,t}$) is calculated according to equations 60a-c).

The total annual carbon balance in year, t, for the project scenario is calculated as ($\Delta C_{PRJ,t}$, in t C yr^{-1}):

$$\Delta C_{PRJ,t} = \Delta C_{PRJ,P,t} \qquad (29)$$

where:

$\Delta C_{PRJ,P,t}$ is the annual change in carbon stocks in all pools in the project across the project activity area; t C yr^{-1} .

$$\Delta C_{PRJ,P,t} = \Delta C_{PRJ,LB,t} + \Delta C_{PRJ,DOM,t} + \Delta C_{PRJ,HWP,t} \qquad (30)$$

Where:

$\Delta C_{PRJ,LB,t}$ = annual change in carbon stocks in living tree biomass (above- and belowground); t C yr^{-1}

$\Delta C_{PRJ,DOM,t}$ = annual change in carbon stocks in dead organic matter; t C yr^{-1}

$\Delta C_{PRJ,HWP,t}$ is the annual change in carbon stocks associated with harvested wood products, t C yr^{-1}.

As in the baseline scenario, the FVS models changes in carbon stocks by pool, by inventory polygon in the Carbon THLB, which is then compiled and summarized by year, polygon and AU and for the project scenario. The FVS stand data outputs (Stand Carbon Report) by pool are imported to the Darkwoods Carbon Database where the data is compiled by AU, polygon, and year for the Project scenario to complete Equation 30 and 31.

$$\Delta C_{PRJ,LB,t} = \Delta C_{PRJ,G,t} - \Delta C_{PRJ,L,t} \qquad (31)$$

where:

$\Delta C_{PRJ,G,t}$ = annual increase in tree carbon stock from growth; t C yr^{-1}

$\Delta C_{PRJ,L,t}$ = annual decrease in tree carbon stock from a reduction in live biomass; t C yr^{-1}.

If the project area has been stratified, carbon pools are calculated for each polygon, i, and then summed during a given year, t.

FVS-FFE models live tree gains and loss by inventory polygon, by carbon pool, and by year based off of the 2011 VRI forest inventory stand data (updated for annual project activities to year, t) and stand and carbon pool dynamics. Further details of the growth curves, data references, and other parameters used in FVS-FFE for live biomass gain and loss can be found in Dixon (2002). The Darkwoods Database tool compiles and summarizes the FVS-FFE carbon outputs across polygons and baseline scenario conditions, including calculating Equation 31.

Live biomass gain in year, *t*, polygon, *i* ($\Delta C_{PRJ,G,i.t}$) is calculated as:

$$\Delta \mathbf{C}_{\mathbf{PRJ,G,t}} = \Sigma(\mathbf{A}_{\mathbf{PRJ,i}} \bullet \mathbf{G}_{\mathbf{PRJ,i,t}}) \bullet \mathbf{CF} \quad \textbf{(32)}$$

where:

$A_{PRJ,i,}$ = area (ha) of forest land in polygon, *i*;

$G_{PRJ,i,t}$ = annual increment rate in tree biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *i*, and;

CF = carbon fraction of dry matter t C t^{-1} d.m. (IPCC default value = 0.5).

$$\mathbf{G}_{\mathbf{PRJ,i,t}} = \mathbf{G}_{\mathbf{PRJ,AG,i,t}} + \mathbf{G}_{\mathbf{PRJ,BG,i,t}} \quad \textbf{(33a)}$$

where $G_{PRJ,AG,i,t}$ and $G_{PRJ,BG,i,t}$ are the annual above- and belowground biomass increment rates (t d.m. ha^{-1} yr^{-1});

$$\mathbf{G}_{\mathbf{PRJ,BG,i,t}} = \mathbf{G}_{\mathbf{PRJ,AG,i,t}} \bullet \mathbf{R}_{\mathbf{i}} \quad \textbf{(33b)}$$

where R_i is the root:shoot ratio in polygon, *i*.

The total annual live biomass gain for each polygon, *i* within the project landbase is tracked by FVS-FFE for each polygon from the Baseline 2011 VRI forest inventory data, and then summarized for each AU and across the project area for the Baseline scenario by year. FVS-FFE determines the amount of C storage in each inventory polygon by carbon pool, including modeling tree growth based on stand inventory tree data and using algorithms calibrated for forests in the IE Variant and other site specific stand data (i.e. polygon elevation, aspect, area lat/long, habitat type, etc.). The FVS-FFE Carbon Stand Table provides values in tC/ha which are then converted to total tons by multiplying by the area of the polygon (Equation 4). The amount carbon stored in above and below ground live biomass in each polygon is calculated and tracked annually by FVS-FFE (Equations 5a-b). FVS-FFE models stand regeneration in the baseline scenario after harvest following the criteria in Table 12.

Note that FVS-FFE does not include biomass in bark. This biomass is manually calculated in the Darkwoods Carbon Database by applying an adjustment factor to the FVS-FFE aboveground live tree biomass outputs (which is then treated as live tree biomass for the purpose of these carbon calculations). Details of this bark calculation and data references can be found in the supplemental Darkwoods Carbon Methods_2019 document.

Live biomass loss ($\Delta C_{PRJ,L,t}$; t C yr^{-1}) is the sum of losses from:

$$\Delta C_{PRJ,L,t} = \Sigma(LBL_{PRJ,NATURALi,t} + LBL_{PRJ,FELLINGS,i,t} + LBL_{PRJ,OTHERi,t}) \bullet CF \quad (34)$$

where:

$LBL_{PRJ,NATURALi,t}$ = annual loss of live tree biomass due to natural mortality in polygon, *i*; t d.m. yr^{-1}

$LBL_{PRJ,FELLINGS,i,t}$ = annual loss of live tree biomass due to commercial felling in polygon, *i*; t d.m. yr^{-1}

$LBL_{PRJ,OTHER,i,t}$ = annual loss of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1}

CF = carbon fraction of dry matter; t C t^{-1} d.m. (IPCC default value = 0.5).

$$LBL_{PRJ,NATURALi,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,NATURAL,i,t} \quad (35)$$

where

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$LB_{PRJ,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{PRJ,i,t}$) added as per calculations in equation 33a.

$f_{PRJ,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in forest type , *i* (unitless; $0 \leq f_{PRJ,NATURALi} \leq 1$), year, *t*.

$$\mathbf{LBL_{PRJ,FELLINGS,i,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,HARVEST,i,t}} \quad \textbf{(36)}$$

where:

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t* (see equation 7 for its calculation).

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{PRJ,HARVESTIi} \leq 1$), in year, *t*.

$$\mathbf{LBL_{PRJ,OTHER,i,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,HARVEST,i,t} \bullet f_{PRJ,DAMAGE,i,t}} \quad \textbf{(37)}$$

where:

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* in year, *t* (unitless; $0 \leq f_{PRJ,HARVEST,i,t} \leq 1$).

$f_{PRJ,DAMAGE,i,t}$ = the proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t* (unitless; $0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$).

The total annual live biomass loss for each polygon, *i* within the project Carbon THLB (Equations 34-37) is calculated and tracked using the FVS-FFE model by year, and then summarized for each AU and across the project area for the Project scenario by year in the Darkwoods Carbon Database and Darkwoods Carbon Model spreadsheet. Within-stand losses related to natural mortality and stand-self thinning are modeled and tracked within FVS-FFE for each polygon based on tree data from inventory and algorithms calibrated for the IE Variant and other site specific polygon data (i.e. polygon elevation, aspect, lat/long, habitat type, etc.). Live biomass loss through harvesting is represented using the ex-post inventory updates for project harvest activities which are included in FVS-FFE by polygon on an annual basis. When harvesting occurs, the polygon has its age reset to 1 and switches to the associated regenerating stand analysis unit. For the project, regeneration is modeled by FVS-FEE functions as planted using the assumptions described in Table 12 and related text.

Live biomass loss due to fire and other natural disturbances are modeled using FVS-FFE sub-routines based on ex-post inventory updates for each disturbance by polygon applied to that years modeled project forest inventory. For fire, FVS-FFE models and tracks live biomass loss and other stand changes and dynamics by fire severity class, by polygon, by carbon pool. Similar live biomass loss processes can be used for other natural disturbance types updated in the project forest inventory as needed and simulating impacts in FVS-FFE. FVS-FFE resumes stand growth and development and carbon pool dynamics based on the modeled outcome of the disturbance impact on affected polygons on an annual basis.

Live biomass loss due to incidental loss are not modeled in the Darkwoods project. Instead, permanent roads are removed during the landbase stratification process and a 5m buffer added to each side. These road buffer polygons are then classified as non-forest and removed from biomass calculations in the baseline and project scenario. Darkwoods is extensively roaded, and these road buffer exclusions, in combination with the clearcut harvesting areas are assumed to suitably capture the incidental losses due to roads and landings. There is very limited road and landing construction in the project scenario.

Dead Organic Matter DOM ($\Delta C_{PRJ,DOM}$; t C yr^{-1}) is calculated as:

$$\Delta C_{PRJ,DOM,t} = \Delta C_{PRJ,LDW,t} + \Delta C_{PRJ,SNAG,t} + \Delta C_{PRJ,DBG,t} \quad (38)$$

where:

$\Delta C_{PRJ,LDW,t}$ = change in lying dead wood (LDW) carbon stocks in year, *t*; t C yr^{-1}

$\Delta C_{PRJ,SNAG,t}$ = change in snag carbon stock in year, *t*; t C yr^{-1}

$\Delta C_{BSL,DBG,t}$ = change in belowground carbon stock in year, *t*; t C yr^{-1}.

The change in DOM derived from lying dead wood (LDW) carbon stock in year, t (t C yr^{-1}) is calculated as:

$$\Delta C_{PRJ,LDW,t} = \Sigma(LDW_{PRJ,IN,i,t} - LDW_{PRJ,OUT,i,t}) \bullet CF \quad (39a)$$

$$LDW_{PRJ,i,t+1} = LDW_{PRJ,i,t} + (LDW_{PRJ,IN,i,t} - LDW_{PRJ,OUT,i,t}) \quad (39b)$$

where:

$LDW_{PRJ,i,t}$= The total mass of lying dead wood accumulated in polygon *i* at time t (t d.m.).

$LDW_{PRJ,IN,i,t}$ = annual increase in LDW biomass for polygon *i*, year, *t* (t d.m ha^{-1} yr^{-1}). LDW increases occur as a result of natural mortality (typically, blowdown), and as a direct or indirect result of harvesting.

$LDW_{PRJ,OUT,i,t}$ = annual loss in LDW biomass through decay, for polygon *i*, year, *t*, (t d.m ha^{-1} yr^{-1})

$LDW_{PRJ,IN,i,t}$ and $LDW_{PRJ,OUT,i,t}$ are summed across polygons.

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$\mathbf{LDW_{PRJ,IN,i,t} = (LBL_{PRJ,NATURALi,t} - LBL_{PRJ,NATURALi,t} \bullet R_i) \bullet f_{PRJ,BLOWDOWN,i,t} + ((LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i) + (LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i)) \bullet f_{PRJ,BRANCH,i,t} + ((LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i) + (LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i)) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet f_{PRJ,BUCKINGLOSS,i,t} + SNAG_{PRJ,,i,t} \bullet f_{PRJ,SNAGFALLDOWN,i,t}} \quad \textbf{(40)}$$

where:

$LBL_{PRJ,NATURALi,t}$, $LBL_{PRJ,FELLINGS,i,t,}$ and $LBL_{PRJ,OTHER,i,t}$ are as calculated in equations 35, 36, and 37, respectively.

R_i is the root:shoot ratio in polygon, *i* (see equation 33b).

$f_{PRJ,BLOWDOWN,i,t}$ = the annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i,* year*, t* (unitless; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$).

$f_{PRJ,BRANCH,i,t}$ = the annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, *i* (unitless; $0 \leq f_{PRJ,BRANCH,i,t} \leq 1$).

$f_{PRJ,BUCKINGLOSS,i,t}$ = the annual proportion of the log bole biomass left on site after assessing and/or merchandizing the log bole for quality, in polygon, *i* (unitless; $0 \leq f_{PRJ,BUCKINGLOSS,i,t} \leq 1$).

$SNAG_{PRJ,i,t}$ = the total mass of the snag pool in polygon, *i*, year, *t* (see equation 42b).

$f_{PRJ,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$).

$$\mathbf{LDW_{PRJ,OUT,i,t} = LDW_{PRJ,i,t} \bullet f_{PRJ,lwDECAY,i,t}} \quad \textbf{(41)}$$

where:

$LDW_{PRJ,i,t}$ = the total amount of lying deadwood mass in polygon *i,* year*, t (see equation 39b)*. $f_{PRJ,lwDECAY,i,t}$ = the annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t* (unitless; ; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$).

The change in <u>standing dead wood (snag)</u> carbon stock in year, *t* (t C yr^{-1}) is calculated as:

$$\Delta \mathbf{C}_{\mathbf{PRJ,SNAG,t}} = \mathbf{\Sigma(SNAG_{PRJ,IN,i,t} - SNAG_{PRJ,OUT,i,t}) \bullet CF} \qquad \mathbf{(42a)}$$

$$\mathbf{SNAG_{PRJ,i,t+1} = SNAG_{PRJ,i,t} + (SNAG_{PRJ,IN,i,t} - SNAG_{PRJ,OUT,i,t})} \qquad \mathbf{(42b)}$$

where:

$SNAG_{PRJ,i,t}$ = The total mass of snags accumulated in polygon *i* at time *t* (t d.m.)

$SNAG_{PRJ,IN,i,t}$ = annual gain in snag biomass for polygon *i*, year, *t* (t d.m ha^{-1} yr^{-1}).

$SNAG_{PRJ,OUT,i,t}$ = annual loss in snag biomass through decay, or falldown (i.e, transfer to the LDW pool)(t d.m ha^{-1} yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

Note that $SNAG_{PRJ,IN,i,t}$ and $SNAG_{PRJ,OUT,i,t}$ are summed across polygons.

$$\mathbf{SNAG_{PRJ,IN,i,t} = (LBL_{PRJ,NATURALi,t} - LBL_{PRJ,NATURALi,t} \bullet R_i) \bullet (1 - f_{PRJ,BLOWDOWN,i,t})} \qquad \mathbf{(43)}$$

where:

$LBL_{PRJ,NATURALi,t}$ is as calculated in equation 35, and

1 - $f_{PRJ,BLOWDOWN,i,t}$ is the proportion of live tree aboveground biomass that dies in polygon, *i*, year, *t*, but remains as standing dead organic matter (i.e. snags) (unitless; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$).

$$\mathbf{SNAG_{PRJ,OUT,i,t} = SNAG_{PRJ,i,t} \bullet f_{PRJ,SWDECAY,i,t} + SNAG_{PRJ,i,t} \bullet f_{PRJ,SNAGFALLDOWN,i,t}} \qquad \mathbf{(44)}$$

where:

$SNAG_{PRJ,i,t}$ = the total amount of snag mass in polygon *i,* year*, t (see equation 42b).*
$f_{PRJ,SWDECAY,i,t}$ = the annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t* (unitless; $0 \leq f_{PRJ,SWDECAY,i,t} \leq 1$).

$f_{PRJ,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$).

The change in dead belowground wood (DBG) carbon stock in year, *t* (t C yr^{-1}) is calculated as:

$$\Delta \mathbf{C}_{\mathbf{PRJ,DBG,t}} = \mathbf{\Sigma(DBG_{PRJ,IN,i,t} - DBG_{PRJ,OUT,i,t}) \bullet CF} \qquad \mathbf{(45a)}$$

$$\mathbf{DBG_{PRJ,i,t+1} = DBG_{PRJ,i,t} + (DBG_{PRJ,IN,i,t} - DBG_{PRJ,OUT,i,t})} \quad \textbf{(45b)}$$

where:

$DGB_{PRJ,i,t}$ = The total quantity of dead belowground biomass accumulated in polygon *i* at time *t* (t d.m.).

$DBG_{PRJ,IN,i,t}$ = annual gain in dead belowground biomass for polygon *i*, year, *t* (t d.m ha^{-1} yr^{-1}).

$DBG_{PRJ,OUT,i,t}$ = annual loss in dead belowground biomass through decay, (t d.m ha^{-1} yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$\mathbf{DBG_{PRJ,IN,i,t} = [(A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet R_i) \bullet (f_{PRJ,NATURAL,i,t} + f_{PRJ,HARVEST,i,t} + f_{PRJ,DAMAGE,i,t})]} \quad \textbf{(45c)}$$

where:

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t.* $LB_{PRJ,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{PRJ,i,t}$) added as per calculations in equation 33 a, b. This value is then multiplied by $A_{PRJ,i,}$ the area (ha) of forest land in polygon, *i*.

R_i is the root:shoot ratio in polygon, *i* (see equation 33b).

$f_{PRJ,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in polygon, *i* (unitless; $0 \leq f_{NATURALi} \leq 1$), year, *t* (see equation 35),

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{PRJ,HARVESTIi} \leq 1$), year, *t* (see equation 36),

$f_{PRJ,DAMAGE,i,t}$ = the proportion of additional biomass removed by for road and landing construction in polygon, *i* (unitless; $0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$), year, *t* (see equation 37)

$$\mathbf{DBG_{PRJ,OUT,i,t} = DBG_{PRJ,i,t} \bullet f_{PRJ,dgbDECAY,i,t}} \quad \textbf{(45d)}$$

where:

$DBG_{PRJ,i,t}$ = the total quantity of dead belowground in polygon *i,* year*, t (equation 17b).*
$f_{PRJ,dgbDECAY,i,t}$ = the annual proportional loss of dead belowground biomass due to decay, in polygon *i,* year*, t* (unitless; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$).

As in the baseline scenario, dead organic matter dynamics including dead wood and snag creation and decay are simulated and tracked by carbon pool using FVS-FFE for each polygon, by year; and then summarized by AU and the project area as needed within the Darkwoods Carbon Database. Dead organic matter dynamics (i.e. mortality/snag recruitment and decay; lying dead recruitment and decay, etc.) are modeled and tracked within FVS-FFE for each polygon based on polygon tree data from inventory and growth, mortality, and decay algorithms calibrated for the IE Variant and other site specific polygon data (i.e. polygon elevation, aspect, lat/long, habitat type, etc.). FVS-FFE also models dead organic matter dynamics as it relates to harvesting and natural disturbances as noted above under liver biomass equations. No additional carbon stocks are attributed to a damage function in the baseline scenario at this time – roads and landings are either accounted for in the road buffer exclusions or assumed to be temporary roads captured by harvesting carbon dynamics

Harvested Wood Products

The annual change in emissions associated with the production of harvested wood products (HWP), $\Delta C_{BSI,HWP,t}$, is calculated as:

$$\Delta \mathbf{C}_{\mathbf{PRJ,HWP,t}} = \Delta \mathbf{C}_{\mathbf{PRJ,STORHWP,t}} - \Delta \mathbf{C}_{\mathbf{PRJ,EMITFOSSIL,t,}} \quad \mathbf{(46)}$$

Where:

$\Delta C_{PRJ,STORHWP,t}$ = the annual change in harvested carbon that remains in storage after conversion to wood products (t C yr^{-1})

$\Delta C_{PRJ,EMITFOSSIL,t}$ = the annual change in fossil fuel emissions from harvesting (logging and log transport) and processing of the various wood products.

The annual change in carbon storage in harvested wood products in year *t* ($\Delta C_{PRJ,STORHWP,t}$; t C yr^{-1}) is calculated as:

$$\Delta \mathbf{C}_{\mathbf{PRJ,STORHWP,t}} = (\mathbf{C}_{\mathbf{PRJ,STORHWP,t2}} - \mathbf{C}_{\mathbf{PRJ,STORHWP,t1}}) / \mathbf{T} \quad \mathbf{(47)}$$

where:

$C_{PRJ,STORHWP,t2}$ = carbon storage in harvested wood products at t=2; t C

$C_{PRJ,STORHWP,t1}$ = carbon storage in harvested wood products at t=1; t C

T = number of years between monitoring t1 and t2

t : 1,2,3…t years elapsed since the project start date

$$\mathbf{C_{PRJ,TIMBER,h} = \Sigma[(LBL_{PRJ,FELLINGS,i,h} - LBL_{PRJ,FELLINGS,i,h} \bullet R_i + LBL_{PRJ,OTHER,i,h} - LBL_{PRJ,OTHER,i,h} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,h}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,h})] \bullet CF} \quad \mathbf{(48)}$$

where:

$C_{PRJ,TIMBER,h}$= carbon contained in timber harvested in period *h* (summed for all harvested polygons, *i*); t C

$LBL_{PRJ,FELLINGS,i,h}$ = annual removal of live tree biomass due to commercial felling in polygon, *i*; t d.m. (equation 36)

$LBL_{PRJ,OTHER,i,h}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. (equation 37)

R_i is the root:shoot ratio in polygon, *i* (see equation 33b).

1 - $f_{PRJ,BRANCH,i,h}$ the proportion of live tree biomass remaining after netting out branch biomass, in polygon *i* (unitless; $0 \leq f_{BRANCH,i,t} \leq 1$)(see equation 12)

1 - $f_{PRJ,BUCKINGLOSS,i,h}$ = the proportion of the log bole remaining after in-woods log processing/bucking for quality, length, etc., in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 40)

h = harvest period ; yr

$$\mathbf{C_{PRJ,MILL,h,k} = (C_{PRJ,TIMBER,h,k} \bullet f_{RND,k} \bullet r_{RND,k})} \quad \mathbf{(49)}$$

where:

$C_{PRJ,MILL,h,k}$ = carbon contained in harvested timber after milling in period h, for product type *k*; t C

$C_{PRJ,TIMBER,h,k}$ = carbon contained in timber harvested in period h, for product type *k*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

$f_{RND,k}$ = fraction of growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

$r_{RND,k}$ = ratio of industrial roundwood to growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

For each product type, *k* : the short-lived fraction ($P_{PRJ,SLF,k}$), medium-lived fraction ($P_{PRJ,MLF,k}$), and long-lived fraction ($P_{PRJ,LLF,k}$):

$$\mathbf{P_{PRJ,SLF,k} = 1\text{-}P_{3\text{-}year}} \quad \textbf{(50a)}$$

$$\mathbf{P_{PRJ,LLF,k} = P_{100\text{-}year}} \quad \textbf{(50b)}$$

$$\mathbf{P_{PRJ,MLF,k} = P_{3\text{-}year} - P_{100\text{-}year}\ ,} \quad \textbf{(50c)}$$

$$\mathbf{C_{PRJ,STORHWP,t,} = \Sigma\ \Sigma\ ((\ C_{PRJ,MILL,h,k} \bullet P_{LLF,k}) + [(C_{PRJ,MILL,h,k} \bullet P_{MLF,k}) \bullet ((20\text{-}h)\ /\ 20)])} \quad \textbf{(51)}$$

where:

$C_{PRJ,STORHWP,t,}$ = carbon stored in harvested wood products in year *t* summed for all product types *k* and then over all harvest periods *h*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

h = year of harvest (the term (20-h) should not be allowed to drop below 0)

The annual change in <u>fossil fuel emissions from harvesting and processing</u> of the various wood products ($\Delta C_{PRJ,EMITFOSSIL,t}$) are calculated as:

$$\mathbf{\Delta C_{PRJ,EMITFOSSIL,t} = C_{PRJ,EMITHARVEST,t} + C_{PRJ,EMITMANUFACTURE,t} + C_{PRJ,EMITTRANSPORT,t}} \quad \textbf{(52)}$$

Where

$C_{PRJ,EMITHARVEST,t}$ = the annual fossil fuel emissions associated with harvesting of raw material (t C yr^{-1})

$C_{PRJ,EMITMANUFACTURE,t}$ = the annual fossil fuel emissions associated with the manufacturing of raw material (t C yr^{-1})

$C_{PRJ,EMITTRANSPORT,t}$ = the annual fossil fuel emissions associated with the transport of raw material (t C yr^{-1})

$$\mathbf{\Delta C_{PRJ,EMITHARVEST,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet c_{HARVEST}} \quad \textbf{(53)}$$

where:

$c_{HARVEST}$ = carbon emission intensity factor (t C emitted/t C raw material) associated with harvesting); all other terms are as defined in equation 48.

$$C_{PRJ,EMITTRANSPORT,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet \Sigma(f_{PRJ,TRANSPORTk} \bullet d_{TRANSPORTk} \bullet c_{TRANSPORTk}) \quad (54)$$

where:

$f_{PRJ,TRANSPORTk}$ = the fraction of raw material transported by transportation type, *k*. (unitless; $0 \leq f_{PRJ,TRANSPORTk} < 1$).

$d_{TRANSPORTk}$ = the distance transported by transportation type, *k*. (km);

$c_{TRANSPORTk}$ = the carbon emission intensity factor (kg C emitted/t C raw material) associated with transportation type, *k*; all other terms are as defined in equation 48.

$$C_{PRJ,EMITMANUFACTURE,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet \Sigma(f_{PRJ,PRODUCTk} \bullet c_{MANUFACTUREk}) \bullet CF \quad (55)$$

Where:

$c_{MANUFACTUREk}$ = the carbon emission intensity factor (t C emitted/t C raw material) associated with manufacture of product type, k; all other terms are as defined in equation 48.

As in the baseline scenario, FVS-FFE models the transition of carbon removed from each polygon during harvest into various harvested wood products pools in the Harvested Products Report. FVS natively calculates and tracks harvested wood products pools following the VCS reference “Section 1605b” (Smith, et al. 2006) documentation methods as required by VCS and VM0012 v1.2, including the modeling of HWP pool decay by product type, by short, medium, and long term HWP pool, and by year (Equation 22a-23). See Rebain, 2010 for additional details on the function of FFE and the Harvested Wood Products Report. Note that in addition to tracking carbon in removed forest products (products in-use), FVS-FFE also outputs and tracks carbon storage and emissions for a portion of the removed product in a landfill pool. Although VCS provides optional guidance to combine treat this pool as HWP products in use, the landfill pool amounts are minimal and the complexity to add these back to the HWP by product type is very high (and not possible within FVS-FFE itself). Therefore the landfill pool is retained in FVS-FFE outputs, but not used by the project, which is consistent with the HWP tracking equations in VM0012 and requirements of VCS. The exclusion of landfill emissions is conservative (a small amount of removed carbon is retained in the landfill pool and not emitted with HWP decay functions).

Fossil fuel emissions from equipment and manufacturing calculations are made separately in the Darkwoods Carbon Model; worksheet: Summary Tables and Figures, using output data from the Harvested Wood Report in FVS-FFE and scheduled harvest volumes from FPS, by year. Key assumptions used for the Darkwoods project in the Darkwoods Carbon Model spreadsheet follow the PD recommendations and are shown in Table 15.

Project Emissions Summary

Summarized, the project forest inventory is updated annually for harvest and disturbances on an ex-post basis. Stand-level inventory is grown from the original 2011 VRI inventory while implementing project harvesting activities and documenting nature disturbances each year. FVS-FFE models and tracks all carbon pools while incorporating the ex-post inventory changes due to harvesting and fires or other natural disturbances. Forests are regrown after harvest and regenerate after fire using the planted regeneration functions in the FVS model, and incorporating the regeneration assumptions shown in Table 12 for managed stands.

The annual emissions calculated for the project scenario is shown in Table 16. Note that the 2008 – 2016 periods were verified using the previous modeling approaches, although the results are similar to the new modeling approaches. The project scenario continues to sequester significant amounts of carbon through biological growth in the protected stands on the property. Of note is the lower carbon emissions reductions amount in 2018 that related to natural fires on the property.

Table 18. Project Emissions/Reductions Summary

Year	Project (Emissions) Reductions (tCO2e)	Volume Harvested (m^3)	Project Storage HWP (tC)	Project Storage Waste Products (tC)	Project (Emissions) Equipment & Production (tC)
2008	1,017	60,645	773	249	(776)
2009	49,729	41,418	528	170	(530)
2010	(21,287)	32,472	414	133	(416)
2011	138,484	11,914	159	46	(152)
2012	127,026	14,152	189	54	(180)
2013	130,376	261	3	1	(3)
2014	119,893	0	0	0	0
2015	50,274	12,077	154	50	(155)
2016	157,455	5,486	70	23	(70)
2017	239,829	0	0	0	0
2018	180,561	0	0	0	0
2019	241,621	0	0	0	0

4.3 Leakage

Activity Shifting Leakage

NCC owns or controls hundreds of properties within B.C. and across Canada (full listing available to auditors upon request); however, as a mission-driven not-for-profit conservation organization NCC rarely undertakes ongoing commercial harvesting on other properties which could be subject to activity shifting leakage risk. Occasionally, NCC may undertake conservation management activities on other properties, which may involve timber removal; however there is no risk of activity shifting of commercial timber operations between properties.

As noted in Section 5, NCC monitors and reports on commercial logging activities on other properties, and assess the risk of activity shifting leakage at each verification. An example of the activity shifting reporting for 2017-2019 is shown in .

Table 19. NCC Logging Activity on Other Properties (activity shifting risk) 2017-2019.

Property	Project Year	Logging Volume (m^3)	Activity shifting evidence/comment
All NCC properties outside Darkwoods	2017	0.0	n/a – no harvest
All NCC properties outside Darkwoods	2018	0.0	n/a – no harvest
All NCC properties outside Darkwoods	2019	0.0	n/a – no harvest

Market Leakage

As noted in the PD deviations, in 2018 the Darkwoods PD required updating to come into compliance with the latest version of VM0012 v1.2. One result of this update is a need to switch from the CAR market leakage approach in VM0012 (used in previous monitoring periods) to the VCS market leakage approach for the current monitoring periods.

VM0012 allows a choice between three market leakage calculation methods. Previously, the project utilized the CAR market leakage approach, as it appeared to best align with the most applicable reference documentation and major carbon markets such as California ARB (as discussed in the VCS PD v1.8). However, VM0012 references the latest version of the CAR market leakage approach. In a recent update in 2017, CAR has significantly changed the original leakage rates from 20% to 80% deduction for LtPF project types. This now departs significantly from the background references in VM0012, leakage rates in other comparable major standards such as California ARB, and the VCS default leakage rates. The new CAR leakage rates do not appear to be supported by any new data, but rather still reference the same documents as VM0012, which is confusing at best. After discussion with Verra, the project has decided the CAR approach in VM0012 is no longer appropriate, and hence has shifted to the alternative default VCS market leakage method in VM0012. This change has resulted in a material increase in the market leakage discount in the Darkwoods project and reduces the emissions reductions claimed by the project.

The VCS leakage discount method (see Table 20) is based upon a comparison of the ratio of merchantable biomass to total tree biomass (aboveground + belowground) in the project area to the same ratio in an assumed likely leakage area.

Table 20. VCS Market Leakage Discount Factors (source: VCS Methodology Requirements v4.0)

Table 2: Market Leakage Discount Factors

Project Action	Leakage Risk	Market Leakage Discount Factor
IFM activity with no effect or minimal effect on total timber harvest volumes (e.g., RIL with less than 25% reduction)	None	0%
IFM activity that leads to a shift in harvests across time periods but minimal change in total timber harvest over time (e.g., ERA with rotation extension of 5-10 years)	Low	10%
IFM activity that substantially reduces harvest levels permanently (e.g., RIL activity that reduces timber harvest across the project area, or project that halts logging by at least 25%)	Moderate to High	Conditional upon where timber harvest is likely to be shifted, as follows: • Where the ratio of merchantable biomass to total biomass is higher within the area to which harvesting is displaced compared to the project area, 20% • Where the ratio of merchantable biomass to total biomass is similar within the area to which harvesting is displaced compared to the project area, 40% • Where the ratio of merchantable biomass to total biomass is lower within the area to which harvesting is displaced compared to the project area, 70% • Where the leakage is out of country, 0%

To calculate the biomass rations for the VCS market leakage factors, the project has used comparable data from the project data and regional data from the Canadian National Forest Inventory (NFI) (https://nfi.nfis.org/en/biomass and https://www.ccfm.org/ci/rprt2005/English/pg59-71_2-1.htm). The Montane Cordillera ecoregion was selected as the most representative regional area dataset from the NFI. This region (Figure 8) fully surrounds the project area and represents a significant regional area that has similar species and ecosystems, and also likely represents the actual comparable log markets where leakage risks might be realized.

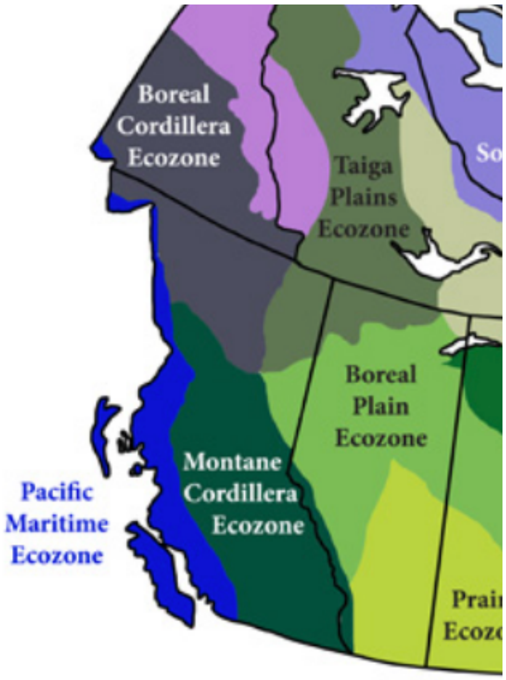

Figure 8. Market Leakage Area - Montane Cordillera Ecozone

The VCS Market Leakage Factor calculations are made as follows:

1. Leakage area Total Volume:

   The Canadian NFI website (https://nfi.nfis.org/en/biomass) includes summary data for the Montane Cordillera Ecozone total volume, area, and average species mix:

   Total Volume using NFI Table 15.1: 7,815,160,000 cubic meters

   Forest Area using NFI Table 4.1: 31,128,470 ha

   Average Total Volume per hectare: 7,815,160,000/31,128.470 = 251.06 cubic meters/ha

   Species Mix is estimated using table NFI Table 16.1:

   Top 4 species in the Montane Cordillera ecozone:

   Lodgepole pine 36%

   Engelmann spruce 29%

   Fir 20%

   D-fir 15%

   The NFI website includes a calculator (https://nfi.nfis.org/en/biomass_stand_merch) which calculates biomass for this average stand in this ecozone from the average m^3/ha and species mix above.

   Inputting these data in the NFI Website Biomass Calculator outputs an average ecozone biomass volume for Total Volume = 170 tons/ha

   Therefore: NFI Website Biomass Calculator Total Stand Volume converted to carbon (@0.5) = 85 tC/ha

2. Leakage Area Merchantable Volume:

   There is a gap in NFI data reports on the current NFI website where Merch Volume is not reported for the Montane Cordillera region (only Total Volume). Therefore an alternative dataset that reported merch volume at the ecozone level ws used from the Canadian Council of Forest Ministers reports (https://www.ccfm.org/ci/rprt2005/English/pg59-71_2-1.htm):

   Note that this CCFM.org dataset uses NFI data (see Table 2.1 header: CaFI (Canadian Forest Inventory) is the prior name for the NFI (National Forest Inventory)), and summarizes and reports the data in merch volume from 2001 by ecozone. Although older, this dataset is expected to be reasonable for the purpose of large scale regional m^3/ha calculations.

   Merch Volume from Table 2.1a: 5,817,410,718 m^3

Forest Land from Table 1.1a (Biological Diversity Tab): 33,379,000 ha.

Average Merch Volume per hectare: 5,817,410,718/33,379,000 = 174.28 m^3/ha

Using same average species mix as above.

Inputting these data in the NFI Website Biomass Calculator outputs an average ecozone biomass volume for Merch Volume = 158 tons/ha

Therefore: NFI Website Biomass Calculator Merch Stand Volume converted to carbon (@0.5) = 79 tC/ha

Average Merch Carbon to Total Carbon Ratio for the leakage area (Montane Cordillera Ecozone):

79/85 = 0.93

Darkwoods Project Area Total and Merch Volume Comparison:

Using 2017, 2018 and 2019 Baseline Carbon Pool Data:

Merch Volume Carbon: (AgML with bark + SD) / 51,887.1 ha

Total Volume Carbon: (AgTL with bark + SD) / 51,887.1 ha

Table 21. Project Merch to Total Carbon Ratio by Year

	Merch tC/ha	Total tC/ha	Merch/Total
2017	51.64	68.87	0.75
2018	52.54	69.72	0.75
2019	53.24	70.60	0.75

Therefore the Leakage Area Merch/Total Ratio of 0.93 is higher than the Project Merch/Total Ratio for the leakage displacement area of 0.75 for each of the monitoring period years, and hence the VCS Leakage Discount Factor is **20%**, as shown in Table 22.

Table 22. Annual Market Leakage Discounts for the 2008-2019 monitoring periods.

Year	Effective VCU Leakage Risk Discount[27]
2008	11.5%
2009	11.5%
2010	9.0%
2011	9.7%
2012	9.8%
2013	11.9%
2014	10.9%
2015	11.6%
2016	10.7%
2017	20%
2018	20%
2019	20%

These market leakage discount factors will be recalculated at each verification.

For project proponents using Market Leakage Option 1:

VCS Leakage Discount Factor = the value for MLF_y **(56a)**

To calculate the project market leakage (LE_Y, t CO2e yr^{-1}):

$$LE_Y = MLF_y \bullet ER_{y,GROSS} \quad \textbf{(56b)}$$

Where,
MLF_y = Market leakage factor, as calculated above.

[27] For 2008-2016 market leakage was calculated using VM0012 method 2 – CAR, which calculated market leakage as 20% of removed timber tC. The VCS leakage factor (2017-2019) is applied against all net ER tC. Table 22 values have been normalized to show the effective difference in leakage discount.

$ER_{y,GROSS}$ = the gross difference in the overall annual carbon change between the baseline and project scenarios in year 'y' (in tonnes CO_2e yr^{-1}). This term is calculated in equation 57.

4.4 Net GHG Emission Reductions and Removals

Uncertainty Factor Calculation

VM0012 utilized an Uncertainty Factor calculation to account for additional 'over-riding confidence deduction as a proxy for collective project uncertainty by assessing statistical uncertainty in the forest carbon inventory and associated modeling.

The methodology monitoring section specifies that all analysis units will have representation by one or more field plots. However, due to the difficulty of determining the independence of plot data within individual homogeneous polygons (i.e. a specifically similar forest type, site, and age), it will be necessary to only calculate a single carbon density observation for each individual polygon sampled; either through the use of a single plot within that polygon, or calculation of the mean of multiple plots within that polygon. Throughout these calculations a plot observation, subscript i, is defined to represent the mean of all plots within a given polygon.

The project-level uncertainty factor is calculated as follows:

Step 1 – Calculate the average percent model error (E_M) for the project based on the average area-weighted difference between measured values in monitored plot observations and model-predicted values using Equations 60a,b. In the case where analysis units have been used for stratification, the difference between the plot observation and model-predicted value (both expressed on a per hectare basis) for a given analysis unit ($y_{d,h,i}$) is weighted by the area of its associated analysis unit ($A_{PRJ,h}$) (Eq. 60a). The use of an area-weighting factor places more emphasis on analysis units that represent a relatively larger proportion of the total project area.

$$\mathbf{E_M = 100 \bullet (\sum y_{d,h,i} / \sum(A_{PRJ,h} \bullet y_{m,h,i}))} \qquad \textbf{(60a)}$$

Where,

The summation is across all plot observations, i, and across all analysis units , h;

$$\mathbf{y_{d,h,i} = A_{PRJ,h} \bullet (y_{m,h,i} - y_{p,h,i})} \qquad \textbf{(60b)}$$

E_M = Mean model error for the project (%)

$y_{d,h,i}$ = the area-weighted difference between measured and predicted carbon storage in analysis unit, h, plot observation, i (t C)

$y_{m,h,i}$ = carbon storage measured in analysis unit, h, plot observation, i (t C ha^{-1})

$y_{p,h,i}$ = carbon storage predicted by model for analysis unit , h, plot observation, i (t C ha^{-1})

$A_{PRJ,h}$ = area of project analysis unit, h (ha)

Step 2 – Calculate the inventory error (E_I) at a 90 percent confidence interval expressed as a percentage of the mean area-weighted inventory estimate from the measured plots.

This methodology was designed to accommodate complex landscapes consisting of hundreds to thousands of polygons, which can be further grouped into analysis units. Inventory error is estimated based upon the difference between modeled and measured values for monitoring plots established in polygons or in polygons grouped within analysis units.

Inventory error, E_I, is estimated by first calculating the standard error of the area-weighted differences between the plot observation measurement and the associated model-predicted carbon storage (both on a per hectare basis) for analysis units or polygons. The standard error is then multiplied by the t-value for the 90 percent confidence interval. Finally E_I is expressed in relative terms (in Equation 60c) by dividing the 90% confidence interval of the area-weighted differences between predicted and measured values in all plots by the area-weighted average of the measured values in all monitoring plots.

$$E_I = 100 \cdot [SE * 1.654 / ((1/N) \cdot \sum(A_{PRJ,h} \cdot y_{m,h,i}))] \quad \textbf{(60c)}$$

Where,

E_I = Inventory error for the project (%)

SE = the project level standard error of the area weighted differences between measured plot observation and predicted values of carbon storage.

N = total number of plot observations in all analysis units or polygons[28]

1.654 = the 90% confidence interval t-value

All other terms as defined in equation 60a.

$$SE = S / \sqrt{N} \quad \textbf{(60d)}$$

Where,

[28] For clarity, the plot observation sample size (N) is equivalent to the number of polygons sampled (for projects using either a polygon or analysis unit stratification method). As noted, a single *plot observation* is created for each polygon using the mean when there are multiple plots within a polygon. Thus, in some situations the number of actual installed plots may be higher than the number of plot observations (N).

N = total number of plot observations in all analysis units or polygons (see Footnote)

S = the standard deviation of the area weighted differences between measured and predicted values of carbon storage across all analysis unit or polygons.

$$\mathbf{S = \sqrt{}\,[(1/\ N-1) \bullet \sum(y_{d,h,i}\ -\ \bar{y}bar_d)^2]} \qquad \textbf{(60e)}$$

Where,

$\bar{y}bar_d$ = the project-level mean of the area weighted differences between measured plot observation and predicted values of carbon storage. See equation 60b for the calculation of $\mathbf{y_{d,h,i}}$

All other terms as defined in equation 60b and 60c.

Step 3 - The total error for the project (E_P; %)is calculated by adding the model and inventory error terms, as calculated in Steps 1 and 2.

$$\mathbf{E_P = E_M + E_I} \qquad \textbf{(60f)}$$

Step 4 – Compare the result of Step 3 against Table 23 to determine the uncertainty factor:

Table 23 - Uncertainty Factor Calculation

Estimated Project Error, E_P (%)	Uncertainty Factor
0 – 10%	= 1.5%[29]
>10%	= 1.5% + E_P – 10%

The results of the project Uncertainty Factor calculated for the 2017-2019 monitoring period is shown in Table 24.

Table 24. Uncertainty factor calculation summary (2017-2019)[30]

Project error by AU	
n =	70[31]
SD of Deviations =	300,427

[29] To be conservative, the minimum uncertainty factor is set to 1.5% to account for possible uncertainty within other unmeasured assumptions used in calculations and modeling.

[30] These UF calculations are undertaken in a supplementary spreadsheet.

[31] The project has 72 plots, but 2 occurrences where carbon plots fall within the same polygon, which are averaged into a single plot data point as per VM0012.

SE of Deviations	35,907.90
Sum of measured values (t C) =	36,372,757
Sum of Model Deviations =	(487.921)
90% CI of Deviations =	59,068
Inventory Error (E_I) =	11.4%
Model Error (E_M) =	-1.3%
Project error (E_P) =	10.0%
Uncertainty Factor =	**1.5%**[32]

Summary of Gross Emissions Reductions and/or Removals

Gross carbon emissions reductions ($ER_{y,gross}$; t CO_2e yr^{-1}) created by the Darkwoods carbon project were calculated annually as the difference between the baseline and project scenario net emission reductions/emissions:

$$ER_{y,GROSS} = (\Delta C_{BSL,t} - \Delta C_{PRJ,t}) \bullet 44/12 \quad (57)$$

Where,

$\Delta C_{BSL,t}$ = total net baseline scenario emissions calculated from equation 1 (t C yr^{-1}).

$\Delta C_{PRJ,t}$ = total net project scenario emissions calculated from equation 29 (t C yr^{-1}).

44/12 = factor to convert C to CO_2e

the Darkwoods Carbon Access Database and Darkwoods Carbon Model spreadsheet. The net changes to emission reductions between the baseline and project scenario to date in the project are shown in Table 25.

Table 25. Summary of emission removals for the baseline and project scenarios for the 2017-19 verification period.

Year	Baseline emissions or	Project emissions	Net GHG emission

[32] See additional explanation in Appendix 1, Equations 60a-60f. See supporting Darkwoods Carbon Database and related spreadsheets as referenced in Darkwoods Carbon Methods_2019.doc.

	removals (tCO_2e)	or removals (tCO_2e)	reductions or removals (tCO_2e)
2008	(316,806)	1,017	317,823
2009	(281,998)	49,729	331,727
2010	(460,747)	(21,287)	439,461
2011	(297,264)	138,484	435,748
2012	(300,470)	127,026	427,496
2013	(241,227)	130,376	371,602
2014	(285,826)	119,893	405,719
2015	(316,975)	50,274	367,248
2016	(257,335)	157,455	414,790
2017	(23,287)	239,829	263,116
2018	(51,437)	180,561	231,998
2019	(74,366)	241,621	315,986
Total	**(2,907,738)**	**1,414,977**	**4,322,715**

Summary of Net Emissions Reductions and/or Removals

The annual *net* carbon emissions reductions is the actual net GHG removals by sinks from the project scenario minus the net GHG removals by sinks from the baseline scenario, were then calculated by applying the leakage and uncertainty discount factors (but not the VCS permanence buffer), on an annualized basis:

$$\mathbf{ER_y = ER_{y,GROSS} - LE_y} \qquad \mathbf{(58)}$$

Where,

ER_y = the net GHG emissions reductions and/or removals in year y (the overall annual carbon change between the baseline and project scenarios, net all discount factors except the permanence buffer) ($t\ CO_2e\ yr^{-1}$).

$ER_{y,GROSS}$ =the difference in the overall annual carbon change between the baseline and project scenarios ($t\ CO_2e\ yr^{-1}$).

LE_y = Leakage in year y ($t\ CO_2e\ yr^{-1}$), as calculated in equation 56b.

This calculation occurs within the Darkwoods Carbon Model Spreadsheet and the results for the project to date are shown in Table 26.

Calculation of Voluntary Credit Units (VCUs)

The number of VCU's the Darkwoods carbon project generates as available for issuance and sale in year, *y* (VCU_y; t CO_2e yr^{-1}), is calculated as:

$$\mathbf{VCU_y = ER_y \cdot (1 - ER_{y,ERR}) - BR_y} \quad \textbf{(59)}$$

Where,

ER_y = the net GHG emissions reductions and/or removals in year (t CO_2e yr^{-1}), as calculated in equation 58.

$ER_{y,ERR}$ = the uncertainty factor for year, y, (calculated in Section 4.5 and Appendix 4), expressed as a proportion.

BR_y = estimated VCU-equivalent tCO_2e issued to the VCS Buffer Pool in year, *y*, calculated using the latest version of the VCS AFOLU Non-Permanence Risk Analysis Tool. BRy is calculated by multiplying the most current verified permanence risk Buffer Withholding Percentage for the project by the change in carbon stocks (difference between baseline and project scenario) for the project.

The VCS Buffer Discount Factor (BR_Y) was calculated as **10%**, as per the non-permanence risk assessment documentation provided to auditors. The BR factor will be re-assessed at each verification as necessary. The BR factor has not changed over the duration of the project to date.

The Uncertainty Factor ($ER_{y,ERR}$) has been calculated at 1.5%, as shown in Table 24.The uncertainty factor will be re-calculated from field plot data at each verification.

Equation 59 is calculated in the Darkwoods Carbon Database. The annual VCUs generated by the Darkwoods project to date are shown in Table 26.

Table 26. Total issuable VCUs and terms used in their calculation for 2008-2019.

Year	Net GHG emission reductions or	Leakage Risk Discount (tCO_2e)	Uncertainty Risk Discount (tCO_2e)	Annual Buffer Set-Aside (tCO_2e)	Issueable VCU's (tCO_2e)

	removals (tCO_2e)				
2008	317,823	(36,587)	(5,625)	(31,463)	244,148
2009	331,727	(38,123)	(5,872)	(32,840)	254,892
2010	439,461	(39,709)	(7,995)	(43,600)	348,157
2011	435,748	(42,375)	(5,901)	(42,226)	345,246
2012	427,496	(42,066)	(5,781)	(41,411)	338,237
2013	371,602	(44,150)	(4,912)	(35,747)	286,793
2014	405,719	(44,099)	(5,424)	(39,160)	317,035
2015	367,248	(42,433)	(4,872)	(35,367)	284,577
2016	414,790	(44,240)	(5,558)	(40,063)	376,211
2017	263,116	(52,623)	(3,157)	(24,788)	182,547
2018	231,998	(46,400)	(2,784)	(21,652)	161,163
2019	315,986	(63,197)	(3,792)	(29,966)	219,031
Total	**4,322,715**	**(536,002)**	**(61,674)**	**(418,283)**	**3,358,038**

5 MONITORING

5.1 Data and Parameters Available at Validation

These values were determined and available at the time of validation.

Data / Parameter	$A_{BSL,i}$
Data unit	Ha
Description	Respective areas of baseline and project polygon, i
Source of data	NCC Darkwoods GIS spatial inventory data used for the validation forest_cover2010v3.2. mdb. This dataset was derived from the inventory data developed over several years for managing the Darkwoods property prior to the purchase of the property by NCC.
Value applied	Ha_BSL field in DW_Carbon_VRI_BASELINE_Re-Join4_Final.xlsx Ha_2018YE field in DW_Carbon_VRI_Project_2018YE_Re-Join4_w2018Fire_wplots.xlsx
Justification of choice of data or description of measurement methods and procedures applied	The method of mapping inventory polygons, identified as homogenous forest management units, is justified as it is based on standard British Columbia inventory methods as outlined in “Inventory Data Collection Standards for VRI Ground Sampling Version 2.1” which can be found at: https://www.for.gov.bc.ca/hts/risc/alphastand.htm
Purpose of the data	Required for calculation of baseline and project emissions
Comments	At Validation the parameter APRJ,I is the same as ABSL,I. In subsequent monitoring periods, these variables can differ and are tracked for each polygon i in the baseline and project scenario respectively. Current monitoring period values can be seen in DW_Carbon_VRI_BASELINE_Re-Join4_Final.xlsx and DW_Carbon_VRI_Project_2018YE_Re-Join4_w2018Fire_wplots.xlsx

Data / Parameter	$\Delta C_{,t}$
Data unit	t C yr^{-1}
Description	The annual carbon balance in the baseline or project scenario for year, *t*. See Equation 57.

Source of data	Calculated following Equation 57 within the Darkwoods Carbon Database and Darkwoods Carbon Model using FVS_FFE Stand Carbon Report outputs. Calculated from Equation 1 and Equation 29; with subscript BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculating gross emission reductions ($ER_{y,\ GROSS}$).
Comments	

Data / Parameter	$\Delta C_{P,t}$
Data unit	t C yr^{-1}
Description	The annual change in carbon stocks in all pools in the baseline or project scenario across the project activity area for year, *t*
Source of data	Calculated within the Darkwoods Carbon Database using FVS_FFE Stand Carbon Report outputs, and following Equation 2 and 29, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{,t}$
Comments	

Data / Parameter	$\Delta C_{LB,t}$
Data unit	t C yr^{-1}
Description	The annual change in carbon stocks in living tree biomass (above- and belowground) for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Stand Carbon Report outputs and following Equation 3 and 31, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{P,t}$
Comments	

Data / Parameter	$\Delta C_{DOM, t}$
Data unit	t C yr^{-1}
Description	The annual change in carbon stocks due to dead organic matter for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report outputs and following Equation 10 and 38, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{P,t}$
Comments	

Data / Parameter	$\Delta C_{HWP,t}$
Data unit	t C yr^{-1}
Description	The annual change in carbon stocks in harvested wood products for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report and Harvest Product Report outputs, following Equation 18 and 47, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{P,t}$
Comments	Fossil fuel emissions from equipment and manufacturing are made within the Darkwoods Carbon Model using harvest volume outputs from FVS-FFE and FPS.

Data / Parameter	$\Delta C_{G,t}$
Data unit	t C yr^{-1}
Description	The annual change in carbon stocks due to live biomass gain for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report outputs, which incorporate Equations 5a-5b and 33a-33b, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.

Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{LB,t}$
Comments	

Data / Parameter	$\Delta C_{L,t}$
Data unit	t C yr^{-1}
Description	The annual change in carbon stocks due to live biomass loss for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report outputs, which incorporate Equations 7-9 and 35-37, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{LB,t}$
Comments	

Data / Parameter	$\Delta C_{LDW,t}$
Data unit	t C yr^{-1}
Description	The annual change in lying dead wood carbon stocks for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report outputs, which incorporate Equations 11b-13 and 39b-41, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{DOM,t}$
Comments	

Data / Parameter	$\Delta C_{SNAG,t}$
Data unit	t C yr^{-1}
Description	The annual change in standing dead wood carbon stocks for year, *t*

Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report outputs, which incorporate Equations 14b-16 and 42b-44, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{DOM,t}$
Comments	

Data / Parameter	$\Delta C_{DBG,t}$
Data unit	t C yr^{-1}
Description	The annual change in dead belowground carbon stocks for year, *t*
Source of data	Calculated by FVS-FFE and compiled within the Darkwoods Carbon Database using FVS_FFE Carbon Report outputs, which incorporate Equations 17b-17d and 45b-45d, for the BSL and PRJ, respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from FVS_FFE model output, used in the calculation of baseline and project emissions, respectively.
Purpose of Data	Calculation of $\Delta C_{DOM,t}$
Comments	

Data / Parameter	CF
Data unit	t C t^{-1} d.m.
Description	Carbon fraction of dry matter
Source of data	IPCC 2006, (Penman and others, 2003), (Smith and Heath, 2002)
Value applied	0.5 applied in FVS to living and dead biomass.
Justification of choice of data or description of measurement methods and procedures applied	IPCC default value with broad support in published work.
Purpose of the data	Required for calculation of baseline and project emissions
Comments	

Data / Parameter	R_i

Data unit	unitless
Description	Root Biomass
Source of data	Jenkins and others (2003)
Value applied	BgL carbon pool in FVS
Justification of choice of data or description of measurement methods and procedures applied	Jenkins estimates are used by FVS-FFE for live and dead root biomass
Purpose of the data	Required for calculation of baseline and project emissions
Comments	

Data / Parameter	BEF
Data unit	unitless
Description	Biomass expansion factors for conversion of productivity metrics to biomass.
Source of data	Modeled by FVS-FFE (FVS CRM setting)
Value applied	FVS-FFE default settings for the IE Variant. Based on the Volume Estimator Library Equations (2009) as developed and maintained by the USFS Forest Products Measurement Group in the Forest Management Service Center.
Justification of choice of data or description of measurement methods and procedures applied	FVS-FFE is widely used, meets the VM0012 modeling requirements, and is calibrated to the project area in the IE Variant.
Purpose of the data	Required for calculation of baseline and project emissions
Comments	

Data / Parameter	$f_{BRANCH,i,t}$
Data unit	unitless ($0 < f_{BSL,BRANCHi}$, $f_{PRJ,BRANCH,i,t} < 1$)
Description	The annual proportion of aboveground tree biomass comprised of branches in polygon i, year t, in the baseline and project scenarios, respectively.
Source of data	Calculated in FVS using regional species specific crown biomass equations based on Brown and Johnston (1976) as described in Rebain (2015).
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	FVS-FFE data is widely reviewed and accepted, and the method is based on published source.

Purpose of the data	Required for calculation of baseline and project emissions.
Comments	

Data / Parameter	$f_{BUCKINGLOSS,i,t}$
Data unit	unitless ($0 < f_{BSL,BUCKINGLOSSi}$, $f_{PRJ,BUCKINGLOSS,i,t} < 1$)
Description	The proportion of the log bole biomass left on site after assessing and/or merchandizing the log bole for quality, in polygon, i, year, t, for the BSL and PRJ cases, respectively.
Source of data	Based on (Smith, Miles, Vissage, & Pugh, 2004)
Value applied	0.10 of stemwood is assumed to be left on site.
Justification of choice of data or description of measurement methods and procedures applied	The estimate is justified as it matches the PD assumptions and is based on the professional judgement of NCC field staff.
Purpose of the data	Required for calculation of baseline and project emissions.
Comments	Applied by the YardLoss keyword in FVS.

Data / Parameter	$P_{3\text{-year}}$ and $P_{100\text{-year}}$
Data unit	Unitless
Description	The proportion of total carbon stored in wood products after 3 years ($P_{3\text{-year}}$); and the proportion of harvested wood stored for 100 years ($P_{100\text{-year}}$), for product type, *k,* for the BSL and PRJ, respectively.
Source of data	Calculated within the FVS-FFE using FVS_FFE Carbon Report and Harvested Wood output reports. FVS_FFE natively tracks HWP pools according to the reference Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605(b).
Value applied	Calculated using FVS-FFE default values for IE variant and VRI inventory data.
Justification of choice of data or description of measurement methods and procedures applied	FVS_FFE utilizes the reference HWP pool tracking method referenced by VCS requirements: Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605(b).
Purpose of the data	Required for calculation of baseline and project emissions.
Comments	

Data / Parameter	$P_{BSL,SLF}$, $P_{BSL,MLF}$, $P_{BSL,LLF}$
Data unit	Unitless

Description	The short-lived fraction (P_{SLF}), medium-lived fraction (P_{MLF}), and long-lived fraction (P_{LLF}), respectively, for product type, *k;* for the BSL and PRJ, respectively.
Source of data	Calculated by FVS-FFE using the FVS_FFE Carbon Report and Harvested Wood output reports. FVS_FFE natively tracks HWP pools according to the reference Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605(b). This matches equations 22a-22c and 50a-50c in the baseline and project, respectively.
Value applied	FVS-FFE default values for IE Variant.
Justification of choice of data or description of measurement methods and procedures applied	FVS_FFE utilizes the reference HWP pool tracking method referenced by VCS requirements: Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605(b).
Purpose of the data	Required for calculation of baseline and project emissions.
Comments	

Data / Parameter	$f_{TRANSPORTk}$
Data unit	Unitless
Description	The fraction of raw material transported by transportation type, k
Source of data	NCC staff professional opinion.
Value applied	Transport type truck = 1
Justification of choice of data or description of measurement methods and procedures applied	All forest products are hauled by truck.
Purpose of the data	n/a
Comments	Applied within the Darkwoods Carbon Model spreadsheet.

Data / Parameter	$C_{HARVEST}$
Data unit	t C emitted/t C raw material
Description	The carbon emission intensity factor associated with harvesting
Source of data	Zhang, Cormier, Lyng, Mabee, Ogino, & McLean (2010)
Value applied	0.016
Justification of choice of data or description of measurement methods and procedures applied	Best available data from published data sources. Default selection in VM0012 v1.2

Purpose of the data	n/a
Comments	Applied within the Darkwoods Carbon Model spreadsheet.

Data / Parameter	$C_{MANUFACTURE_k}$
Data unit	t C emitted/t C raw material
Description	The carbon emission intensity factor associated with manufacture of product k.
Source of data	(Pingoud & Lehtila, 2002)–Calculated from Table I & III
Value applied	Sawnwood = 0.040 Plywood & Structural Panels = 0.060 Non-structural Panels = 0.120 Paper = 0.0
Justification of choice of data or description of measurement methods and procedures applied	Best available data from published data sources. Default selection in VM0012 v1.2
Purpose of the data	n/a
Comments	Applied within the Darkwoods Carbon Model spreadsheet.

Data / Parameter	$C_{TRANSPORT_k}$
Data unit	t C emitted/t C raw material
Description	The carbon emission intensity factor associated with the transport of product k, by transport type.
Source of data	(Heath, et al., 2010)-From Supporting Information Table S16
Value applied	Truck = 0.0000700
Justification of choice of data or description of measurement methods and procedures applied	Best available data from published data sources. Default selection in VM0012 v1.2
Purpose of the data	n/a
Comments	Applied within the Darkwoods Carbon Model spreadsheet.

Data / Parameter	$d_{TRANSPORT_k}$
Data unit	km
Description	The distance transported by transport type, k
Source of data	NCC field staff assumed average haul distance.
Value applied	Truck = 50.
Justification of choice of data or description	Local staff professional opinion.

of measurement methods and procedures applied	
Purpose of the data	n/a
Comments	Applied within the Darkwoods Carbon Model spreadsheet.

Data / Parameter	$C_{EMITTRANSPORT}$
Data unit	tC/yr
Description	The annual fossil fuel emissions associated with the transport of raw material, for the BSL and PRJ scenarios respectively.
Source of data	Calculated within the Darkwoods Carbon Model using harvest volumes from FPS and FVS-FFE.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Best available data from published data sources. Default selection in VM0012 v1.2
Purpose of the data	n/a
Comments	

Data / Parameter	$G_{AG,i,t}$
Data unit	t d.m. ha^{-1} yr^{-1}
Description	Annual increment rate in aboveground biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *I;* for the BSL and PRJ, respectively.
Source of data	Modeled and compiled by FVS_FFE by polygon based on VRI stand inventory.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions
Purpose of the data	Calculation of $\Delta C_{G,t}$
Comments	

Data / Parameter	$G_{BG,i,t}$
Data unit	t d.m. ha^{-1} yr^{-1}
Description	Annual increment rate in belowground biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *I;* for the BSL and PRJ, respectively.
Source of data	Modeled and compiled by FVS_FFE by polygon based on VRI stand inventory.

Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions
Purpose of the data	Calculation of $\Delta C_{G,t}$
Comments	

Data / Parameter	$LBL_{NATURALi,t}$
Data unit	t d.m. yr^{-1}
Description	Annual loss of live tree biomass due to natural mortality in polygon, i; t d.m. yr^{-1}; for the BSL and PRJ, respectively.
Source of data	Mortality functions modeled and compiled in FVS. (Wykoff and others (1982); Hamilton (1986). Represents calculation of Equation 7 and 35
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$LBL_{FELLINGSi,t}$
Data unit	t d.m. yr^{-1}
Description	Annual loss of live tree biomass due to commercial felling in polygon, i; t d.m. yr^{-1}; for the BSL and PRJ, respectively.
Source of data	Modeled by FVS_FFE based on the FPS harvest schedule or ex-post inventory updates for the baseline and project scenarios, respectively. FVS volume equations from the National Volume Estimator Library. Compiled and summarized by polygon in the Darkwoods Carbon Database. Represents calculation of Equation 8 and 36
Value applied	Variable. Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions. FVS utilizes a national database of tree volume that is maintained by the Forest Products Measurements Group in the Forest Management Service Center of the USFS.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$LBL_{OTHERi,t}$
Data unit	t d.m. yr^{-1}
Description	Annual loss of live tree biomass from incidental sources in polygon, i; t d.m. yr^{-1}; for the BSL and PRJ, respectively.
Source of data	Modeled by FVS_FFE. Uses volume equations from the National Volume Estimator Library if required. Uses FVS-FFE algorithms for fire impacts to biomass stocks. Compiled and summarized by polygon Darkwoods Carbon Database. Represents calculation of Equation 9 and 37
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	Relates to biomass changes in modeled fire or other natural disturbances.

Data / Parameter	$LB_{i,t}$
Data unit	t d.m. yr^{-1}
Description	Average live tree biomass in polygon, *i*, for year, *t;* for the BSL and PRJ, respectively.
Source of data	Calculated from $G_{i,t}$. Modeled and tracked by FVS-FFE and the Darkwoods Carbon Database.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$f_{BSL,NATURAL,i,t}$
Data unit	unitless; $0 \leq f_{NATURAL,i,t} \leq 1$
Description	The annual proportion of biomass that dies from natural mortality in forest type analysis unit or polygon *i*, year *t*.
Source of data	Modeled and tracked by FVS-FFE, calibrated by the IE Variant.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description	Required for calculation of baseline and project emissions.

of measurement methods and procedures applied	
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$f_{BSL,HARVEST,i,t}$
Data unit	unitless; $0 \leq f_{BSL,HARVESTi} \leq 1$
Description	The proportion of biomass removed by harvesting from polygon, *i*, in year, *t*.
Source of data	Modeled and tracked by FVS-FFE
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$f_{BSL,DAMAGE,i,t}$
Data unit	unitless; $0 \leq f_{BSL,DAMAGEi} \leq 1$
Description	The proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t*.
Source of data	Modeled by FVS-FFE based on forest inventory updates in each scenario.
Value applied	Typically zero, otherwise calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	The Darkwoods property area is generally fully roaded, and road and landing biomass are removed by forest inventory spatial stratification (i.e. 5m road buffers). This variable is otherwise typically assumed to be included in $f_{BSL,HARVEST,i,t}$ unless otherwise specified in a monitoring period.

Data / Parameter	$f_{BSL,BLOWDOWN,i,t}$
Data unit	unitless; $0 \leq f_{BSL,BLOWDOWNi} \leq 1$

Description	Modeled by FVS-FFE. Note episodic mortality such as tree blowdown is not modeled separately in FVS, however the stand mortality functions in FVS are representative of all types of individual tree mortality affecting stand density over time, and include snag fall, etc. Stand level blowdown events (>4 hectares) will be captured by updating the inventory data by monitoring on an ex-ante basis. No such large blowdown disturbances occurred in the project to date.
Source of data	Within stand blowdown accounted for by FVS-FFE stand mortality and snag fall functions. >4ha blowdown events based on ex-post monitoring.
Value applied	Typically zero, otherwise calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$f_{BSL,SNAGFALLDOWN,i,t}$
Data unit	unitless; 0 $\leq$ $f_{BSL,SNAGFALLDOWNIi}$ $\leq$ 1
Description	The annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool. Relates to Equation 12, 14a-16 and Equation 40, 42a-44 for the BSL and PRJ, respectively.
Source of data	Modeled within FVS-FFE based on species and dbh class. FVS snag fall functions are based on input by Bruce Marcot (USFS, Portland, OR, unpublished).
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$,
Comments	

Data / Parameter	$f_{BSL,lwDECAY,i,t}$
Data unit	unitless; 0 $\leq$ $f_{BSL,lwDECAY,i,t}$ $\leq$ 1
Description	The annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t.*
Source of data	Modeled within FVS-FFE. Default decay rates are based on Abbott and Crossley (1982).

Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$f_{BSL,SWDECAY,i,t}$
Data unit	unitless; $0 \leq f_{BSL,SWDECAY,i,t} \leq 1$
Description	The annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t*.
Source of data	Modeled within FVS-FFE. Default decay rates are based on Abbott and Crossley (1982).
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$SNAG_{BSL,i,t}$
Data unit	t d.m. yr^{-1}
Description	The total amount of snag mass in polygon *i,* year, *t*
Source of data	Modeled within FVS-FFE. Reported in the Stand Carbon Report, Standing Dead.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$DBG_{,i,t}$
Data unit	t d.m. yr^{-1}
Description	The total quantity of dead belowground biomass accumulated in polygon *i* since the project start; t biomass.

Source of data	Modeled within FVS-FFE. Reported in the Stand Carbon Report, Belowground Biomass.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{L,t}$
Comments	

Data / Parameter	$\Delta C_{STORHWP,t}$
Data unit	t C yr^{-1}
Description	Annual harvested carbon that remains in permanent storage after conversion to wood products during primary processing
Source of data	Modeled within FVS and output in the Harvest Products Report Stand Carbon Report, for the BSL and PRJ scenario respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$C_{MILL,h,k}$
Data unit	t C
Description	The carbon contained in harvested timber after milling in period h, for product type *k*
Source of data	Modeled within FVS and output in the Harvest Products Report Stand Carbon Report for the BSL and PRJ scenario respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$C_{TIMBER,h}$
Data unit	t C
Description	The carbon contained in timber harvested in period *h*
Source of data	Modeled within FVS and output in the Harvest Products Report and Stand Carbon Report for the BSL and PRJ scenario respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$C_{STORHWP,h,t}$
Data unit	t C
Description	The carbon stored in harvested wood products in year *t* summed for all product types *k* and then over all harvest periods *h*; t C
Source of data	Modeled within FVS and output in the Harvest Products Report Stand Carbon Report for the BSL and PRJ scenario respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$f_{RND,k}$
Data unit	dimensionless
Description	The fraction of growing stock volume removed as roundwood for product type *k*
Source of data	Modeled within FVS and output in the Harvest Products Report and Stand Carbon Report for the BSL and PRJ scenario respectively. FVS-FFE uses values from the ‘1605b’ documentation (Smith, et al (2006)).
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description	Required for calculation of baseline and project emissions.

of measurement methods and procedures applied	
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$r_{RND,k}$
Data unit	dimensionless
Description	The ratio of industrial roundwood to growing stock volume removed as roundwood for product type *k.*
Source of data	Modeled within FVS and output in the Harvest Products Report and Stand Carbon Report for the BSL and PRJ scenario respectively. FVS-FFE uses values from the '1605b' documentation (Smith, et al (2006)).
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$\Delta C_{EMITFOSSIL,t}$
Data unit	t C yr^{-1}
Description	The amount of carbon emitted from the burning of fossil fuels by equipment during harvesting and transport of wood products.
Source of data	Modeled within the Darkwoods Carbon Model spreadsheet based on annual harvest volumes from the FPS harvest schedule modeled by FVS-FFE, for the BSL and PRJ scenario annual harvests respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta HWP_{,t}$
Comments	

Data / Parameter	$\Delta C_{EMITHARVEST,t}$
Data unit	t C yr^{-1}

Description	The amount of carbon emitted from the burning of fossil fuels by equipment during harvesting of wood products.
Source of data	Modeled within the Darkwoods Carbon Model spreadsheet based on annual harvest volumes from the FPS harvest schedule modeled by FVS-FFE, for the BSL and PRJ scenario annual harvests respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{EMITFOSSIL,t}$
Comments	

Data / Parameter	$\Delta C_{EMITMANUFACTURE,t}$
Data unit	t C yr-1
Description	The amount of carbon emitted from the burning of fossil fuels by equipment during manufacture of wood products.
Source of data	Modeled within the Darkwoods Carbon Model spreadsheet based on annual harvest volumes from the FPS harvest schedule modeled by FVS-FFE, for the BSL and PRJ scenario annual harvests respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of $\Delta C_{EMITFOSSIL,t}$
Comments	

Data / Parameter	$\Delta C_{EMITTRANSPORT,t}$
Data unit	t C yr-1
Description	The amount of carbon emitted from the burning of fossil fuels by equipment during transport of wood products.
Source of data	Modeled within the Darkwoods Carbon Model spreadsheet based on annual harvest volumes from the FPS harvest schedule modeled by FVS-FFE, for the BSL and PRJ scenario annual harvests respectively.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement	Required for calculation of baseline and project emissions.

methods and procedures applied	
Purpose of the data	Calculation of $\Delta C_{EMITFOSSIL,t}$
Comments	

Data / Parameter	LE_y
Data unit	t CO_2e yr^{-1}
Description	The project market leakage in year, *y*
Source of data	Calculated within the Darkwoods Carbon Model using Equation 56b.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of annual project market leakage under Option 1.
Comments	

Data / Parameter	MLF_y
Data unit	%
Description	The market leakage factor determined for year 'y'
Source of data	Determined based upon the approach defined in Section 3.3. Calculated within the Darkwoods Carbon Database.
Value applied	20%
Justification of choice of data or description of measurement methods and procedures applied	Value determined using the latest version of the VCS Market Leakage Tool as defined in Agriculture, Forestry and Other Land Use (AFOLU) Requirements v3.6 and specified in the VM0012 Methodology
Purpose of the data	Calculation of leakage under Option 1.
Comments	

Data / Parameter	$ER_{y,GROSS}$
Data unit	t CO_2e yr^{-1}
Description	The gross difference in the overall annual carbon change between the baseline and project scenarios in year, *y*
Source of data	Calculated within the Darkwoods Carbon Model. Relates to equation 57.
Value applied	Calculated annually for baseline and project scenario.

Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of LE_y
Comments	

Data / Parameter	$ER_{y,}$
Data unit	t CO_2e yr^{-1}
Description	The net GHG emissions reductions and/or removals in year y (the overall annual carbon change between the baseline and project scenarios, net all discount factors except the permanence buffer)
Source of data	Calculated within the Darkwoods Carbon Model using Equation 58.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of VCU_y
Comments	

Data / Parameter	$VCU_{y,}$
Data unit	t CO_2e yr^{-1}
Description	Amount of Verified Carbon Units the project estimates are available for issuance and sale in year 'y'
Source of data	Calculated within the Darkwoods Carbon Model using Equation 59.
Value applied	Calculated annually for baseline and project scenario.
Justification of choice of data or description of measurement methods and procedures applied	Required for calculation of baseline and project emissions.
Purpose of the data	Calculation of claimed VCU's.
Comments	

Data / Parameter	E_M
Data unit	%

Description	An estimate of model error based on the relative AU area-weighted difference between model-predicted values of carbon storage and those values measured in field plots
Source of data	Model output and field data (see Equation 60a). Calculated using FVS-FFE and the Darkwoods Carbon Database.
Value applied	See Table 24
Justification of choice of data or description of measurement methods and procedures applied	Value determined using approach described in the VM0012 Methodology
Purpose of the data	Calculation of baseline & project emissions
Comments	

Data / Parameter	E_I
Data unit	%
Description	An estimate of Inventory sampling error calculated as the 90% confidence limit of the AU area-weighted differences between the model-predicted values of carbon storage and those values measured in field plots
Source of data	Model output and field data (see Equation 60c). Calculated using FVS-FFE and the Darkwoods Carbon Database.
Value applied	See Table 24
Justification of choice of data or description of measurement methods and procedures applied	Value determined using approach described in the VM0012 Methodology
Purpose of the data	Calculation of baseline & project emissions
Comments	

Data / Parameter	E_P
Data unit	%
Description	An estimate of total project error used to determine the uncertainty factor.
Source of data	Model output and field data (see Equation 60f). Calculated using FVS-FFE and the Darkwoods Carbon Database.
Value applied	See Table 24
Justification of choice of data or description of measurement methods and procedures applied	Value determined using approach described in the VM0012 Methodology
Purpose of the data	Calculation of baseline & project emissions

Comments	

Data / Parameter	$ER_{y,ERR,}$
Data unit	%
Description	The uncertainty factor calculated for year 'y' (See Section 4.4.3)
Source of data	Model output and field data (see Equation 60f). Calculated using FVS-FFE and the Darkwoods Carbon Database.
Value applied	See Table 24
Justification of choice of data or description of measurement methods and procedures applied	Value determined using approach described in the VM0012 Methodology
Purpose of the data	Calculation of baseline & project emissions
Comments	

Data / Parameter	$BR_{y,}$
Data unit	t CO2e yr^{-1}
Description	Estimated VCU-equivalent tCO_2e issued to the VCS Buffer Pool in year, *y*.
Source of data	Calculated using the latest version of the VCS AFOLU Non-Permanence Risk Tool and in the Darkwoods Carbon Model.
Value applied	10%
Justification of choice of data or description of measurement methods and procedures applied	Value determined using approach described in the VM0012 Methodology
Purpose of the data	Calculation of VCU_y
Comments	

5.2 Data and Parameters Monitored

Data / Parameter	$A_{PRJ,i}$
Data unit	Ha
Description	Area of forest land in polygon, i
Source of data	GIS database for polygon i.
Description of measurement methods and procedures to be applied	Determined as part of the inventory work (see Darkwoods Inventory Update Report Darkwoods_VRIEM_Ecora2012.pdf). Updated annually based on ex-post field and remote sensing data.
Frequency of monitoring/recording	Annual
Value monitored	See HA_2018YE field in: DW_Carbon_VRI_Project_2018YE_Re-Join4_w2018Fire_wplots.xlsx
Monitoring equipment	Visual, satellite, aerial photos
QA/QC procedures to be applied	GIS analysis is undertaken by experienced analysts utilizing standard and typical industry best practice, ArcGIS and QGIS software, and local expertise and the latest NCC Standard Operating Procedures (SOP) – 'Darkwoods Data Standards_28Aug17.doc'
Purpose of the data	Required for calculation of project emissions.
Calculation method	Area of polygons calculated using GIS software
Comments	

Data / Parameter	$A_{p,i,t}$
Data unit	Ha
Description	Area of permanent sample plot in polygon, i
Source of data	Field measurement
Description of measurement methods and procedures to be applied	Standard variable radius plot layout design using field measuring tape from plot center. Methods outlined in 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf' were followed for the re-measured plots and
Frequency of monitoring/recording	Plot measurements are repeated on 5-year intervals
Value monitored	See Plot Data in the submitted Excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	GPS, measuring tape
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP) followed, including check cruising processes. – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf' Specifically, this includes: 1) crew training to carefully follow the SOP document, 2) the establishment of blind check plots

	on 10% of the plots w/o access to original plot data, 3) the use of standardized equipment, and 4) keeping detailed data records on field sheets or data loggers.
Purpose of the data	Required for determination of Uncertainty Factor
Calculation method	Measuring tape. Area = pi*r^2
Comments	

Data / Parameter	DBH_t
Data unit	Cm
Description	Diameter at breast height measured for each tree in the sample plots at time, t
Source of data	Field measure.
Description of measurement methods and procedures to be applied	Field measurements in permanent sample plots. Measurement with DBH tape for trees > 5 cm DBH.
Frequency of monitoring/recording	Individual plot tree re-measurements are repeated on 5-year intervals
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	DBH tape, data logger
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'. Specifically, this includes: 1) crew training to carefully follow the SOP document, 2) the establishment of blind check plots on 10% of the plots w/o access to original plot data, 3) the use of standardized equipment, and 4) keeping detailed data records on field sheets or data loggers.
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Measured by hand
Comments	

Data / Parameter	$Height_t$
Data unit	M
Description	Tree height measured for each tree in the sample plots at time, t
Source of data	Field measurement
Description of measurement methods and procedures to be applied	Field measurements in permanent sample plots. Measurement with DBH tape for trees > 5 cm DBH. Used methods detailed in 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Frequency of monitoring/recording	Individual plot tree re-measurements are repeated on 5-year intervals

Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	Hypsometer, a transit, a clinometer, a relascope, a laser or other instrument designed for the measuring height.
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP)– 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'. Specifically, this includes: 1) crew training to carefully follow the SOP document, 2) the establishment of blind check plots on 10% of the plots w/o access to original plot data, 3) the use of standardized equipment, and 4) keeping detailed data records on field sheets or data loggers.
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Measured using Vertex
Comments	

Data / Parameter	L_t
Data unit	m
Description	Calculation of lying dead wood: Length of the transect used to determine volume of lying dead wood in the sample plot, at time, t (default 100m)
Source of data	Permanent sample plots
Description of measurement methods and procedures to be applied	Field measurements
Frequency of monitoring/recording	Every 5 years
Value monitored	100m
Monitoring equipment	Tape
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Measuring tape
Comments	

Data / Parameter	$d_{n,t}$
Data unit	cm
Description	Calculation of lying dead wood: Diameter of each piece n of dead wood along the transects in the sample plot at time, t
Source of data	Permanent sample plots
Description of measurement methods	Lying dead wood must be sampled using the line intersect method (Harmon & Sexton, 1996). Two 50-m lines are

and procedures to be applied	established bisecting each plot and the diameters of the lying wood (> 10 cm diameter) intersecting the lines are measured. Minimum measurement diameter must not be less than 10cm.
Frequency of monitoring/recording	Every 5 years
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	Caliper, diameter tape
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Measuring tape
Comments	

Data / Parameter	$D_{LDWc,i,t}$
Data unit	t d.m. m^{-3}
Description	Basic wood density of dead wood in the density class, c along the transect in polygon, i, at time, t .
Source of data	Two 50-m lines are established bisecting each plot and wood pieces > 10 cm diameter intersecting transect are measured.
Description of measurement methods and procedures to be applied	Decay class is determined from visual and tactile inspection (See NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf)
Frequency of monitoring/recording	Every 5 years
Value monitored	See 'Decay classes' worksheet in Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	Visual and tactile inspection
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf''
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Values for different decay classes derived from literature values from Heath and Chojnacky (1995) – softwood species
Comments	In prior monitoring periods these have been compared to values reported for more local species in Harmon et al. (2011) and found to be consistent. Further a sensitivity analysis shows that the decay class wood densities can shift +/- 50% and still have no effect on the uncertainty factor.

Data / Parameter	$N_{,t}$
Data unit	unitless

Description	Total number of wood pieces intersecting the transect in the sample plot, in time t.
Source of data	Field Measurement
Description of measurement methods and procedures to be applied	Lying dead wood is sampled using the line intersect method (Harmon & Sexton, 1996). Two 50-m lines are established bisecting each plot and the total number of wood pieces intersecting transect are counted.
Frequency of monitoring/recording	Every 5 years
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	Visual observation
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Field count
Comments	

Data / Parameter	$B_{AG\ i,t}$
Data unit	t d.m. ha^{-1}
Description	Aboveground live tree biomass in polygon, i, year, t.
Source of data	Permanent sample plots
Description of measurement methods and procedures to be applied	Calculated from $Height_t$, DBH_t, and $A_{p,i,t}$
Frequency of monitoring/recording	Upon establishment of PSP. Every 5 years, thereafter.
Value monitored	See Plot Data in the excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	See equipment for Height and DBH
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Calculated by inputting plot tree data into FVS-FFE. Area-based estimates of biomass are then be derived by summing all trees in plot and dividing by plot area.
Comments	Data used to validate ex-ante values from inventory + model output.

Data / Parameter	$B_{BG\ i,t}$

Data unit	t d.m. ha^{-1}
Description	Belowground live tree biomass in polygon, i, year, t, in the project case.
Source of data	Derived from above ground biomass calculations within permanent sample plots.
Description of measurement methods and procedures to be applied	Calculated from $B_{AGi,t}$ and R_i
Frequency of monitoring/recording	Upon establishment of PSP. Every 5 years, thereafter.
Value monitored	See Plot Data in the excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	N/A
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP).
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	$B_{BGi,t} = B_{AGi,t} * R_i$
Comments	Estimated.

Data / Parameter	$B_{TOTAL\ i,t}$
Data unit	t d.m. ha^{-1}
Description	Sum of $B_{AGi,t}$ and $B_{BGi,t}$
Source of data	Derived from above ground biomass calculations within permanent sample plots.
Description of measurement methods and procedures to be applied	Sum of $B_{AGi,t}$ and $B_{BGi,t}$
Frequency of monitoring/recording	Upon establishment of PSP. Every 5 years, thereafter.
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP) – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Sum of $B_{AGi,t}$ and $B_{BGi,t}$
Comments	

Data / Parameter	$DOM_{LDW,i,t}$

Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Description	Average mass of dead organic matter contained in lying dead wood in polygon, i, year, t.
Source of data	Permanent sample plots
Description of measurement methods and procedures to be applied	Calculated from using line intersect method (See – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf) and Pearson et al (2007). '
Frequency of monitoring/recording	Every 5 years
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	Tape and visual inspection
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Calculated using the following field- measured parameters $L_{i,t}$, $dn_{i,t}$, $D_{LDWc,i,t}$, and $N_{i,t}$ as follows: $DOM_{LDW} = \sum M_{LDW,c}$ where, $M_{LDW,c}$ = the mass of LDW in density class, c (t ha^{-1}) $M_{LDW,c} = V_{LDW,c} * D_{LDW,c}$ where, $V_{LDW,c}$ = the volume per unit area calculated for each density class, c, $D_{LDW,c}$ = the density of LDW in density class, c (t d.m. m^{-3})
Comments	

Data / Parameter	$DOM_{SNAG,i,t}$
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Description	Average mass of dead organic matter contained in standing dead wood in polygon, i, year, t in the project case.
Source of data	Permanent sample plots
Description of measurement methods and procedures to be applied	Compiled in FVS from field plot measurements.
Frequency of monitoring/recording	Every 5 years
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx
Monitoring equipment	na

QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP). – 'NCC Carbon PSP Plot Re-measurement SOP 2016 v1.0.pdf'
Purpose of the data	Required for determination of Uncertainty Factor and ultimately for calculation of project emissions.
Calculation method	Compiled in FVS-FFE
Comments	

Data / Parameter	$f_{PRJ,NATURAL,i,t}$
Data unit	unitless ($0 < f_{PRJ,NATURAL,i,t} < 1$)
Description	The proportion of biomass that dies from natural mortality in polygon, i, year, t, in the project case.
Source of data	Permanent sample plots; FVS-FFE modeling and forest inventory updates (i.e. fires by severity, etc.).
Description of measurement methods and procedures to be applied	Height and dbh of dead trees in permanent sample plots will be recorded and compiled in FVS-FFE Field GPS measured or remote sensing to update forest inventory for fires and other disturbances, which are then modeled for mortality using FVS-FFE.
Frequency of monitoring/recording	Every 5 years in the case of plots Annually in the case of inventory updates for disturbances.
Value monitored	See Plot Data in the attached excel file Darkwoods Plot Data Final_2019.xlsx in the case of individual plot trees; see Figure 2 in the case of fire boundaries.
Monitoring equipment	Field measurement and remote sensing/GIS analysis.
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures (SOP)
Purpose of the data	Required for project calculations
Calculation method	Compiled in FVS-FFE.
Comments	

Data / Parameter	$f_{PRJ,HARVEST,i,t}$
Data unit	unitless ($0 < f_{PRJ,HARVEST,i,t} < 1$)
Description	The proportion of biomass removed by harvesting from polygon, i, in year, t.
Source of data	Either NCC harvesting records or estimated from FVS-FFE modeled inventory data for the harvest area(s).
Description of measurement methods and procedures to be applied	Harvest boundaries are mapped using field GPS or remote sensing methods and then overlaid with inventory data to determine how much biomass is removed from polygon i. New polygon boundaries may be formed when harvest boundaries don't match underlying inventory polygons. NCC delivered harvest volumes may be substituted.

Frequency of monitoring/recording	Annually
Value monitored	No project harvesting in the 2017-2019 period.
Monitoring equipment	GPS,
QA/QC procedures to be applied	Data will be verified by ground-truthing and comparison with remote sensing information.
Purpose of the data	Required for calculation of project emissions.
Calculation method	Harvest boundaries are mapped using field GPS methods or remote sensing and then overlaid with inventory data to determine how much biomass is removed from polygon i. New polygon boundaries may be formed when harvest boundaries don't match underlying inventory polygons.
Comments	

Data / Parameter	$f_{PRJ,DAMAGE,i,t}$
Data unit	unitless ($0 < f_{PRJ,DAMAGE,i,t} < 1$)
Description	The proportion of additional biomass removed for road and landing construction in polygon, i, year, t, in the project case.
Source of data	Remote sensing
Description of measurement methods and procedures to be applied	Remote sensing or field GPS measurements
Frequency of monitoring/recording	Annually
Value monitored	No project damage was recorded in the 2017-2019 period.
Monitoring equipment	Remote sensing or field GPS measurement
QA/QC procedures to be applied	Data will be verified by ground-truthing or remote sensing information.
Purpose of the data	Required for calculation of project emissions.
Calculation method	Any new permanent road or landing polygons are determined by field GPS or remote sensing, and then are overlaid on inventory polygons and biomass that was removed from those areas is quantified.
Comments	

Data / Parameter	$f_{PRJ,BLOWDOWN,i,t}$
Data unit	unitless; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$
Description	The annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i*, year, t.
Source of data	Remote sensing or field GPS measurements.
Description of measurement methods	Measured in plots.

and procedures to be applied	Field GPS or remote sensing for areas >4 ha which are then updated in the inventory polygons.
Frequency of monitoring/recording	At plot remeasurement, or annually via remote sensing
Value monitored	No areas of blowdown >4 ha occurred in the 2017-19 period.
Monitoring equipment	Aerial photos or plot measurement equipment
QA/QC procedures to be applied	Data will be verified by ground-truthing or remote sensing information.
Purpose of the data	Required for project calculations
Calculation method	Areal estimate of removals is multiplied by average carbon density within a polygon or plot.
Comments	

Data / Parameter	$f_{PRJ,SNAGFALLDOWN,i,t}$
Data unit	unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$
Description	The annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool.
Source of data	Permanent sample plots; FVS-FFE modeling and forest inventory updates
Description of measurement methods and procedures to be applied	Modeled by FVS, Also measured during plot remeasurements.
Frequency of monitoring/recording	Annually; every 5 years for plot remeasurements.
Value monitored	Variable.
Monitoring equipment	FVS software; standard plot remeasurement equipment.
QA/QC procedures to be applied	For plot remeasurements, see King County Standard Operating Procedures (SOP).
Purpose of the data	Required for project calculations
Calculation method	Modeled by FVS based on changes in plot data over time.
Comments	

Data / Parameter	$f_{PRJ,lwDECAY,i,t}$
Data unit	unitless; $0 < f_{PRJ,lwDECAY,i,t} < 1$
Description	The annual proportional loss of lying dead biomass due to decay, in polygon *i*, year, *t*,
Source of data	Permanent sample plots; FVS-FFE modeling and forest inventory updates
Description of measurement methods and procedures to be applied	For plot data, LDW decay is estimated naturally by changes in CWD remeasurements across multiple remeasurement periods. Otherwise modeled by FVS-FFE for inventory updates.

Frequency of monitoring/recording	Every 5 years for plot remeasurements, annually for modeled inventory updates.
Value monitored	Variable.
Monitoring equipment	Standard plot remeasurement equipment, GIS and FVS-FFE.
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures for plots and data.
Purpose of the data	Required for project calculations
Calculation method	Calculated using the following field- measured parameters $L_{i,t}$, $dn_{i,t}$, $D_{LDWc,i,t}$, and $N_{i,t}$
Comments	

Data / Parameter	$f_{PRJ,SWDECAY,i,t}$
Data unit	unitless; $0 < f_{PRJ,SWDECAY,i,t} < 1$
Description	The annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t*.
Source of data	Permanent sample plots; FVS-FFE modeling and forest inventory updates
Description of measurement methods and procedures to be applied	For plot data, SW decay is estimated naturally by changes in dead tree remeasurements across multiple remeasurement periods. Otherwise modeled by FVS-FFE for inventory updates.
Frequency of monitoring/recording	Every 5 years for plot remeasurements; annually for modeled inventory updates.
Value monitored	Variable.
Monitoring equipment	Standard plot remeasurement equipment, GIS and FVS-FFE.
QA/QC procedures to be applied	Latest NCC Standard Operating Procedures for plots and data.
Purpose of the data	Required for project calculations
Calculation method	Calculated by FVS-FFE from plot data
Comments	

5.3 Monitoring Plan

The objective of the Darkwoods project monitoring program is to reliably monitor changes in carbon stocks related to the calculation of VCU's prior to each verification. In particular, the program will monitoring changes in spatial forest inventory conditions and collect field data on carbon stocks to compare against modeled carbon stocks and to calculate an uncertainty factor.

NCC is a national conservation organization with a defined set of roles and responsibilities based generally on a regional leadership model to handle all aspects of their business, with the Darkwoods property sitting within the BC Region. The NCC BC Region Manager (Nancy

Newhouse) is responsible for the management of the Darkwoods property overall. Operational property oversight and management is handled by the Darkwoods Site Manager with support from various regional and national personnel. The Director of Carbon Finance (Rob Wilson) at NCC National Office heads all carbon initiatives and carbon business in conjunction with Tom Swann from the BC Region. Carbon project design, reporting, and related advisory services and expertise are provided by the Project Implementation Partner (RainCloud Forests) to NCC. Operationally, the monitoring for all elements of the carbon project are undertaken by BC Regional staff, primarily headed by the Darkwoods Site Manager (Adrian Leslie). RainCloud Forests handles all carbon project data analysis and modeling (in conjunction with NCC GIS staff), complies project reporting, and provides technical oversight and advice to the project on an ongoing basis.

The Darkwoods project monitoring plan contains three primary activities:

1. **Annual inventory change monitoring**

The NCC Darkwoods Site Manager is responsible for monitoring spatial inventory changes on the Darkwoods project area, and then updating the GIS forest inventory datasets for spatial changes >4 ha. This is undertaken via a combination of aerial helicopter overflight reconnaissance, field observations, field surveys of identified project activities, and field surveys of any identified disturbance events (i.e. fires, etc.). NCC undertakes various other property monitoring activities as part of implementation of the Darkwoods Property Management Plan and other research and operational monitoring activities.

Specific to the carbon project, NCC monitors the property annually for at:

a. Natural disturbance events >4 ha (i.e. fires, high mortality pest and disease areas, blow-down areas, slides, etc.).
b. Planned project activity results (i.e. timber harvesting, road construction, or other management activities >4 ha affecting carbon stocks).
c. Unplanned man-made disturbances (i.e. non-de minimis illegal or unplanned harvests, if applicable).

The results of these monitoring activities will be digitally mapped by GPS or remote sensing data (i.e. satellite image interpretation, etc.) and the Darkwoods forest inventory GIS database updated annually.

2. **Other Monitoring Requirements of the Project**

NCC will also document other monitoring requirements of the PDD, including:

a. Activity shifting leakage (annually)
b. Annual market leakage calculations (annually)

Activity shifting leakage risks will be reported during each verification by updating the timber harvest levels on other regional NCC forest properties following the data requirements outlined in Section 4.3.

Market leakage calculations will be updated at each verification following the data requirements outlined in Section 4.3.

3. **Carbon field plot monitoring**

NCC has installed and maintains a network of permanent carbon plots across the property area. As of 2017, 72[33] active permanent carbon plots were established on the property in 2012 and 2014. These plots have been remeasured in 2017 and 2019 respectively. One plot was re-established during the 2019 re-measurement due to a fire in 2018. The QA/QC blind checks on 10% of plots has been completed and all sampled plots meet the required thresholds to date. As of the 2017-2019 monitoring period the Uncertainty Factor inventory error term is 11.4% and the project error term is 10.0%, which suggests the project has a reasonable plot network established to achieve the accuracy targets in VM0012 and in bullet 4 below.

Plot Network Development Methods:

The permanent, geo-located carbon plot network was established following the process outlined in VM0012 v1.2:

4. Stratification for Field Plot Sampling: the plot network design is based on the same stratification of the project landbase into analysis units as described in Section 4.

- The project is expected to refine the analysis unit criteria from time to time, which may result in the reallocation of polygons in analysis units, and the plot installation network will be updated to match these AU criteria. In other words, plots may occasionally shift AU's with new data.
- The project will also periodically update the forest inventory with new stand data and potentially new stand polygon boundaries, which may result in reallocation of polygons into new AU's. The plot network will be tracked according to the most current forest inventory data and AU designations.
- The project may choose to install additional field plots over time to improve AU representation, stand age representation, or otherwise to improve inventory sampling accuracy over time. The project may also choose to install temporary or supplemental plots of compatible design to provide additional coverage or accuracy refinement in a cost effective manner.

[33] An additional eight plots that were originally installed on the project area were determined to be in the non-productive forest landbase (AU 111) in current inventory data and have been discontinued.

5. Plot locations: plots are geolocated by a GIS grid overlay or GIS random point generator over the Carbon THLB area, with an additional 50-75m buffer to any polygon boundary (to prevent plot locations near boundaries where plot transect lines could extending beyond the target AU area); from which a randomized potential plot location list is created by AU. The plots to be installed are then selected in order from this randomized list within each AU until the target number of new plots are selected for each AU. If a generated potential plot location is unsafe or unfeasible due to access or logistical issues, then the next plot on the same randomized list is selected. This plot reselection process may be repeated if necessary.

- Each selected plot is to be installed at the geolocated target point if possible; however, the Darkwoods Carbon Plot SOP document provides additional installation guidance for systematically altering the center point of plots due to physical barriers or safety concerns.
- The project may keep a running list of potential plot locations by AU, but likely will generate new lists each time to use the latest inventory and AU areas.

6. Number of Plots: the plot network is designed to provide representation of each AU[34], and the plots distributed to approximate area weighted representation of each AU[35].

7. Precision: The plot network has a design target of establishing enough plots such that the estimate of carbon stocks across all analysis units will lie within 10% of the the value of the mean at the 90-percent confidence level[36].

8. Plot Design: The carbon plots are designed as variable area fixed plots. The plot design and installation procedures are outlined in the Darkwoods Carbon Plot SOP document. Any new plots will be installed following this document unless otherwise documented in accordance with VM0012 requirements.

[34] The project has created a methodology deviation to not require plot representation of AU's representing less 1% of the project area.

[35] Noting that changes to the forest inventory and or AU allocation criteria may result in AU plot representation varying somewhat over time. The project will strive to maintain AU representation within 20% of the expected plot count by AU based on AU weighted area and install additional plots within 5 years if representation is outside this bound.

[36] As per VM0012, this plot design accuracy criteria is a target and not a hard requirement. The Uncertainty Factor calculation used by VM0012 incentives projects to improve inventory/plot accuracy as well as modeling accuracy over time.

9. Measurement and Data Analysis Techniques: 100% of live and dead trees >= 5 cm DBH are measured for height and DBH to determine aboveground live and standing dead biomass and calculate below ground live and dead biomass for each plot on an area basis. Additionally, the mass of lying dead wood is measured using the line intersect method outlined in Pearson, Brown & Birdsey, 2007. Two 50 m perpendicular transect lines are installed centered on the plot center and all downed wood >= 5cm diameter are measured, along with a wood density field estimate. The specific plot data measurement procedures for all plot measurements to be followed are outlined in the latest version of Darkwoods Carbon Plot SOP document, and any new plots installed will follow the procedures in the latest version of this document. This document may be refined from time to time and plot measurements updated at the next measurement opportunity. These plot data are then analyzed by inputting the resulting tree data into FVS-FFE to calculate above- and below-ground biomass by pool in the same manner as the main carbon modeling for the project area. The lying dead data is analyzed independently in an Excel spreadsheet to calculate the biomass volume following the calculations outlined below (Equations 60a-60c from VM0012 v1.2). This measured lying dead wood volume replaces the lying dead volume calculated by FVS-FFE for calculating total plot carbon. All plot data are then converted to area based stand-level measurements (tC/ha) based on the plot area.

- Each piece of deadwood will be assigned to one of three density classes, sound (1), intermediate (2), and rotten (3) by field tests as described in the latest version of the Darkwoods Carbon Plot SOP document. The volume per unit area is calculated for each density class using Equations 61a-c from VM0012. For transparency, the equation numbers used here are the same as those used in the methodology document.

$$\mathbf{V_{LDW,c} = \pi^2 * [(d_1^2 + d_2^2 \ldots d_n^2)/8L]} \qquad \mathbf{(60a)}$$

Where,

d_1, d_2, d_n = diameter (cm) of each of *n* pieces intersecting the line, and

L = the length of the line (100 m default (Harmon, et al., 1986).

The mass of LDW in density class, *c* (t ha^{-1}), is:

$$\mathbf{M_{LDW,c} = V_{LDW,c} * D_{LDW,c}} \qquad \mathbf{(60b)}$$

Where,

$V_{LDW,c}$ = the volume per unit area calculated for each density class, *c*, as calculated in 60a.

$D_{LDW,c}$ = the density of LDW in density class, *c* (t d.m. m^{-3})

The total mass of LDW in each plot summed over all density classes (t ha^{-1}) is:

$$\mathbf{DOM_{LDW} = \sum M_{LDW,c}} \qquad \mathbf{(60c)}$$

Where,

$M_{LDW,c}$ = the mass of LDW in density class, *c* (t ha^{-1}), is as calculated in 60b.

The total mass of lying dead wood for a given polygon should be calculated as the average of all transects measured for that polygon using equations 60a-c. This value is then used for calculations of carbon storage in lying dead organic matter for each plot.

10. Plot Re-measurement. The carbon plots will be re-measured each within 5 calendar years of last measurement[37]. The re-measurement methods are detailed in the Darkwoods Carbon Plot Re-measurement SOP document. The project will use the most recent plot data available prior to the current monitoring period. Plots may occasionally be re-established in the event of a disturbance to the plot area such as fire or harvest, if it is safe to do so. If the plot cannot be safely re-established or re-measured then it can be replaced following the plot location procedures.

11. Quality Assurance/Quality Control for Field Measurements: The Darkwoods Plot SOP and Darkwoods Plot Re-measurement SOP documents provide detailed instructions for completing accurate and repeatable field plot measurements. Field crews are trained in field data collection as per the SOP's, and records are kept of training for each field crew. The 'hot check' QA/QC procedures described in VM0012 are the responsibility of crew leaders, and are completed as needed to insure the crews are trained and completing the plot installations according to the SOP. The primary project QA/QC procedure for plot measurements involves a "cold check": at minimum, 10% of the measured field plots will be check-cruised using blind checks (without prior data) with 100% remeasurement of all plot variables. The minimum thresholds for a successful QA/QC check are:

- DBH (standing live and dead): +/- 10% standard error at 90% confidence interval
- Height (standing live and dead): +/- 10% standard error at 90% confidence interval
- Tree Count (standing live and dead): +/- 10% standard error at 90% confidence interval

Plots that fail these QA/QC checks are to be re-measured, and then the blind QA/QC checked until the plot is in compliance with the threshold.

12. Quality Assurance/Quality Control for Data Entry: NCC maintains standard procedures for data entry, and the project documentation for plot data, inventory data, and other data entry and analysis follow these procedures. The data stardards are outlined in the latest Darkwoods Data Standards document.

[37] Note that this is a re-interpretation of VM0012 v1.2, wherein plots are to be remeasured "within 5 years". This minor deviation allows flexibility for plot remeasurement across the field season in the 5th year, which will not materially affect plot carbon results.

13. Quality Assurance/Quality Control for Data Archiving: NCC stores electronic field data files, GIS dataset, carbon analysis files, and all supporting project documentation on NCC servers and in Dropbox project folders. Plot age core samples are retained at the Darkwoods field audit. The project will retain all relevant documentation for 2 years past the end of the project.

Leakage Monitoring

Activity shifting leakage is monitored annually and reported at each verification, as per methods outlined in Section 4. NCC will review and report on commercial harvesting on any other properties owned or controlled by NCC, and if any, demonstrate there is low or no risk of activity shifting leakage.

Market leakage is not specifically monitored by the project; however the project recalculates a market leakage rating[38] on an annual basis at each verification, following the procedures outlined in Section 4.

Frequency of Monitoring

Permanent carbon plots will be re-measured within 5 calendar years of last measurement.

Spatial inventory and property monitoring is undertaken annually and reported at each verification.

Leakage monitoring is reported on an annual basis at each verification.

Use of Monitoring Data to Update Carbon Stock Calculations

Data gathered through the monitoring process will be used to:

1. Update the project inventory data and related modeling and monitoring stratification as per Section 3;
2. Update the leakage calculations in Section 4;
3. Update error estimates used in the calculation of the uncertainty factor as per Section 3; and,

[38] VM0012 v1.2 provides 3 options for market leakage calculations. As of 2017, the project has shifted to select Market Leakage Option 1 – VCS Default Market Leakage Discount Factors. No further leakage monitoring or mitigation is necessary under this method, other than reporting on the required calculations at each verification.

4. Update and improve calculations of carbon stocks in Section 3.

Updating of Monitoring Polygons

The ex-post stratification and polygon assignment to specific analysis units shall be updated at minimum prior to each verification, for any of the following reasons:

1. Errors in the inventory from field sampling or other monitoring. If the criteria used to allocate a polygon are not in accordance with field evidence, that polygon can be updated and re-assigned accordingly if necessary. Any non-*de minimis* updates due to errors in the inventory will require recalculation of both the annual project emissions and the annual baseline emissions for the current monitoring period prior to the next verification;
2. Changes to spatial inventory from monitoring for natural disturbance and planned/unplanned project activities. Updates will be made for any monitored event (at minimum >4 ha) that affects the criteria used to define a given polygon or analysis unit in the project inventory. Note that disturbance or activity events may result in creation of a new polygon, or an age reclassification for the stand, and/or a re-assignment of the polygon. These updates only affect the calculation of carbon emissions from the project scenario.
3. Established polygons may be merged if the original justification for their separate creation no longer applies. These updates only affect the calculation of carbon emissions from the project scenario.

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