PROJECT DESCRIPTION DOCUMENT
VOLUNTARY CARBON STANDARD

The Nature Conservancy of Canada

DARKWOODS FOREST CARBON PROJECT

v. 1.8

Darkwoods Forest Carbon Project	April 21, 2011
Version 1.8	3GreenTree Ecosystem Services Ltd. & ERA Ecosystem Restoration Associates Inc. For: Nature Conservancy of Canada

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1. Project Details:

1.1. Summary Description of Project:

The Nature Conservancy of Canada (NCC) acquired the fee simple 54,792 ha (135,394 acre) Darkwoods Property near Creston, BC from the Pluto Darkwoods Corporation in April of 2008, with the objective of managing the land for ecological conservation objectives. NCC is developing a 100 year VCS IFM-LtPF forest carbon project with a start date of the acquisition date to provide carbon finance as a significant part of acquisition financing and funding for ongoing property management and ownership costs.

The Darkwoods Forest Carbon Project achieves net GHG emission reductions and removals through the avoidance of emissions due to logging in the baseline scenario. The Darkwoods property was being sold by the previous owner, Pluto Darkwoods on a bid basis based on a sales price from a formal property and timber valuation/appraisal similar to the baseline scenario. The most plausible baseline scenario is a market-driven acquirer who implements a 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 anticipates a low level of timber removal as part of conservation management activities for ecosystem/habitat enhancement and risk management.

1.2. Sectoral Scope and Project Type

Sector 14 - AFOLU

Improved Forest Management (IFM)

Logged Forest to Protected Forest (LtPF)

The Darkwoods Property is consistent with the VCS eligibility for an IFM-LtFP project by "protecting unlogged forests that would be logged in the absence of carbon finance".

1.3. Project Proponent

Organization	Role	Contact/Address
Nature Conservancy of Canada	Project Proponent	Tom Swann 825 Broughton Street, Suite 200 Victoria, BC, Canada V8W 1E5 Tel: +1 250-479-3191

1.4. Other Project Participants

Organization	Role	Contact/Address
3GreenTree Ecosystem Services Ltd.	Project Developer	Mike Vitt 3960 Marine Ave. Belcarra, BC, Canada V3H 4R9 Tel: +1 778-998-5478
ERA Ecosystem Restoration Associates Inc.	Project Developer	Dave Rokoss Suite 116B – 980 West 1st Street North Vancouver, BC, Canada V7P 3N4 Tel: +1 604-646-0400
Pluto Darkwoods Forestry Corp.	Darkwoods Property Forestry Management	Christian Schadendorf P.O. Box 620 Nelson, BC, Canada V1L 5R4 Tel: +1 250-825-4343
Pat Field	Darkwoods Consulting Forester	Pat Field 1697 Ridgewood Drive Castlegar, BC, Canada V1N 2L5 Tel: +1 250-365-0425

1.5. Project Start Date and Project Crediting Period

The Darkwoods carbon project and the crediting period start dates are the date of closing on the acquisition. The GHG emission reductions began the day of acquisition, when competing bidder's development plans were avoided by NCC's acquisition.

Project Start Date: April 1, 2008 - The project start date is the date of acquisition, and is the same as the crediting period start date.

Crediting Period Start Date: April 1, 2008 - The GHG emission reductions began at the acquisition, when avoided logging began due to NCC's ownership.

Crediting Period: 100 years - NCC intends to own and manage the Darkwoods property in perpetuity, and has selected the maximum carbon project length.

1.6. Estimated GHG Emission Reductions or Removals:

Micro-Project	
Project	X
Mega-Project	

The Darkwoods IFM-LtPF carbon project is projected to generate approximately 14.66 million tCO_2e emissions reductions over 100 years on an ex-ante basis.

Annual emission reductions are estimated to range from 10,000 to 440,000 tCO_2e (See Table 17 and Table 18).

1.7. Description of Project Activity:

The Darkwoods carbon project will create GHG emission reductions by avoiding the release of carbon caused associated with timber harvesting, road building, other forestry operations in the baseline scenario.

In contrast to the baseline scenario, the Darkwoods Carbon Project will retain and restore the land to conservation-based forests for the duration of the project and in perpetuity. This will retain the carbon contained in the current and future forest biomass and avoid emissions from logging in the baseline scenario.

As a conservation-based IFM project, there are no specific technologies, products, or services involved in the implementation of the project. Beyond the creation and sale of verified emissions reductions, the Darkwoods project activities will be primarily focused on property supervision and monitoring, conservation research and other conservation-based land management activities. A low level of ongoing forest management activity by NCC (averaging 10,000 m^3/year) for conservation management purposes is expected in the project scenario which will result in GHG emissions which have been accounted for in the carbon flow projections.

As noted in the NCC Darkwoods Property Management Plan 2010-2015 (NCC, 2010), “Darkwoods will be managed to provide productive, resilient ecosystems to support native species through time, while balancing conservation objectives with the need for strong community support. Six biodiversity targets and associated goals have been identified: 1) mountain caribou; 2) hydro-riparian ecosystems; 3) dry interior cedar-hemlock forest; 4) grizzly bears; 5) old-growth cedar-hemlock forest; and, 6) rare ecosystems and features.”

Further details and specifics of the project scenario ex-ante and ex-post data, assumptions and modeling are found in Section 4.2.

1.8. Project Location:

The Darkwoods property is a 54,792 ha (135,394 acre) contiguous parcel of fee simple private property in south eastern British Columbia just north east of the municipality of Creston. 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 which is owned and managed by the Windall Box Company, with access rights through the Darkwoods property. The boundaries are surveyed (see Table 1, Figure 1, and Figure 2) with the following legal land description:

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

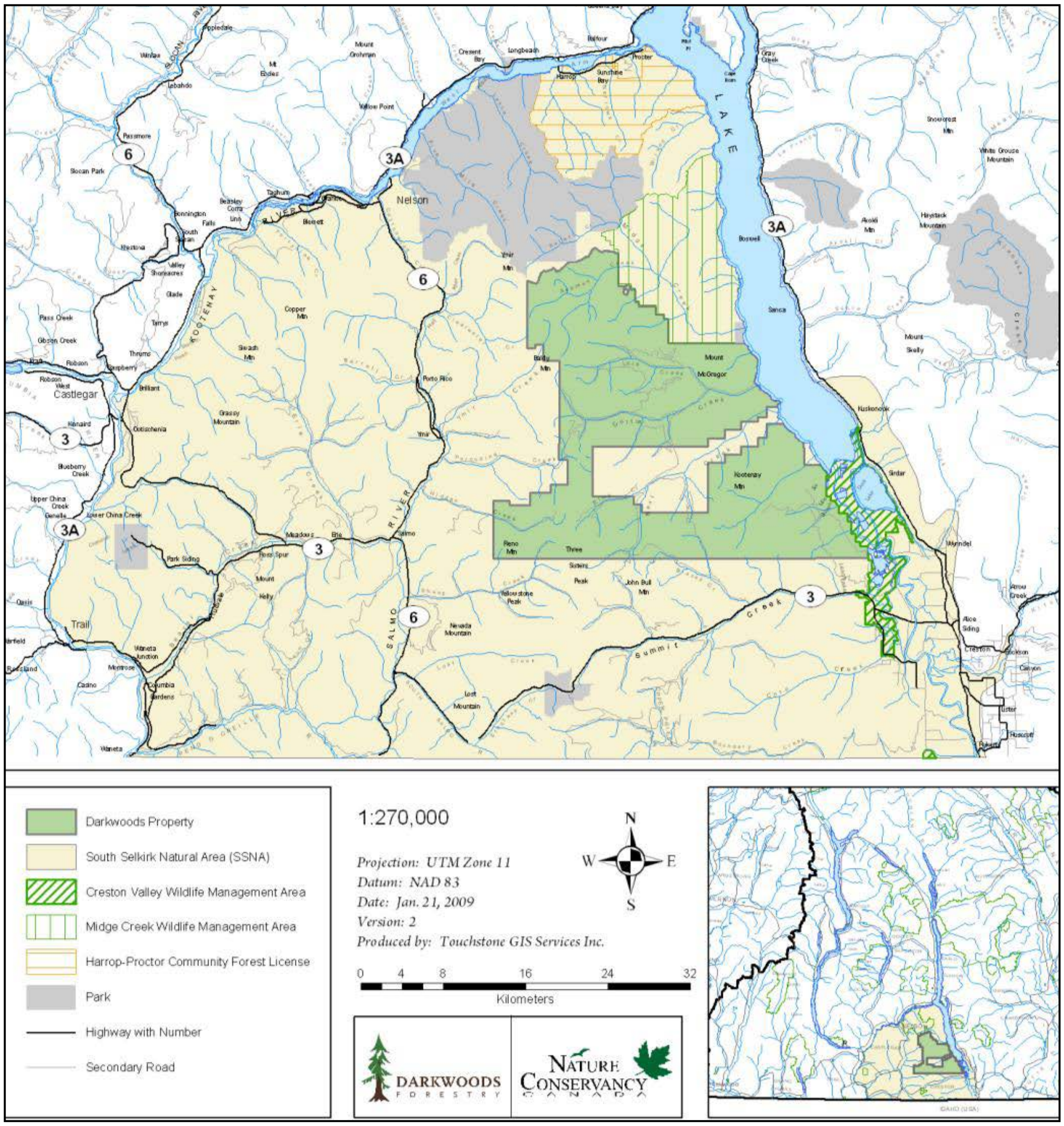


Figure 1 - Darkwoods Overview Map

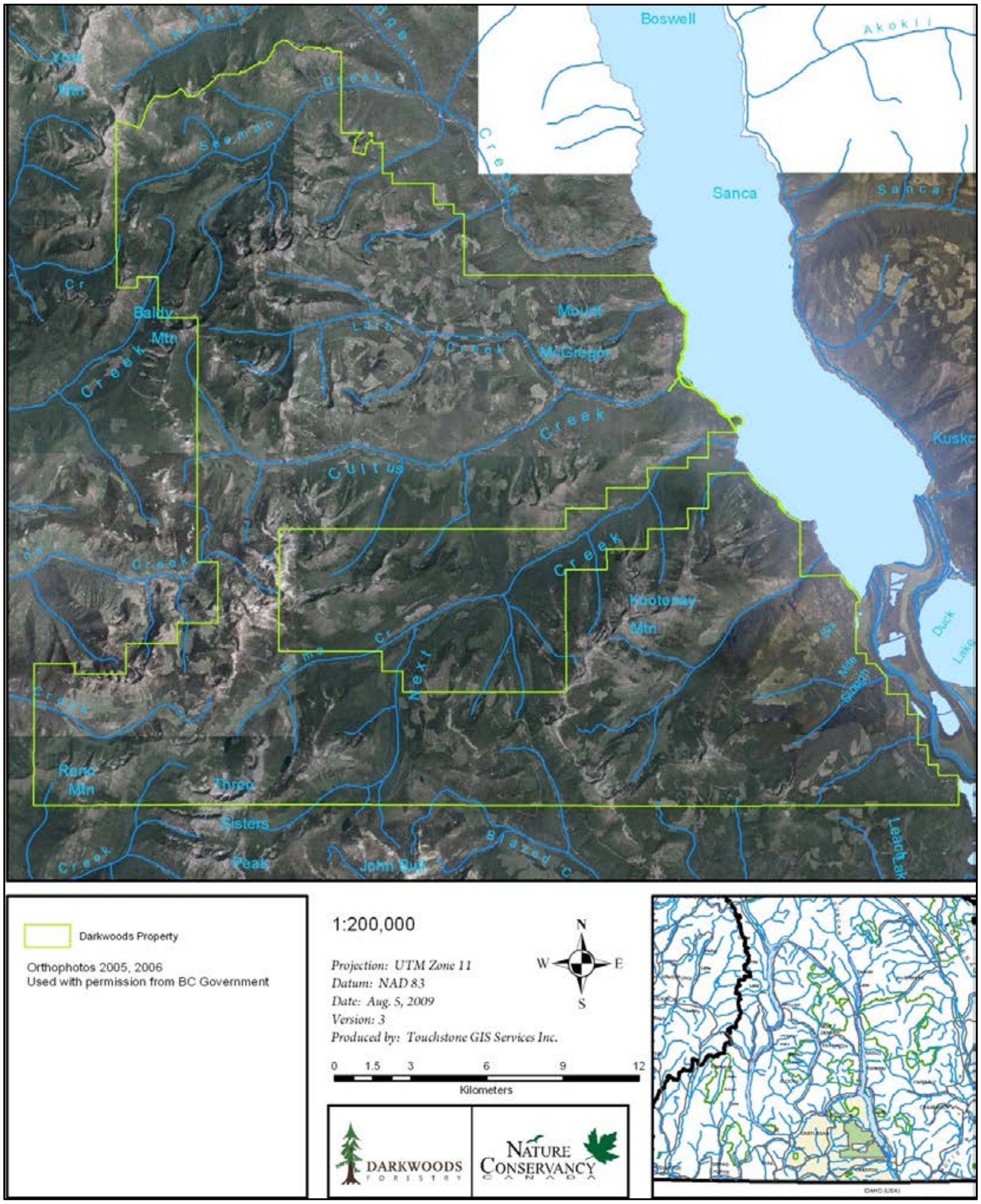


Figure 2- Darkwoods Property Ortho Mosaic

1.9. 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 real estate development opportunities to attract 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 little government 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 Information

The following is a property overview summary from the draft Darkwoods Property Management Plan 2010-2015 (NCC, 2010):

The size of the property is 54,792 ha (135,394 acre). Forest harvesting, wild fire and forest pathogens have disturbed the 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 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 and Context:

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).

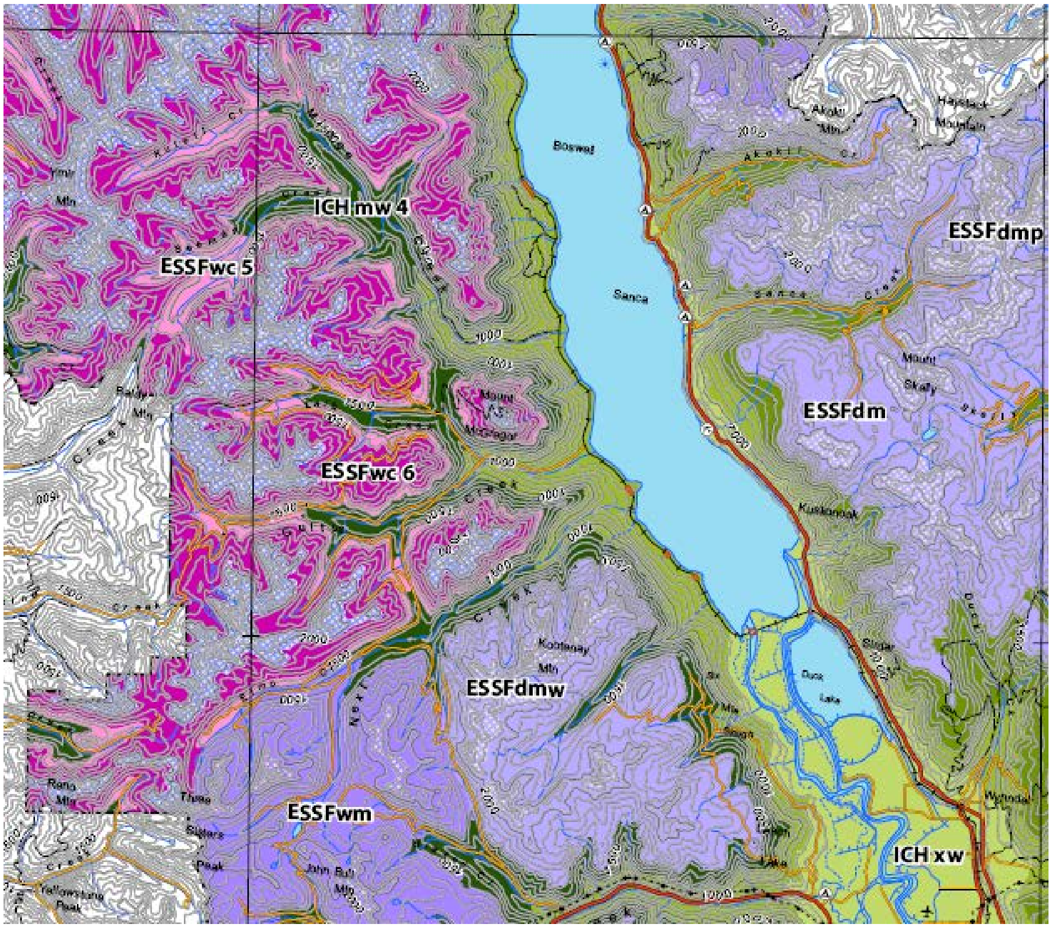


Figure 3 - Darkwoods Area Biogeoclimatic Subzone/Variant Field Map (http://www.for.gov.bc.ca/HRE/becweb/)

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). No single forest/site type accounting for more than 10% of the area (Table 2).

Approximately 68% of the property (37,250 ha) is considered operable for timber harvesting, as shown in Table 2. Within this operable area, approximately 9,012 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 for all intensive purposes will behave similar to natural forest conditions.

The property is well-roaded, with main haul routes located into each drainage area, as shown on Figure 2 and Figure 4. The last harvest was undertaken in 2010, primarily in remaining mature pine-leading stands which have been attacked by or are at high risk for mountain pine beetle.

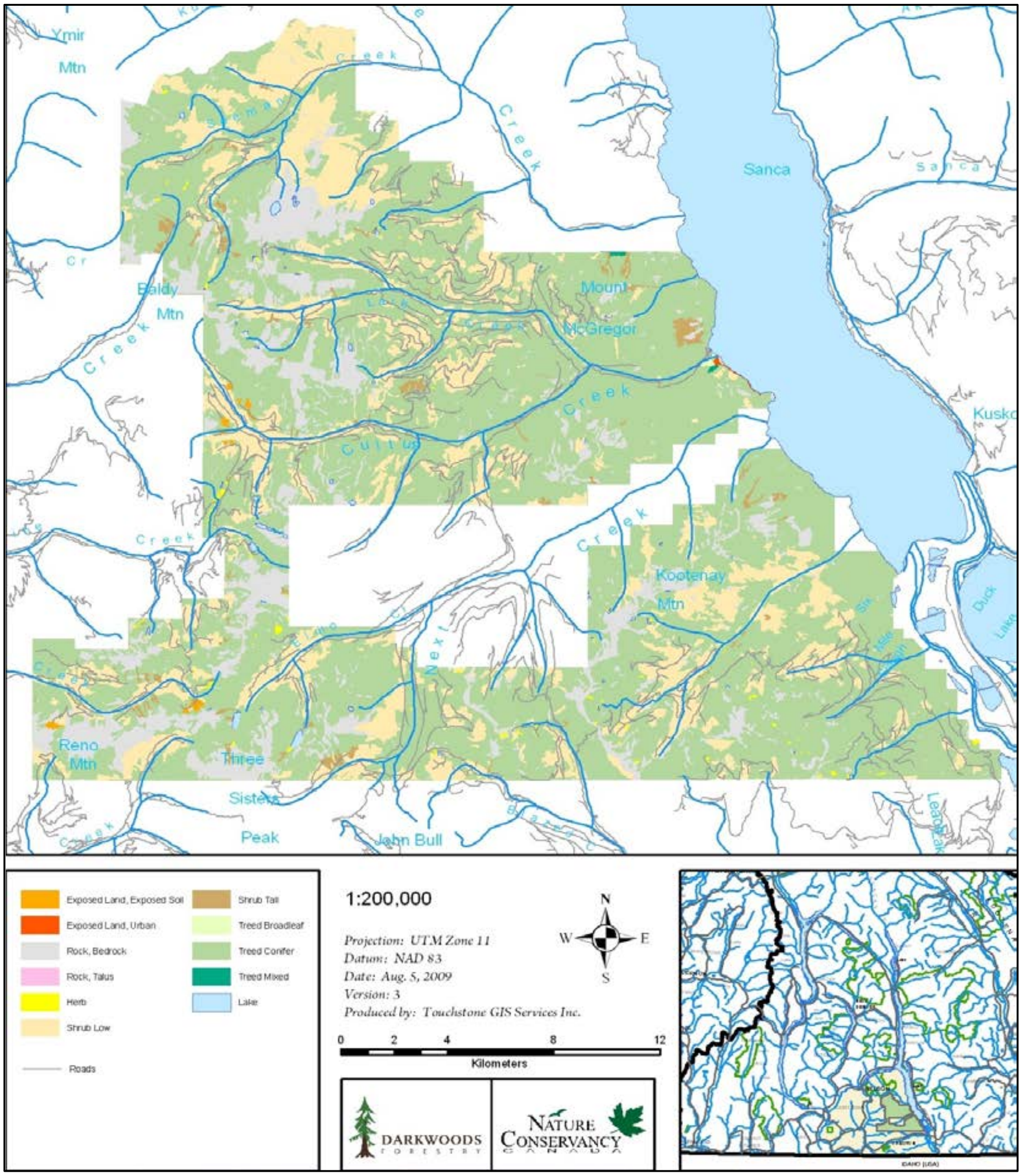
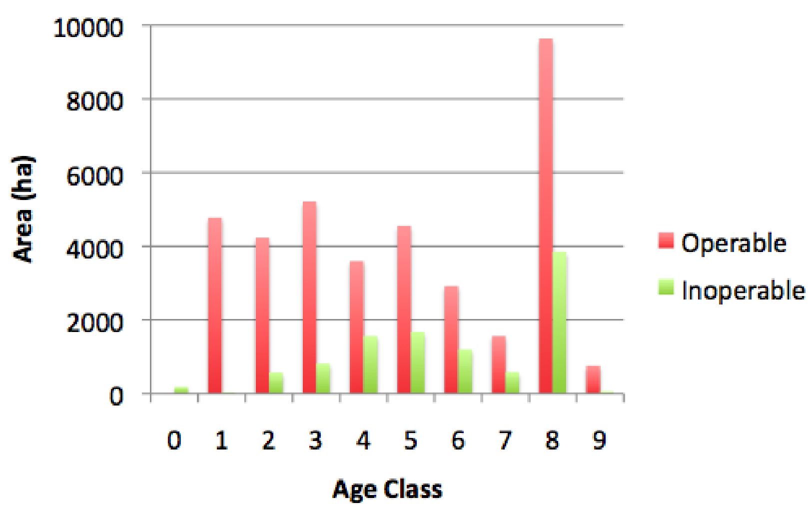


Figure 4 - Darkwoods Land Cover Map

Table 2 - Darkwoods Forest Cover Description, Grouped by Leading Species, Productivity, Age group, and Operability[1]

Description	Lead	Other	Productivity	SI**	Age	Operable	Inoperable
non-forest						0.0	7018.6
F / L_med	F / L	Pl	med	13-17	>40	1909.7	419.4
F / L_good	F / L	H & C	good	>17	>40	2589.8	91.0
B / L / F_poor	B / L / F	S, Pl	poor	<13	>40	7945.2	7742.8
B_med	B	S,Pl	med	>=13	>40	5202.2	294.5
P_poor	P	B, S	poor	<13	>40	1839.3	489.9
P_med	P	F, S	med	>=13	>40	2601.7	557.7
C / H_med-good	C / H	S,F	med-good	all	>40	2333.4	78.6
S_med	S	Bl, Pl	med	<=16	>40	2778.0	240.2
S_good	S	F, H, C	good	>16	>40	1023.2	9.2
E / A_Med	E / A		Med	all	>40	15.3	0.0
F / L_med	F / L	Pl	med	13-17	<=40	119.7	0.0
F / L_good	F / L	Pl	good	>17	<=40	326.5	1.2
S/P/B poor	S/P/B	L	poor	<13	<=40	2068.8	586.1
S/P/B Med	S/P/B	L	med	>=13	<=40	3615.0	4.1
C / H_med-good	C/H	F, S	med-good	all	<=40	231.9	7.6
S_good	S	F, H, C	good	>16	<=40	2649.8	1.5
					Total	**37,250**	**17,542**



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

[1] 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.

1.10. 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 designated B.C. Registered Professional Foresters.

The project has projected the baseline scenario to be fully compliant with laws and regulations. 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 and Regulation:

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 expected to be material to the baseline or project scenarios.

1.11. Participation in Other GHG Programs:

Darkwoods has not participated in any other GHG program. Further, Canada did not include forest management accounting in their Kyoto section 3.4 selections, and therefore Darkwoods has no risk of double counting in national Kyoto accounting.

Darkwoods VCS credits are anticipated to be compliant with the B.C. Emissions Offset Regulations, 2008, however this regulation relates to voluntary participation of eligible carbon offset projects in sales to the Pacific Carbon Trust in British Columbia. Participation in any potential sales will be in the form of voluntary sales of issued VCU's, and not registered or issued credits in any other form.

1.12. 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.

1.13. Additional Information Relevant to the Project:

Eligibility Criteria:

The Darkwoods project meets both of the criteria for VCS Improved Forest Management – Logged to Protected Forest (IFM-LtPF) eligible projects as defined in the VCS Guidance for AFOLU Projects (Voluntary Carbon Standard, 2008a):

a. Protecting currently logged or degraded forests from further logging.
b. Protecting unlogged forests that would be logged in the absence of carbon finance.

Leakage Management:

Darkwoods does not employ plans specifically designed for leakage management; however, the project activities do inherently include a level of leakage mitigation by 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 entirely 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.

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, and NCC financial information and business plans provided to validators and verifiers outside this PDD document are confidential, unless otherwise indicated. Other confidential information may be identified during validation or verifications.

Further Information:

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2. Application of Methodology:

2.1. Title and Reference of Methodology:

VCS methodology:

VM0012 Improved Forest Management on Privately Owned Properties in Temperate and Boreal Forests (LtPF) v1.0.

2.2. Applicability of Methodology

Table 3 - Compliance with Methodology Applicability Criteria

Summarized Applicability Criteria	Darkwoods Fit
Meets either current VCS IFM-LtPF criteria	Darkwoods meets both criteria
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.

Therefore, the Darkwoods Forest Carbon Project is fully compliant with all of the listed applicability measures in the selected methodology.

2.3. GHG Sources, Sinks and Reservoirs:

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

Table 4 - Selection of Carbon Pools

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 – generally considered as a transitional pool only.	Litter is a short-lived transition pool, and differences between the project and baseline are *de minimis* over time
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 5 - Emissions Sources Included/Excluded from the Project Boundary

Emissions Sources	Gas	Selected?	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. 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 either scenario; however, carbon stock decreases due to burning are accounted as a carbon stock change. These exclusion assumptions do not increase the emission reductions in the project.

2.4. Baseline Scenario

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. Italicized text indicates methodology or VCS requirements in baseline scenario selection.

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 6 - Previous Owner Operations History (Pluto Darkwoods 2004-2008)

Year[2]	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, 2004) 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 valuation anticipated 3 harvesting scenarios for an expected market buyer of the property:

[2] 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).

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.

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[3]. 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[4] supported by financial analysis of achieving typical market returns from forest products.

The project proponent shall select the baseline scenario that:

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*

[3] 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%.

[4] 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).

  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, 2004)), with the different harvest volumes over the first 30 years[5]:

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 **<u>selected most plausible baseline</u> condition is:**

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

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

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[5] 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.

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, 2004). There are regional (and adjacent) examples of similar and higher harvest levels during timberland acquisitions[6].
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, 2004).

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

a. 10 year depletion rate harvesting regime
    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.

2.5. Demonstration and Assessment of Additionality:

The project uses the Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities (Voluntary Carbon Standard, 2010b):

This PDD meets the eligibility requirements of this tool by:

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

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
    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[7] (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

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

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 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 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 (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 clearly additional based on Investment Analysis.

2.6. Methodology Deviations:

No material deviations from the methodology were made. It is expected, however, that monitoring deviations may be required at the time of first verification, which will be documented in the monitoring report.

3. Monitoring:

Monitoring relates to the ongoing measurement of carbon pools and for compliance of the project's activities. In the case of the Darkwoods project, the monitoring plan has the purposes of:

a) ensuring that non-*de minimis* unanticipated GHG emissions have not occurred or are accounted for in net GHG calculations,
b) ensuring that the net GHG emissions from project activities are accounted for as described in this document,
c) to verify that parameter values and simulated carbon pools are consistent with their ex ante estimates,
d) Ensuring that the other requirements of the PDD are tracked (i.e. leakage).

3.1. Data and Parameters Available at Validation:

A list of the data and parameters available at the time of validation is provided in Table 7.

Table 7 – Data and Parameters available at validation.

Data/parameter	**THLB**
Data unit	Ha
Description:	Timber harvesting landbase area
Source of data	GIS
Value Applied	See GIS databases.
Justification of choice of data or description of measurement methods and procedures applied:	Required for baseline and project calculations
Comments:	

Data/parameter	$A_{BSL,i}$, $A_{PRJ,i}$

Data unit	Ha
Description:	Respective areas of baseline and project polygon, *i*
Source of data	Latest NCC Darkwoods GIS spatial inventory data (see Appendix 5).
Value Applied	See GIS databases.
Justification of choice of data or description of measurement methods and procedures applied:	Data are inputted into FPS-ATLAS
Comments:	First used in equations 4 and 32, for the baseline and project cases, respectively

Data/parameter	**CF**
Data unit	t C t^{-1} d.m.
Description:	Carbon fraction of dry matter
Source of data	IPCC 2006
Value Applied	0.5
Justification of choice of data or description of measurement methods and procedures applied:	IPCC default value
Comments:	First used in equations 4 and 32 for the baseline and project cases, respectively

Data/parameter	R_i
Data unit	unitless
Description:	Root:shoot ratio in polygon, *i*
Source of data	Based on Li et al. 2003 but modified according to tree age according to Lehtonen et al. 2004
Value Applied	Variable – calculated as a function of age and species based on the references. Conifers range in value from 0.19 to 0.25 depending age. Hardwoods range in value for 0.18 to 0.24. See root biomass worksheet in the Douglas fir example (Appendix 5).
Justification of choice of data or description of measurement methods and procedures applied:	Root biomass is difficult to measure directly.
Comments:	First used in equations 5b and 33b for the baseline and project cases, respectively

Data/parameter	$f_{BSL,NATURAL,i,t}$, $f_{PRJ,NATURAL,i,t}$
Data unit	unitless ($0 \leq f_{BSL,NATURALi}$, $f_{PRJ,NATURAL,i,t} \leq 1$)
Description:	The proportion of biomass that dies from natural mortality in polygon, *i*, year, *t*, in the baseline and project cases, respectively.
Source of data	Expert opinion
Value Applied	0.2 % per annum
Justification of choice of data or description of measurement methods and procedures applied:	Estimate established over years of FORECAST development comparing model outputs of coarse woody debris and snag accumulation against field data.
Comments:	First used in equations 7 and 35 for the baseline and project cases, respectively.

Data/parameter	$f_{BSL,HARVEST,i,t}$, $f_{PRJ,HARVEST,i,t}$
Data unit	unitless ($0 \leq f_{BSL,HARVEST,i,t}, f_{PRJ,HARVEST,i,t} \leq 1$)
Description:	The proportion of biomass removed by harvesting from polygon, *i*, in year, *t*, in the baseline and project cases, respectively.
Source of data	Annual arvest schedule produced from FPS ATLAS, by statum (inventory polygon).
Value Applied	Variable – see Table 14 for summarized total annual harvest volume and area. Summarized from individual inventory data produced with FPS Atlas.
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 8 and 36 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,DAMAGE,i,t}$, $f_{PRJ,DAMAGE,i,t}$
Data unit	unitless ($0 \leq f_{BSL,DAMAGE,i,t}, f_{PRJ,DAMAGE,i,t} \leq 1$)
Description:	The proportion of additional biomass removed by for road and landing construction in polygon, *i,* year, *t*, in the baseline and project cases, respectively.
Source of data	Expert opinion initially as a conservative measure. Monitoring data on an ex-post basis.
Value Applied	Zero in ex-ante baseline and project scenarios. From monitoring data for project ex-post calculations.
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 9 and 37 for the

	baseline and project cases, respectively

Data/parameter	$f_{BSL,BLOWDOWN,i,t}$, $f_{PRJ,BLOWDOWN,i,t}$
Data unit	unitless ($0 \leq f_{BSL,BLOWDOWN,i,t}, f_{PRJ,BLOWDOWN,i,t} \leq 1$)
Description:	The proportion of live aboveground tree biomass subject to blowdown in polygon, *i*, year, *t*, in the baseline and project cases, respectively.
Source of data	Included within the natural mortality factor calculated in $f_{BSL,NATURAL,i,t}$, $f_{PRJ,NATURAL,i,t}$ Also captured by spatial monitoring if >4ha, which would be incorporated as a new polygon on an ex-post.
Value Applied	Zero for the baseline and project ex-ante calculations (part of the natural mortality factor source data).
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 12 and 40 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,BRANCH,i,t}$, $f_{PRJ,BRANCH,i,t}$
Data unit	unitless ($0 \leq f_{BSL,BRANCH,i,t}, f_{PRJ,BRANCH,i,t} \leq 1$)
Description:	The proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, *i*, year, *t*, in the baseline and project cases, respectively.
Source of data	Calculated within FORECAST using calibration data from allometric biomass equations by species based upon (Standish, Manning, & Demaerschalk, 1985).

Value Applied	Variable, see source of data.
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 12 and 40 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,BUCKINGLOSS,i,t}$, $f_{PRJ,BUCKINGLOSS,i,t}$
Data unit	unitless ($0 \leq f_{BSL,BUCKINGLOSS,i,t}, f_{PRJ,BUCKINGLOSS,i,t} \leq 1$)
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*, in the baseline and project cases, respectively.
Source of data	Based on (Smith, Miles, Vissage, & Pugh, 2004), and expert opinion based on FORECAST modeler previous experience.
Value Applied	0.10 of stemwood and bark is assumed to be left on site.
Justification and choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 12 and 40 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,SNAGFALLDOWN,i,t}$, $f_{PRJ,SNAGFALLDOWN,i,t}$
Data unit	unitless ($0 \leq f_{BSL,SNAGFALLDOWN,i,t}, f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$)
Description:	The proportion of snag biomass in polygon, *i*, year, *t*, that falls over, in the baseline and project cases, respectively.

Source of data	From: (Parish, Antos, Ott, & Di Lucca, 2010)
Value Applied	Variable, depending on species and dbh. Modeled by species and dbh class within FORECAST.
Justification of choice of data or description of measurement methods and procedures applied:	Fall rates derived from accelerated failure rate model described in Parish et al. 2009.
Comments:	First used in equations 12 and 40 for the baseline and project cases, respectively.

Data/parameter	$f_{BSL,lwDECAY,i,t}$, $f_{PRJ,lwDECAY,i,t}$
Data unit	unitless ($0 \leq f_{BSL,lwDECAY,i,t}$, $f_{PRJ,lwDECAY,i,t} \leq 1$)
Description:	The annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t* (unitless; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$), in the baseline and project cases, respectively.
Source of data	Based upon: (Harmon, et al., 1986), (Laiho & and Prescott, 2004).
Value Applied	Variable, modeled within FORECAST, based upon a an exponential decay function similar to: Mass loss occurs in proportion to the amount of mass remaining in accordance with an a single exponential model, of the general form: $Y_t = Y_o e^{-kt}$ where Y_o is the initial quantity of material, Y_t the amount left at time *t*, and *k* is a decay constant. *k*-values for the species present on the Darkwoods project area are derived from references provided above.
Justification of choice of data or description of measurement methods and procedures applied:	

Comments:	First used in equations 13 and 41 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,SWDECAY,i,t}$, $f_{PRJ,SWDECAY,i,t}$
Data unit	unitless ($0 \leq f_{BSL,SWDECAY,i,t}$, $f_{PRJ,SWDECAY,i,t} \leq 1$)
Description:	The proportional loss of snag biomass due to decay, in polygon, *i*, year, *t*, in the baseline and project cases, respectively.
Source of data	Based upon: (Vanderwel, Caspersen, & Woods, 2006a); (Vanderwel, Malcolm, & Smith, 2006b); (Kurz & et al, 2009)
Value Applied	Modeled within FORECAST by species based on calibration from the source data references above.
Justification of choice of data or description of measurement methods and procedures applied:	As with lying dead wood (see $f_{BSL,lwDECAY,i,t}$), $f_{BSL,SWDECAY,i,t}$ is assumed to occur in proportion to the amount of mass remaining in accordance with a first order exponential model
Comments:	First used in equations 13 and 41 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,dgbDECAY,i,t}$, $f_{PRJ,dgbDECAY,i,t}$
Data unit	unitless ($0 \leq f_{BSL,dgbDECAY,i,t}$, $f_{PRJ,dgbDECAY,i,t} \leq 1$)
Description:	The proportional loss of dead belowground biomass due to decay, in polygon *i,* year*, t*, in the baseline and project cases, respectively.
Source of data	Based upon: (Moore, Trofymow, Siltanen, Prescott, & CIDET, 2005); (Melin, Petersson, & Nordfjell, 2009)
Value Applied	Modeled within FORECAST by species based on calibration from the source data

	references above.
Justification of choice of data or description of measurement methods and procedures applied:	As with lying dead wood (see $f_{BSL,lwDECAY,i,t}$), $f_{BSL,SWDECAY,i,t}$ is assumed to occur in proportion to the amount of mass remaining in accordance with a first order exponential model
Comments:	First used in equations 17d and 45d for the baseline and project cases, respectively

Data/parameter	$\mathbf{f_{BSL,PRODUCTk}}$, $\mathbf{f_{BSL,PROCESSk}}$, $\mathbf{f_{PRJ,PRODUCTk}}$, **and** $\mathbf{f_{PRJ,PROCESSk}}$
Data unit	unitless; $0 \leq f_{BSL,PRODUCTk}$, $f_{BSL,PROCESSk}$, $f_{PRJ,PRODUCTk}$, and $f_{PRJ,PROCESSk} < 1$
Description:	The respective fractions of harvested biomass allocated to a given forest product type, *k*, and its associated processing efficiency for the baseline (BSL) and project (PRJ) cases.
Source of data	(Thrower & Orr-Ewing, 2004), (Miner, 2006).
Value Applied	See Appendix 2, Table 1 or Darkwoods Carbon Model spreadsheet.
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 20 and 48 for the baseline and project cases, respectively

Data/parameter	$\mathbf{f_{BSL,PERMHWPk}}$, $\mathbf{f_{PRJ,PERMHWPk}}$
Data unit	unitless ($0 \leq f_{BSL,PERMHWPk}$, $f_{PRJ,PERMHWPk} \leq 1$)
Description:	The fraction of biomass allocated to permanent storage, for each product type, *k*, in the baseline and project cases, respectively.

Source of data	Permanent carbon storage was calculated here using the 100-year method developed by (Miner, 2006).
Value Applied	Values are product-specific, as derived below.
Justification of choice of data or description of measurement methods and procedures applied:	$f_{BSLPERMHWPk} = (1/(1 + (Ln(2)/HL_k)))\text{^}\,Y$ where: HL_k is the half-life of a given product type, *k* (years), and *Y* is the elapsed time (i.e, 100 years). See Appendix 2, Table 1 for HL_k values.
Comments:	First used in equations 19 and 47 for the baseline and project cases, respectively

Data/parameter	$f_{BSL,BARK}$, $f_{BSL,COARSE}$, and $f_{BSL,FINE}$ $f_{PRJ,BARK}$, $f_{PRJ,COARSE}$, and $f_{PRJ,FINE}$
Data unit	unitless; $0 \leq f_{BSL,BARK}$, $f_{BSL,COARSE}$, $f_{BSL,FINE}$, $f_{PRJ,BARK}$, $f_{PRJ,COARSE}$, and $f_{PRJ,FINE} < 1$
Description:	The proportions of bark, coarse, and fine residual biomass, respectively, (unitless; $0 \leq f_{BSL,BARK}$, $f_{BSL,COARSE}$, $f_{BSL,FINE}$, < 1) that comprise $B_{BSL,RESIDUAl,t}$ and $B_{PRJ,RESIDUAl,t}$ for the baseline (BSL) and project (PRJ) cases.
Source of data	(Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)
Value Applied	26.5%, for $f_{BSL,BARK}$ and $f_{PRJ,BARK}$ 42.9%, for $f_{BSL,COARSE}$ and $f_{PRJ,COARSE}$ 30.7%, for $f_{BSL,FINE}$ and $f_{PRJ,FINE}$
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	First used in equations 23a-c and 51a-c for

	the baseline and project cases, respectively

Data/parameter	$f_{BSL,BARKUSE}$, $f_{BSL,COARSEUSE}$, and $f_{BSL,FINEUSE}$ $f_{PRJ,BARKUSE}$, $f_{PRJ,COARSEUSE}$, and $f_{PRJ,FINEUSE}$
Data unit	unitless; $0 \leq f_{BSL,BARKUSE}$, $f_{COARSEUSE}$, $f_{FINEUSE} < 1$
Description:	The proportions of bark, coarse, and fine residual biomass, respectively, allocated to secondary manufacturing, for the baseline (BSL) and project (PRJ) cases.
Source of data	(Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)
Value Applied	100%, for $f_{BSL,BARKUSE}$ and $f_{PRJ,BARKUSE}$ 85%, for $f_{BSL,COARSEUSE}$ and $f_{PRJ,COARSEUSE}$ 42%, for $f_{BSL,FINEUSE}$ and $f_{PRJ,FINEUSE}$
Justification of choice of data or description of measurement methods and procedures applied:	Evidence indicates that on average 80% of bark is combusted for energy, with the remainder used principally as mulch (Perlack et al. 2005). Decay rates for mulch are difficult to estimate. Hence, as a default, all bark ($f_{BSL,BARKUSE}$)is assumed to be 100% combusted, a conservative assumption.
Comments:	First used in equations 23a-c and 51a-c for the baseline and project cases, respectively

Data/parameter	$f_{BSL,PROCESSc}$ and $f_{BSL,PROCESSf}$ $f_{PRJ,PROCESSc}$ and $f_{PRJ,PROCESSf}$
Data unit	unitless; $0 \leq f_{PRJ,PROCESSc}$, $f_{PRJ,PROCESSf} < 1$
Description:	Processing efficiencies of coarse and fine residuals, respectively, in secondary manufacturing, for the baseline (BSL) and project (PRJ) cases.

Source of data	(Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)
Value Applied	85 % to all processing efficiencies
Justification of choice of data or description of measurement methods and procedures applied:	Processing efficiencies of coarse and fine residuals in secondary manufacturing are typically much higher than primary manufacturing.
Comments:	First used in equations 24 and 52 for the baseline and project cases, respectively

Data/parameter	BEF
Data unit	unitless
Description:	Biomass expansion factors
Source of data	Not applicable
Value Applied	No specific BEF are used other than the root:shoot variable described above.
Justification of choice of data or description of measurement methods and procedures applied:	
Comments:	

Data/parameter	Allometric equation parameters
Data unit	Unitless
Description:	Convert height and DBH into biomass of component pools.
Source of data	Allometric equations from (Standish, Manning, & Demaerschalk, 1985) are used to calibrate biomass modeling within FORECAST. See Appendix 5.
Value Applied	Variable by species, see source of data.
Justification of choice of data or description	Used to derive biomass estimates for pools

of measurement methods and procedures applied:	that are difficult to measure.
Comments:	Are used in conjunction with permanent sample plot data to estimate biomass.

3.2. Data and Parameters Monitored

A list of the data and parameters to be included in the monitoring program is provided in Table 8.

Table 8 – Data and Parameters to be Monitored.

Data/parameter	$A_{PRJ,i,}$
Data unit	Ha
Description:	Area of forest land in polygon, *i*
Source of data	Latest NCC Darkwoods GIS spatial inventory data (see Appendix 5).
Description of measurement methods and procedures to be applied:	GIS inventory data updated from GPS coordinates and Remote Sensing data.
Frequency of monitoring/recording:	Annual
Value Applied	
Monitoring equipment:	Visual, satellite, orthophotos
QA/QC procedures to be applied:	Standard GIS QA/QC procedures. Latest NCC Standard Operating Procedures (SOP)
Calculation method:	
Comments:	First used in equations 4 and 32, for the baseline and project cases, respectively.

Data/parameter	$A_{PSP,i}$
Data unit	m^2
Description:	Area of permanent sample plot in polygon, *i*

Source of data	Field measurement
Description of measurement methods and procedures to be applied:	Standard plot layout design
Frequency of monitoring/recording:	Plot measurements are repeated on 5-year intervals
Value Applied	TBD – Fixed area
Monitoring equipment:	GPS, measuring tape
QA/QC procedures to be applied:	GPS of plot center. Latest NCC Standard Operating Procedures (SOP) followed, including check cruising processes.
Calculation method:	GPS positioning of plot centre. Tape measurements to calculate area. Potential use of prisms to derive plots size.
Comments:	

Data/parameter	**$DBH_{i,t}$**
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 Applied	As measured
Monitoring equipment:	DBH tape, data logger
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Measured

Comments:	Used in allometric biomass equations

Data/parameter	**$Height_{i,t}$**
Data unit	M
Description:	Tree height measured for each tree in the sample plots at time, *t*
Source of data	Permanent sample plots
Description of measurement methods and procedures to be applied:	All trees > 1.3 m tall within a permanent sample plot
Frequency of monitoring/recording:	Individual tree measurements are repeated on 5-year intervals
Value Applied	As measured
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).
Calculation method:	Measured
Comments:	Used in allometric biomass equations.

Data/parameter	$B_{AGi,t}$
Data unit	t d.m. ha^{-1}
Description:	Aboveground live tree biomass in polygon, *i*, year, *t*, in the project case.
Source of data	Permanent sample plots.
Description of measurement methods and procedures to be applied:	Calculated from $Height_{i,t}$, $DBH_{i,t}$, and $A_{p,i,t}$
Frequency of monitoring/recording:	Upon establishment of PSP. Every 5 years, thereafter.

Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Above ground biomass for each tree within a permanent sample plot will be estimated from allometric equations using height and dbh (Standish, Manning, & Demaerschalk, 1985). Area-based estimates of biomass will then be derived.
Comments:	Data will be used to validate ex-ante values from inventory + model output

Data/parameter	$B_{BGi,t}$
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 Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Equation 28d
Comments:	Data will be used to validate ex-ante values from inventory + model output

Data/parameter	$B_{TOTALi,t}$
Data unit	t d.m. ha^{-1}
Description:	Total live tree biomass in polygon, *i*, year, *t*, in the project case.
Source of data	Permanent sample plots.
Description of measurement methods and procedures to be applied:	Calculated from $B_{AGi,t}$ and $B_{BGi,t}$
Frequency of monitoring/recording:	Upon establishment of PSP. Every 5 years, thereafter.
Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Equation 28b
Comments:	Data will be used to validate ex-ante values from inventory + model output

Data/parameter	$C_{LB,i,t}$
Data unit	t C ha^{-1}
Description:	Total carbon storage in live tree biomass in polygon, *i*, year, *t*, in the project case.
Source of data	Permanent sample plots.
Description of measurement methods and procedures to be applied:	Calculated from $B_{AGi,t}$ and $B_{BGi,t}$ and CF
Frequency of monitoring/recording:	Upon establishment of PSP. Every 5 years, thereafter.
Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures

	(SOP).
Calculation method:	Equation 28c
Comments:	Data will be used to validate ex-ante values from inventory + model output

Data/parameter	$C_{DOM,i,t}$
Data unit	t C ha^{-1}
Description:	Total carbon storage in dead organic matter in polygon, *i*, year, *t*, in the project case.
Source of data	Permanent sample plots.
Description of measurement methods and procedures to be applied:	Calculated from $DOM_{SNAGi,t}$ and $DOM_{LDWi,t}$ and CF
Frequency of monitoring/recording:	Upon establishment of PSP. Every 5 years, thereafter.
Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Equation 28e
Comments:	Data will be used to validate ex-ante values from inventory + model output

Data/parameter	**Mean tree age**
Data unit	years
Description:	Mean tree age with a given permanent sampling plot in polygon, *i*, for the project case.
Source of data	Permanent sample plots
Description of measurement methods and	Age will be recorded from a sample of

procedures to be applied:	dominant trees within a PSP
Frequency of monitoring/recording:	Upon establishment of permanent a sample plot.
Value Applied	Variable
Monitoring equipment:	Tree coring bit.
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Cores will be analyzed by counting rings following NCC SOP's. .
Comments:	Data will be used to validate and update inventory (see Section 3.4)

Data/parameter	$f_{PRJ,NATURAL,i,t}$
Data unit	unitless ($0 \leq f_{PRJ,NATURAL,i,t} \leq 1$)
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
Description of measurement methods and procedures to be applied:	Height and dbh of dead trees in permanent sample plots will be recorded.
Frequency of monitoring/recording:	Every 5 years
Value Applied	Proportion
Monitoring equipment:	Observation
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Tree mass components calculated from allometric equations (Standish, Manning, & Demaerschalk, 1985)and biomass expansion factors (Li, Kurz, Apps, & Beukema, 2003); (Lehtonen et al. 2004). Mass is converted to its carbon equivalent by multiplying by the

	carbon fraction (0.5). Proportion derived by comparison with calculated estimates of total carbon in polygon, *i*.
Comments:	First used in equations 7 and 35 for the baseline and project cases, respectively.

Data/parameter	**$f_{PRJ,HARVEST,i,t}$**
Data unit	unitless ($0 \leq f_{PRJ,HARVEST,i,t} \leq 1$)
Description:	The proportion of biomass removed by harvesting from polygon, *i*, in year, *t*, in the project case.
Source of data	Darkwoods harvesting records
Description of measurement methods and procedures to be applied:	Volume derived from harvesting records. Wood density (see below) used to derive biomass estimates. Modeled estimates of total biomass in polygon, *i*, used to derive parameter.
Frequency of monitoring/recording:	Every 5 years
Value Applied	Proportion
Monitoring equipment:	
QA/QC procedures to be applied:	Data will be verified by ground-truthing and comparison with remote sensing information.
Calculation method:	Harvested volume is converted to mass by multiplying by average wood density (0.4; Gonzalez 1990). Proportion derived by comparison with modeled estimates of total biomass in polygon, *i*.
Comments:	First used in equations 8 and 36 for the baseline and project cases, respectively.

Data/parameter	$f_{PRJ,DAMAGE,i,t}$
Data unit	unitless ($0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$)
Description:	The proportion of additional biomass removed by 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:	Areal estimate of removals derived from remote sensing data.
Frequency of monitoring/recording:	Annual.
Value Applied	Proportion
Monitoring equipment:	
QA/QC procedures to be applied:	Data will be verified by ground-truthing or remote sensing information.
Calculation method:	Areal estimate of removals is multiplied by average carbon density within a polygon.
Comments:	First used in equations 9 and 37 for the baseline and project cases, respectively.

Data/parameter	$DOM_{SNAG,i,t}$
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Description:	Total 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:	Calculated from $Height_{i,t}$, $DBH_{i,t}$, and $A_{p,i,t}$ of dead trees measured in permanent sample plots described in Section 3
Frequency of monitoring/recording:	Every 5 years
Value Applied	Variable

Monitoring equipment:	Observation
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Standing biomass for all snags within a permanent sample plot will be estimated from allometric equations using height and dbh (Standish, Manning, & Demaerschalk, 1985).
Comments:	

Data/parameter	**$DOM_{LDW,i,t}$**
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Description:	Total mass of dead organic matter contained in lying 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:	Calculated from the line intersect method described in Section 3
Frequency of monitoring/recording:	Every 5 years
Value Applied	Variable
Monitoring equipment:	Observation
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Calculated using the following field-measured parameters $L_{,i,t}$, $d_{n,i,t}$, $D_{LDW,c,i,t}$, and $N_{i,t}$
Comments:	

Data/parameter	$V_{LDW,c}$
Data unit	$m^{-3}\ ha^{-1}$
Description:	Total volume of dead organic matter contained in lying 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:	Calculated from the line transect method described in Section 3
Frequency of monitoring/recording:	Every 5 years
Value Applied	Variable
Monitoring equipment:	Observation
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Calculated using the following field-measured parameters $L_{,i,t}$, $D_{LDW,c,i,t}$, and $N_{i,t}$
Comments:	

Data/parameter	$L_{,i,t}$
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	Tape
Description of measurement methods and procedures to be applied:	Field measurements
Frequency of monitoring/recording:	Plot measurements are repeated on 5-year intervals
Value Applied	Default 100m

Monitoring equipment:	Tape
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	
Comments:	

Data/parameter	$d_{n,i,t}$
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	Field measurement
Description of measurement methods and procedures to be applied:	Lying dead wood must be sampled using the line intersect method (Harmon & Sexton, 1996). Two 50-m lines are 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:	Plot measurements are repeated on 5-year intervals
Value Applied	As measured
Monitoring equipment:	Caliper, diameter tape
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	
Comments:	Used to calculate mass of lying dead wood DOM_{LDW}

Data/parameter	$N_{i,t}$
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:	Plot measurements are repeated on 5-year intervals
Value Applied	As measured
Monitoring equipment:	Visual observation
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	
Comments:	Used to calculate mass of lying dead wood DOM_{LDW}

Data/parameter	$D_{LDW,c,i,t}$
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 sampled.
Description of measurement methods and procedures to be applied:	Pieces of know volume are take to lab, dried and weighed to calculate density
Frequency of monitoring/recording:	Transects are re-sampled every 5 years

Value Applied	As determined from estimated density class- (1) sound , (2) intermediate and (3) rotten.
Monitoring equipment:	Drying oven, scale
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Mass/Volume
Comments:	Used to calculate mass of lying dead wood DOM_{LDW}

Data/parameter	E_M
Data unit	%
Description:	An estimate of model error based on the relative area-weighted difference between of model-predicted values of carbon storage and those values measured in field plots
Source of data	Model output and field data
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	At each verification
Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Equation 60a
Comments:	Used in the calculation of uncertainty factor (Section 4.5)

Data/parameter	E_I
Data unit	%
Description:	An estimate of Inventory sampling error calculated as the 90% confidence limit of the 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
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	At each verification
Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Equation 60c
Comments:	Used in the calculation of uncertainty factor (Section 4.5)

Data/parameter	E_P
Data unit	%
Description:	An estimate of total project error based sum of the model and inventory error terms
Source of data	Model output and field data
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	At each verification
Value Applied	Variable
Monitoring equipment:	

QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	Equation 60f
Comments:	Used in the calculation of uncertainty factor (Section 4.5)

Data/parameter	**$ER_{y,ERR,}$**
Data unit	%
Description:	The uncertainty factor calculated for year 'y' in Section 4.5
Source of data	Model output and field data
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	At each verification
Value Applied	Variable
Monitoring equipment:	
QA/QC procedures to be applied:	Latest NCC Standard Operating Procedures (SOP).
Calculation method:	As shown in Table 19.
Comments:	Used in the calculation of VCUs (Section 4.4)

3.3. Description of the Monitoring Plan

The objective of the project monitoring plan 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.

Ongoing monitoring is the primary operational task for the project, and such will be a part of the role of the carbon project manager and NCC onsite supervisor.

Darkwoods Pre-Validation Monitoring Status:

As detailed throughout this document (and outlined in more detail in the uncertainty factor calculations in Section 4.5), the Darkwoods property has excellent historical spatial and forest inventory data from the previous forest management company which has been updated and upgraded annually since the project start date of April, 2008 (Kleine, 1992); (Thrower & Orr-Ewing, 2004); (BC MOF, 2005); (Ennis, 2010); (Nature Conservancy of Canada, 2010).

The Darkwoods property also has an existing documented monitoring protocol and field plot network which is designed for biodiversity monitoring and management. This NCC biodiversity program is extensively documented and outlines standard procedures used across all NCC properties (Durand, 2003). NCC deployed this monitoring program beginning prior to the Darkwoods acquisition closing, and have undertaken extensive annual monitoring activities which are directly applicable to the carbon project monitoring needs in 2008, 2009, and 2010 (Gao, 2010); (Giesbrecht, Field, Wilson, & Ennis, 2010); (Nature Conservancy of Canada, 2010); (Ennis, 2010).

All historical and NCC monitoring to date has been incorporated into the property inventory and GIS data updates used in this project design document.

However, due to the uncertainties of the specific details of the forest carbon project monitoring program and the NCC planning cycles, some elements of the monitoring program remain to be finalized and implemented in the 2011 field season, after the initial validation has confirmed the monitoring requirements. Particularly this includes the final design and implementation of the forest carbon permanent field plot network.

The Darkwoods forest carbon monitoring program will be fully integrated into the existing NCC standard operating procedures, property stewardship plans, and field season plans in 2011, with the plot network design finalized and implemented in the 2011 field season (June – September).

Darkwoods Monitoring Program

Fundamentally, the Darkwoods project contains 4 monitoring activities which will be reported at each verification in a Monitoring Report:

1. Annual Inventory Change Monitoring

At a minimum, NCC will undertake and document an annual update to the current state of the forest inventory data on the property. This will be undertaken using property helicopter observation flight(s) covering the entire property, in combination with individual ground observations and measurements from specific disturbance events (either field measured using helicopter or ground-based GPS, or other remote sensing methods). At minimum, the inventory will be updated for (at a minimum scale of 4ha):

   a. Natural disturbance events >4 ha (i.e. fires, high mortality pest and disease areas, blowdown areas, slides, etc.).

b. Planned project activities (i.e. harvests, road construction, reforestation, etc.)
c. Unplanned man-made disturbances (i.e. non-*de minimis* illegal or unplanned harvests, etc., if applicable)

These monitored spatial elements will be updated in the NCC Darkwoods GIS database annually according to NCC SOP's for data collection and handling.

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 verification by updating the timber harvest levels on other regional NCC forest properties in Table 15. Market leakage calculations will be updated at each verification using the baseline scenario harvest levels and latest ex-post project activities data (Table 16).

3. Field plot monitoring

At minimum, NCC will update the inventory, uncertainty calculations, and carbon calculations from field plot measurement data as outlined in Sections 3.4 and 4.5. The following sections follow the methodology document, and outline the field plot monitoring plan elements:

Stratification of Land Area

The project landbase has been stratified using an analysis unit approach as described in Section 4.1. It is expected the project may refine the analysis unit criteria over time, which may involve redefining analysis unit criteria or polygons allocation criteria.

Post-stratification

The inventory polygons will be updated if necessary following ground-truthing with field plots, or as the result of annual monitoring for natural and man-made disturbances and other inventory updates.

Type and Number of Sampling Plots:

Plot type

The Darkwoods project will employ a permanent fixed and geo-located plot network for monitoring changes in stand level forest biomass stocks over time. Where possible, these plots will be located at the same plot locations as the existing biodiversity field plot network, or in independently locations as necessary for carbon project strata plot coverage.

The project may utilize supplemental temporary plots as necessary to provide additional coverage or accuracy refinement in a cost effective manner.

Number of Plots, Precision, and Sample Size

The plot network design is currently being developed by NCC for integration into the existing NCC biodiversity monitoring programs, as part of their existing annual field planning process in 2011.

The target will be to establish sufficient plots such that the net change in carbon stocks within a given analysis unit will lie within 10 percent of the true value of the mean at the 90-percent confidence level.

It is anticipated that for budgetary, field capacity, and ongoing workflow purposes, the plot network will be developed over a 5 year period. Samples sizes will be evaluated for suitability following the initial monitoring period (2011 field season) and then adjusted as appropriate to achieve the desired level of precision. Temporary plots and or additional permanent plots may be used to supplement sampling in particular strata, or if plots are damaged or lost for any reason.

Sampling Design

Plot Layout

Permanent plot locations will be determined using a combination of systematic and random locations on an analysis unit basis. Some location modifications may be made due to accessibility issues.

Size and Shape of Sample Plots

The project may deploy several variations of size and shape of the sample plots as the carbon plot network is designed and integrated the biodiversity monitoring wherever feasible. It is anticipated that all permanent plots will be fixed area. Any supplemental temporary plots may use different measurement techniques, depending on the specific target purpose (i.e. prism methods versus fixed area).

Carbon pools to be calculated from plot measurements:

- Live trees: above ground
- Standing dead trees: above ground
- Lying dead wood

Measurement and Data Analysis Techniques

Trees

Tree biomass will be estimated from equations that relate biomass to DBH and/or height. Biomass equations have been developed for 22 commercial tree species in British Columbia that includes those species typical of the Darkwoods property (Standish, Manning, & Demaerschalk, 1985). These equations will be used in conjunction with the DBH and height data measured within the plot network to calculate total aboveground biomass within each plot (t ha^{-1}).

Aboveground biomass, B_{AG}, will be measured in each permanent sample plot. Specifically, all living trees within a sample plot with dbh ≥ 5cm will be measured including height (m) and diameter (cm) at breast height (1.3m). Belowground biomass (t ha^{-1}) will be calculated using equations in (Li, Kurz, Apps, & Beukema, 2003) (see Appendix 2, equations 5b and 33b, for the baseline and project case, respectively). Tree-level measurements (kg biomass per tree) will be converted to area-based stand-level measurements (t ha^{-1}) and a conversion factor will then be used to convert biomass into carbon.

Dead organic matter

The mass of lying dead wood, DOM_{LDW}, will be measured in the permanent sampling plots using the line intersect method. Two 50-m sections of line will be placed at right angles across the plot center (note that the final DOM sample length may be different, due to integration with existing DOM measurements in existing NCC biodiversity plots). To allow re-measurement of the same deadwood transect, the line will be physically field marked. The diameters of all pieces of wood $\geq$ 5 cm diameter that intersect the line are measured and the density class noted.

Each piece of deadwood will be assigned to one of three density classes[8], sound (1), intermediate (2), and rotten (3). The volume per unit area is calculated for each density class using Equations 61a-c described in the VCS methodology document. For transparency, the equation numbers used here are the same as those used in the methodology document.

$$V_{LDW,c} = \pi^2 * [(d_1^2 + d_2^2 \ldots d_n^2)/8L] \qquad (60a)$$

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:

$$M_{LDW,c} = V_{LDW,c} * D_{LDW,c} \qquad (60b)$$

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:

[8] Note, the project may choose to employ alternative DOM density classification methods based on other published methods currently in use in biodiversity plot networks. In the meantime, the PDD includes the methodology default procedure.

$$DOM_{LDW} = \sum M_{LDW,c} \quad (60c)$$

Where,

$M_{LDW,c}$ = the mass of LDW in density class, *c* (t ha^{-1}), is as calculated in 60b.

A key step in this method is classifying the dead wood into its correct density class and then sampling a sufficient number of logs in each class to derive a reasonable estimate of wood density. Ideally at least 10 logs should be sampled for each density class (Pearson, Brown, & Birdsey, 2007). For a given piece of deadwood, a field characterization of its density class can be made by striking it with a strong sharp blade. If the blade bounces off it is classed as sound, if it enters slightly it is of intermediate density, and if the wood falls apart it is rotten. Samples of deadwood in each class will then be collected to determine their density in the laboratory, after drying for 48 hours. Mass of dead wood is calculated as the product of volume per density class and the wood density for that class (as per equations 60 a-c)[9].

The total mass of lying dead wood for a given polygon should be calculated as the average of all transects measured for that polygon. This value is then used for calculations of carbon storage in dead organic matter ($DOM_{LDW,i,t}$).

Standing deadwood should be measured in the same plots as used for measuring live trees. Snags suitability is defined using the same criteria for live trees. However, measurement records will differ slightly from those for live trees, depending on the degree to which branches and twigs are present. If the snag possesses branches and twigs and its structure resembles a live tree (but without leaves), this should be indicated in the field data records. From the measurement of DBH, the amount of biomass can then be estimated using the appropriate allometric biomass equation and subtracting the biomass of leaves. Snags may possess only a fraction of their full complement of small and large branches, only large branches, or no branches at all. These conditions will be recorded in the field measurements. Branches will then be classified in proportion to the size of the standing dead tree so that the total biomass can be reduced accordingly to account for less of the dead tree remaining. When a tree has no branches and is only the bole, biomass can be estimated from measurements of its basal diameter and height and an estimate of top diameter.

Once the biomass of standing dead trees within a plot has been calculated, the tree-level measurements (kg biomass per tree) must be converted to area-based stand-level measurements (t ha^{-1}) by summing the total mass (aboveground + belowground) of all the standing dead trees within a sample plot (converting kg to t) and dividing the sum by the plot area in ha. All plots within a particular polygon should be averaged to get an average

[9] Note, the project may choose to utilize different dead biomass measurement techniques based on other published methods in order to integrate with biodiversity sampling plots.

estimate of stand-level live biomass (t ha^{-1}). This value is an estimate of the average snag biomass variable ($DOM_{SNAG,i,t}$).

4. Quality Assurance/Quality Control Measures (QA/QC)

NCC is currently in the process of updating existing field monitoring processes to reflect forest carbon monitoring requirements. The updated NCC standard operating procedures include or will include procedures for: (1) collecting reliable field measurements; (2) verifying laboratory procedures; (3) verifying data entry and analysis techniques; and (4) data maintenance and archiving. Standard operating procedures and guidelines detailed in Pearson et al (2007) and the IPCC GPG LULUCF (IPCC 2003) will be used as the basis for developing the carbon QA/QC components.

QA/QC for Field Measurements

NCC existing Standard Operating Procedures (SOP) are being updated and adapted to include the field carbon measurement procedures to ensure carbon field measurements are made accurately and reliably.

Field crews will receive annual training and be fully cognizant of all procedures and the importance of collecting accurate data.

At a minimum, 10% of the measured field plots will be check-cruised using blind checks with 100% re-measurement of all variables. Minimum thresholds in measurement error are as follows:

1. DBH (standing live and dead): +/- 10% standard error at 90% confidence interval

2. Height (standing live and dead): +/- 10% standard error at 90% confidence interval

3. Tree Count: +/- 10% standard error at 90% confidence interval

These are minimum thresholds for monitoring plot field accuracy, and will require re-measurement or re-establishment of plots as necessary to meet these requirements.

QA/QC for Laboratory Measurements

SOPs will be prepared and followed for each laboratory analyses. The SOP for laboratory measurements will include calibrating standards for instruments used. Where practical, 10 percent of the samples will be re-analyzed/re-weighed following the check cruise thresholds outlined above.

QA/QC for Data Entry

NCC standard procedures and ongoing QA/QC programs for data will be followed to ensure proper entry of data from paper to electronic format. If there are anomalies that cannot be resolved, the plot will be re-measured or omitted from the analysis.

QA/QC for Data Archiving

NCC has document control procedures which adapted to cover the carbon monitoring data, including retaining the following for 2 years past the duration of the project:

1. Original copies of the field measurement, check plots, laboratory data, and related data summaries will be maintained in their original and electronic form
2. Copies of all monitoring data analyses, models, model input and output files, carbon calculations required for this methodology, , GIS inventory dated by year, and copies of the monitoring reports.
3. Records of the version and relevant change history of software or data storage media changed between monitoring periods.

Frequency of monitoring

Given the dynamics of forest processes, permanent plots will be re-measured at intervals of not longer than 5 years (beginning at their date of first measurement). As noted, permanent plots may be established over multiple years, and such re-measurement schedules will be tracked on for each plot based on its establishment date.

Inventory data will be update annually, including the results of project activities, natural disturbances, and other changes to the inventory, at a minimum resolution of 4 hectares.

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 3.4;
2. update the leakage calculations in Section 4.3;
3. update error estimates used in the calculation of the uncertainty factor as per Section 4.5; and,
4. Update and improve calculations of carbon stocks in Section 4.2 and possibly Section 4.1 as described in Sections 3.4 and 4.2.

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 should 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.

3.4. Ex-Post Calculations of Carbon Stocks

Ex-post carbon stocks will be determined (at a maximum interval of 5 years) by updating the project's forest carbon inventory from monitoring data.

This will be done by:

1. Incorporating any new forest inventory data (including data from new or re-measured sampling plots, and other monitored data as outlined in Section 3.3) obtained during the previous year into the inventory estimate.
2. Updating the forest inventory for spatial monitoring results, including annual project activities and/or disturbances that have occurred during the monitoring period.
3. Using the selected model(s) to project prior-year data from the forest inventory to the current reporting year (as described in Section 4.2).
4. Comparing estimates of live biomass and dead organic matter in polygons and calculated from monitoring activities against current-year modeled values in the project scenario.
5. Making calibration adjustments to models and/or parameters such that the fit between the equivalent modeled and measured variables meets targets (see description of stratification in Section 3).
6. If any changes are made to the model assumptions or parameters used in Section 4.2, the calculation of baseline emissions (from the current date forward, Section 4.1) will be redone using the updated model(s) and parameter sets.
7. Calculating the error terms for use in calculating the uncertainty factor (Section 4.5).

After each monitoring event, actual (ex-post) annual net carbon stocks will be calculated using the following equations from the VCS methodology document. For transparency, the equation numbers used here are the same as those used in the methodology document.

$$C_{ACTUAL,i,t} = C_{LB,i,t} + C_{DOM,i,t} \tag{28a}$$

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

Average aboveground biomass for measured stratum, *i,* in year, *t* ($B_{AG,i,t}$) will be determined by converting the aboveground, tree-level measurements (kg biomass per tree) described in Section 3.3 to area-based, stand-level measurements (t ha^{-1}). This is achieved by summing the aboveground biomass of all the trees within a sample plot, converting kg to t, and then dividing the sum by the plot area in ha. All plots within a particular stratum will be averaged to get an average estimate of stand-level aboveground biomass (t ha^{-1}). Once the average aboveground biomass has been determined for each measured stratum, belowground biomass is estimated by multiplying the aboveground biomass by the root:shoot ratio, R_i (Equation 28d) and the two are summed to determine total stand-level live biomass for measured stratum i, time t, ($B_{TOTAL,i,t}$). R_i is described in Section 4.1. Finally, the average measured carbon stock in living tree biomass for measured stratum *i*, time *t*, ($C_{LB,i,t}$) is calculated as shown in Equation 28c. This value of $B_{BG,i,t}$ will be compared to the equivalent calculation of live biomass ($LB_{PRJ,i,t}$) calculated in the project scenario (Section 4.2) (see the section on updating the modeled project carbon balance below).

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

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

where:

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

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

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

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

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

Dead organic matter

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

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

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 stratum, *i,* in year, *t* ($DOM_{LDW,i,t}$) is calculated according to Equations 61a-c in Section 3.3. The value of $DOM_{LDW,i,t}$ will be compared to the equivalent calculation of lying dead wood mass ($LDW_{PRJ,i,t}$) in the project scenario (Section 4.2) (see comparison method and steps below).

The average quantity of dead organic matter contained in standing snags for measured stratum, *i,* in year, *t* ($DOM_{SNAG,i,t}$ is calculated by summing the mass (aboveground only) of all the measured standing dead trees within a sample plot (converting kg to t) and dividing the sum by the plot area in ha (See Section 3.3). The belowground component of snags is treated as dead below ground biomass (See Section 4.2) and is not directly measured. All plots within a particular stratum should be averaged to get an average estimate of $DOM_{SNAG,i,t}$. The value of $DOM_{SNAG,i,t}$ will be compared to the equivalent calculation of standing dead tree mass ($SNAG_{PRJ,i,t}$) in the project scenario (Section 4.2) (see the section on updating the modeled project carbon balance below).

Updating the Modeled Project Carbon Balance

The precision of the modeled carbon stocks will be evaluated for each analysis unit using the method described for determining mean model error in Section 4.5 (Equations 60a,b). If the model error term is > 10% the proponents will attempt to improve the model fit by re-evaluating and adjusting model parameters until model error term is < 10%. Model error terms greater than 10% (after model adjustments) will be penalized according the calculation of the uncertainty factor described in Section 4.5. If changes in model assumptions or parameters are made, the baseline scenario (from the next year forward) must be recalculated using the revised model (Section 4.1).

4. Ex-Ante Calculation of GHG Emission Reductions and Removals:

4.1. Baseline Emissions

The Darkwoods project meets the Valid Starting Inventory Requirements from the methodology (*methodology criteria in italics*):

1. *Pertaining directly to the entire project area; and,*

The Darkwoods inventory data covers the entire project area, and meets this criteria.

2. *Created, updated, or validated <10 years ago; and,*

The latest base inventory was created in 1999, followed by updates in 2004 and 2008. The inventory has undergone additional updated in 2008, 2009, and 2010. The inventory meets this criteria.

3. *Documentation is available describing the methods used to create, update, or otherwise validate the starting inventory, including statistical analysis, field data, and/or other evidence.*

The inventory methods and related inventory updates are described in (Pluto Darkwoods Corp., 1992), (Thrower & Orr-Ewing, 2004), (BC MOF, 2005), (Nature Conservancy of Canada, 2010), and (Ennis, 2010); which therefore meets this criteria.

Baseline Scenario Area Stratification

STEP 1 – Stratify to create homogeneous units

The Darkwoods forest inventory is contained within a robust Geographic Information System dataset, which in broken into more than 3,500 individual polygons. The polygons are homogeneous based on forest cover species, stand age, productivity class, and other stand attributes.

Development of Analysis Units

Due to the complexity of the Darkwoods forest inventory, it was necessary to stratify the inventory into relatively homogeneous analysis units (AUs) from the perspective of similarity in biomass production. A total of 17 different analysis units were created (stratified by leading species and productivity class) to represent existing naturally originated stands and managed stands within the Darkwoods spatial forest inventory. The criteria used to assign analysis units to each forested polygon within the forest cover inventory database are presented in and shown spatially in .

Each of these natural stand analysis units was assigned a future managed stand analysis unit to which it would transition following a harvest event in the project or baseline scenario (). The future managed stand units have levels of site productivity that are consistent with their parent natural stand units. There are relatively fewer managed stand analysis units because a smaller variety of species are planted relatively to those in the diverse natural stands in the project area.

A third category of analysis unit was developed to represent the development of stands after harvest that were not replanted. These stands are assumed to regenerate naturally, and because of a delay in regeneration (a typical characteristic), they possess lower stocking densities relative to planted managed stands.

This stratification process resulted in three basic stand analysis unit types; natural stands, planted managed stands (these include current managed stands ≤ 40 years old), and harvested stands that were not re-planted. These unique analysis units were subsequently assigned to individual polygons within the Darkwoods inventory database within the FPS-ATLAS model (described below).

A fourth category of stand analysis unit was then created to represent the impact of mountain pine beetle attack and related pine mortality in Lodgepole pine-leading stand types (AUs 105 and 106). A mountain pine beetle (MPB) epidemic has swept across the interior of British Columbia over the past decade and affected most of the mature pine stands within the region. Pine-dominated stands within the Darkwoods property were initially attacked beginning in 2003-2004. Since then there has been significant mortality in these stands. To account for this impact in the modeling, all of the pine-leading inventory polygons (labeled as AU 105 or 106) that were not harvested by 2010 were transferred to an associated MPB curve based on the originating analysis unit and the age of the stand at the time of mortality. Non-pine trees within these stands remained intact and continue to grow in the linked MPB analysis unit. These MPB analysis units also include additional regeneration with a 10-year delay related to the breakup of the dead pine trees. The model keeps track of the carbon contained in the dead and dying wood created from the MPB-induced mortality.

The specific regeneration assumptions for each of the analysis units are shown in Table 10.

Once the analysis units were created and assigned to the FPS-ATLAS inventory database, FORECAST was used to create a series of stand attribute curves for each unit including merchantable volume and carbon storage by ecosystem pool. Stand attribute curves, as described above, were consolidated within an MS Access database that was linked to the FPS-ATLAS model using specific inventory polygon IDs (see Figure 8).

Table 9 – Analysis Unit Criteria Descriptions for Natural Stands (100 series) and Managed Stands (200 series), and Resulting Total Area for Each Analysis Unit.

AU	Description	Lead Sp.[10]	Age[11]	Productivity class	Site index Range[12]	Average Site Index[13]	Area Operable (ha)	Area Inoperable (ha)
999	no trees							7018.6
101	Natural F / L_med	F / L	>40	med	13-17	15.2	1909.7	419.4
102	Natural F / L_good	F / L	>40	good	≥17	21.0	2589.8	91.0
103	Natural B / L / F / S_poor	B / L / F / S	>40	poor	<13 ≤13 (S)	9.8	7945.2	7742.8
104	Natural B_med	B	>40	med	≥13	15.5	5202.2	294.5
105	Natural P_poor	P	>40	poor	<13	10.6	1839.3	489.9
106	Natural P_med	P	>40	med	≥13	16.8	2601.7	557.7
107	Natural C / H_med-good	C / H	>40	med-good	all	16.9	2333.4	78.6
108	Natural S_med	S	>40	med	13-16	15.2	2778.0	240.2
109	Natural S_good	S	>40	good	≥16	21.6	1023.2	9.2
110	Natural E / A_Med	E / A	>40	Med	all	15.8	15.3	0.0
201	Managed F / L_med	F / L	<=40	med	13-17	16.0	119.7	0.0
202	Managed F / L_good	F / L	<=40	good	≥17	21.7	326.5	1.2
203	Managed S/P/B poor	S/P/B	<=40	poor	<13	8.9	2068.8	586.1
204	Managed S/P/B Med	S/P/B	<=40	med	≥13	15.5	3615.0	4.1
207	Managed C / H_med-good	C/H	<=40	med-good	all	16.9	231.9	7.6
209	Managed S_good	S		good	≥16	20.0	2649.8	1.5
210	Natural E / A_Med	E / A		Med		n/a	0.0	0.0

[1] 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.
[2] Age group separates managed from natural stands.
[3] Site Index based on ht at breast-height age 50. The average shown is for the operable landbase.
[3] Site Index based on ht at breast-height age 50.

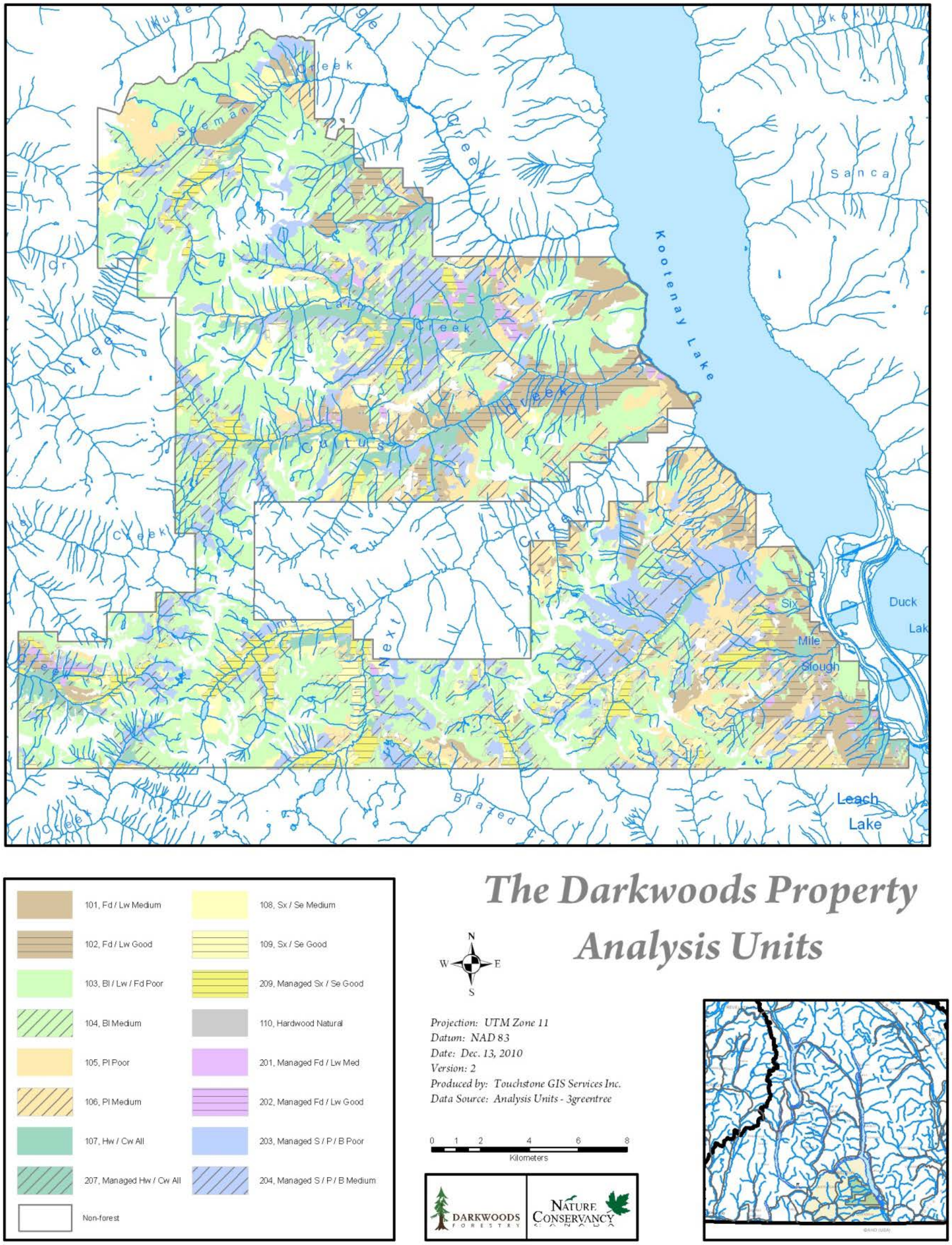

Figure 6. Map of the Darkwoods property showing the spatial distribution of analysis units at project initiation.

Table 10 - FORECAST Regeneration Assumptions by Analysis Units. Post-Harvest transitions are shown for: planting after harvest (Trans. Path 1; used in the project scenario) and no planting after harvest (Trans. Path 2; used in the baseline scenario).

AU	Description[14]	Sp 1	Sp 2	Sp 3	Sp1 %	Sp2 %	Sp3 %	Stems / ha	Regen delay (y)	Trans. Path 1	Trans. Path2
Natural Stands											
101	F / L_med	Fd	Pl		75	25		1200	4	201	301
102	F / L_good	Fd	Hw	Cw	70	20	10	1600	3	202	302
103	B / L / F_poor	Bl	Se		75	25		1200	6	203	303
104	B_med	Bl	Se		65	35		1800	4	204	304
105	P_poor	Pl	Bl		70	30		1900	3	203	303
106	P_med	Pl	Se		70	30		2000	3	204	304
107	C / H_med-good	Hw	Cw		60	40		2000	3	207	307
108	S_med	Se	Bl	Pl	60	20	20	1500	6	204	304
109	S_good	Sx	Fd	Cw	50	30	20	1600	5	209	309
110	E / A_Med	Ep	At		75	25		2000	2	210	310
Planted Managed Stands											
201	F / L_med	Fd	Pl		75	25		1500	1	201	301
202	F / L_good	Fd	Hw	Cw	70	20	10	2000	1	202	302
203	S/P/B poor	Se	Bl	Pl	40	35	25	1600	1	203	303
204	S/P/B Med	Se	Bl	Pl	40	35	25	1600	1	204	304
207	C / H_med-good	Hw	Cw		60	40		2000	1	207	307
209	S_good	Sx	Fd	Cw	50	30	20	2000	1	209	309
210	E / A_Med	Ep	At		75	25		2000	1	210	310
Harvest no plant											
301	F / L_med	Fd	Pl		75	25		1000	6	301	301
302	F / L_good	Fd	Hw	Cw	70	20	10	1200	5	302	302
303	S/P/B poor	Se	Bl	Pl	40	35	25	800	8	303	303
304	S/P/B Med	Se	Bl	Pl	40	35	25	1000	6	304	304
307	C / H_med-good	Hw	Cw		60	40		1400	5	307	307
309	S_good	Sx	Fd	Cw	50	30	20	1000	7	309	309
310	E / A_Med	Ep	At		75	25		2000	1	310	310
Mountain Pine Beetle attacked stands											
405a	Origin 105 >85y	Pl	Bl		70	30		800	10	205	305
405b	Origin 105 <=85y	Pl	Se		70	30		900	10	206	306
406a	Origin 105 >85y	Pl	Bl		70	30		800	10	205	305
406b	Origin 105 <=85y	Pl	Se		70	30		900	10	206	306

[14] In the case of Mountain Pine Beetle attacked stands the originating stand AU and age at MPB attacked are specified.

STEP 2 – Identify areas eligible for specific management activities

The portion of the larger Darkwoods property area included within the baseline (and project) analysis was defined using a series of steps to identify stands that would be economically operable. The first step in this process was to define the productive landbase. This was determined by removing from the GIS database areas where trees were unable to grow, non-forested areas, buffers around creeks (3m each side of the channel), buffers around existing roads (5m buffer each side of centerline), and otherwise unreachable or uneconomic timber, as defined according to British Columbia Ministry of Forest and Range methodology. This resulted in about 68% of the area (37,250 ha) classified as operable.

Within the operable area further limitations were imposed with respect to stands that could be harvested. 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 (the high number of senescent trees in these stands render them uneconomical to harvest); or 2) stands in which the volume was less than $150 m^3 ha^{-1}$ (volumes are too low to be harvested economically).

The same operable areas and excluded stand types were used in both the project and baseline scenarios. However, in contrast to the baseline scenario, in the project scenario the additional Environmental Protection Areas (EPA's)[15] were excluded from harvesting (~ 8,600 ha. These EPA areas were identified and located by Pluto Darkwoods, and transferred to NCC. These are voluntary protection areas with no regulatory or legal requirement or expectation of protection which were retained by NCC as a constraint on project activities in the project scenario only.

The resulting land base for both scenarios is spatially identified in Darkwoods GIS data, and was used as a spatially explicit data set for FORECAST/ATLAS simulation. Figure 7 shows the spatial distribution of the operable forest land base for the Darkwoods property, while the actual area breakdown by stand type is provided in Table 2.

[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.

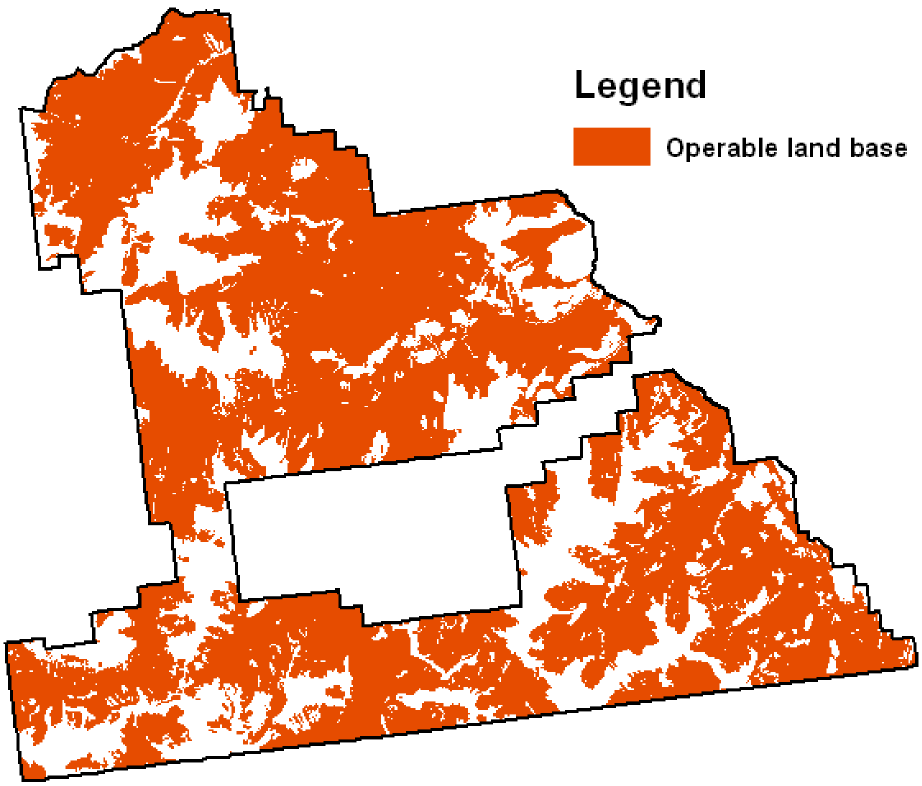

Figure 7 - Darkwoods Timber Operability Map.

Model Selection and Use

The FORECAST model (v8.4) and FPS-ATLAS model (v6.0.2.0) were used in conjunction with a Microsoft Excel spreadsheet model (Darkwoods Carbon Model v.8.7, as referenced in Appendix 5).

The combination of FORECAST and FPS-ATLAS meet all six criteria for model selection in the methodology document. In addition, these tools also meet preferred criteria #7 and #8. Further details about these models and their application in the Darkwoods Carbon Project are provided in the sections below.

Calculating the Baseline Carbon Balance

The carbon accounting approach employed for the Darkwoods carbon project utilized the management interface and biomass output from a locally calibrated stand-level model, FORECAST, in conjunction with a forest-level harvest scheduling model, FPS-ATLAS.

FORECAST was used to simulate the temporal changes in carbon storage of different ecosystem pools for each of 17 stand-level analysis units (further details below). The stand-level output from FORECAST was linked to the FPS-ATLAS model using a shared database library approach. This allowed the FPS-ATLAS landscape model to obtain information on the carbon pools associated with all of the inventory polygons that comprise the Darkwoods GIS database. FPS-ATLAS provided the framework and options for simulating sequential harvesting on the landbase, as well as large-scale natural disturbance events for the baseline and project scenarios. In addition, it generated summary output of the carbon balance across the project area over time. Figure 8 provides an overview of the model linkages and their relationship to input sources and output data.

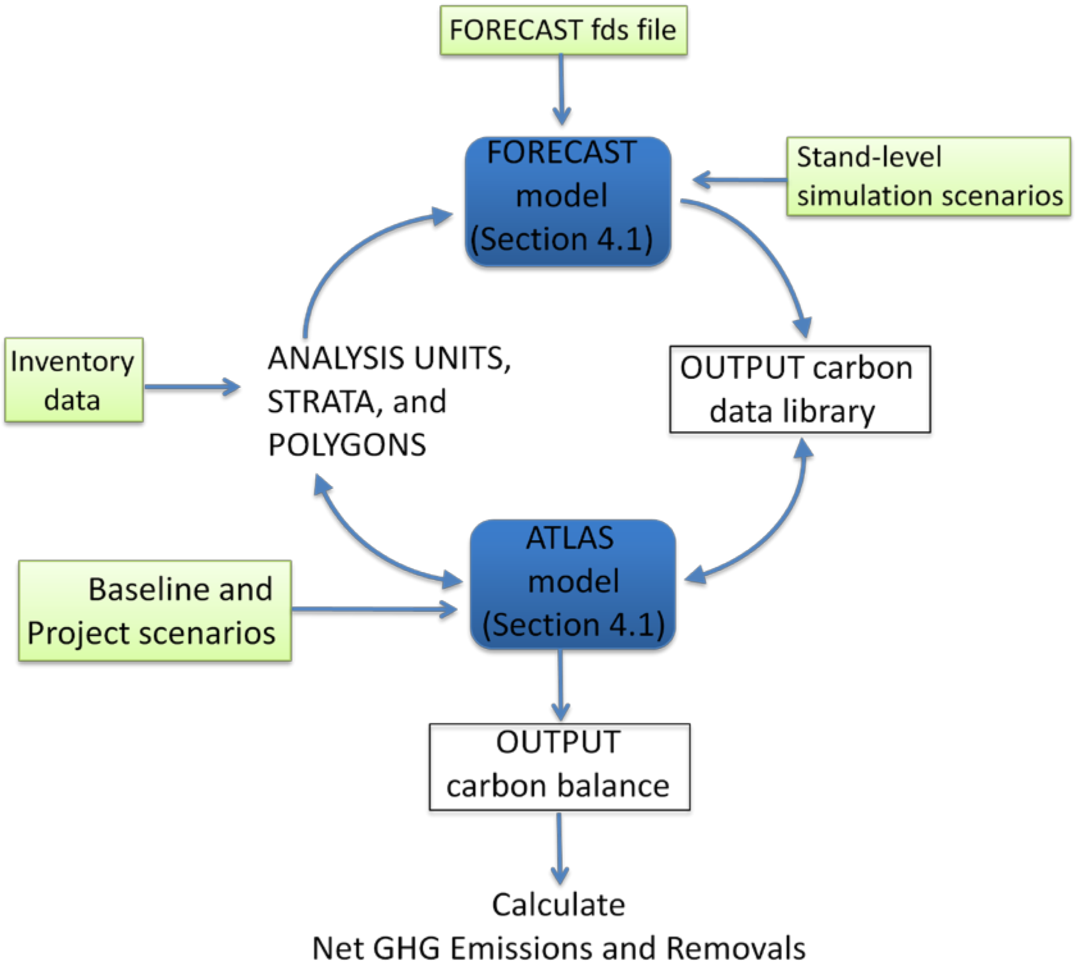

Figure 8 - Model Interaction, input sources (green boxes) and outputs.

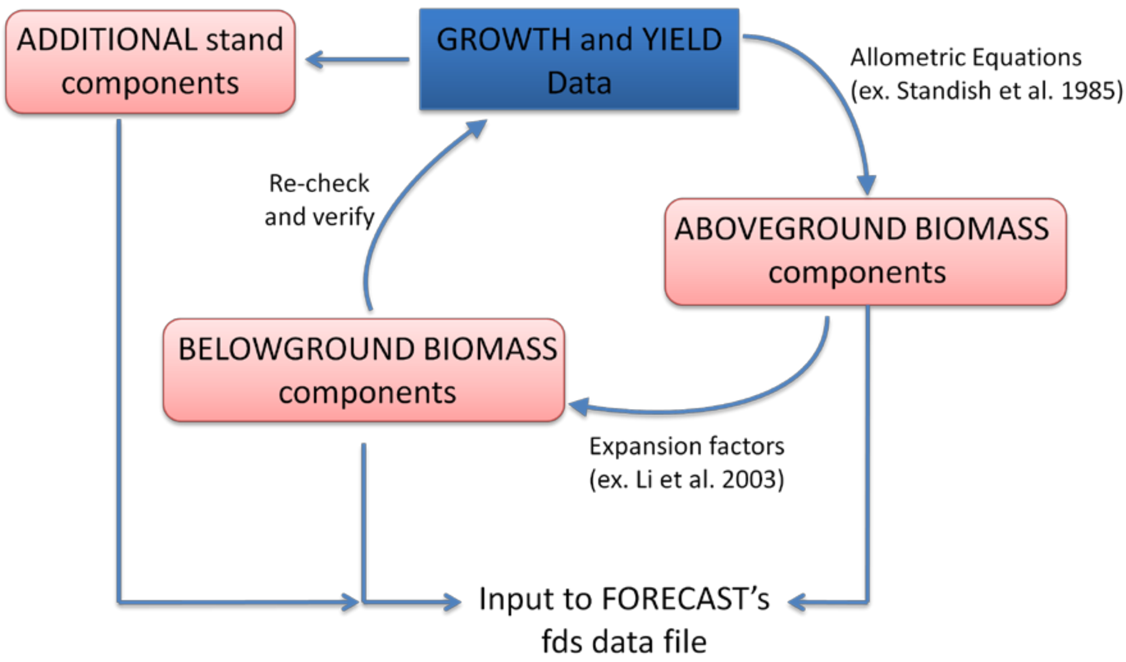

Figure 9 - Creating the calibration data set for FORECAST simulations (as input into an fds file)[16].

Stand-Level Calculations of Carbon Storage Using FORECAST

FORECAST is a management-oriented, stand-level forest ecosystem dynamics simulator. It was constructed using a hybrid modeling approach whereby the rates of ecological processes are calculated from a combination of historical bioassay data (biomass accumulation in component pools, stand density, etc.) and calculated measures of specific ecosystem variables (decomposition rates, foliar N efficiency, nutrient uptake demand, for example). This is achieved by relating 'biologically active' biomass components (foliage and small roots) to calculations of nutrient uptake, the capture of light energy, and net primary production (see (Seely, Kimmins, Welham, & Scoullar, 1999); (Kimmins, Mailly, & Seely, 1999)). Since FORECAST is a biomass-based model, its core simulations routines reflect the accumulation and decay of all the principal biomass pools within a forest ecosystem, including foliage, branches, stemwood, bark, coarse and fine roots, and the various pools of dead organic matter (litter, snags & logs). As such it is well suited to carbon budget assessments (see, for example, (Seely, Welham, & Kimmins, 2002). Further detailed information on FORECAST, its structure and simulation algorithms, and application can also be found at www.forestry.ubc.ca/ecomodels/moddev/forecast/forecast.htm.

[16] Data derived from approved growth and yield models are used in conjunction with allometric volume equations and expansion factors to generate biomass estimates for living organic matter pools. Typically, growth and yield output provides information on stand characteristics (tree density, for example) that are also used as input to the fds data file.

FORECAST has been subject to on-going development and testing for over 3 decades and its application documented in almost 40 refereed publications. The model has been applied in many parts of Canada, Europe (Norway, Spain, and the UK), China, and Cuba. The British Columbia Ministry of Forests has approved it in British Columbia as a model for carbon budget assessments.

FORECAST has been calibrated with a dataset that reflects the autecology and vegetation dynamics of the tree species typical of the project area. These are Douglas-fir (*Pseudotsuga menziesii*), Western larch (*Larix occidentalis*), Lodgepole pine (*Pinus contorta*), Western red cedar (*Thuja plicata*), Western hemlock (*Tsuga heterophylla*), Subalpine fir (*Abies lasiocarpa*), White spruce (*Picea glauca*), Trembling aspen (*Populus tremuloides*), and Paper birch (*Betula papyrifera*).

Assembling a calibration dataset for FORECAST typically begins with a set of growth and yield curves that predict volume accumulation over time for stands of varying site quality. In the case of the Darkwoods project, these curves were derived from the approved BC Ministry of Forests and Range models, VDYP (available at www.for.gov.bc.ca/hts/vdyp/) and TIPSY (www.for.gov.bc.ca/hre/gymodels/tipsy/index.htm). The curves were first converted into their aboveground biomass equivalents through a series of allometric equations (for example, (Standish, Manning, & Demaerschalk, 1985)). An example of this exercise is provided in the file TIPSY Fd 18 output with Standish equations.xls. Next, belowground data was derived using biomass expansion factors, an example of which is provided in the file FORECAST calibration data example.xls. Additional calibration data associated with population dynamics were derived from the growth and yield models and also entered into the calibration data set. Figure 9 provides and overview of the calibration process. An example of the calibration dataset for Douglas-fir, and used in the Darkwoods project is referenced in Appendix 5. Simulated biomass output from FORECAST is converted to its carbon equivalent using a simple multiplier (0.5; see Appendix 2). An example of FORECAST output (expressed in terms of carbon units) is contained in the file FORECAST output example.xls; referenced in Appendix 5.

Simulation of Landscape-Scale Carbon Storage Using FPS-ATLAS

FPS-ATLAS is a forest-level harvest simulation model. The model is applied using a spatial forest inventory comprised of stand polygons, and each of these is linked to one of the age-dependent stand attribute tables according to the assigned analysis unit (Table 9; Figure 8). These attributes tables (produced by FORECAST) contain information describing merchantable volume (m^3 ha^{-1}) and carbon storage within each ecosystem pool (t ha^{-1}) for annual time steps from age 1 to 250 years (see Appendix 5). FPS-ATLAS is spatially explicit with respect to forest polygons and road networks and it can schedule harvests according to a broad range of spatial and temporal objectives (for example, harvest flows, stand age and volume, opening size, seral stage distributions and patch size distributions).

At each time step, polygons are first ranked according to a cutting priority (i.e., oldest first, etc.) and then harvested from this queue subject to constraints designed to meet forest level objectives (i.e. minimum volume, opening size, seral stage targets, etc.). Polygons are harvested until a constraint becomes binding, the harvest queue is exhausted, or the period harvest target is met. Natural disturbance events can also be scheduled by the user to occur within a given time step. The forest is then aged to the next time period, and the process repeated. The FPS-ATLAS model has seen widespread application in British Columbia, and its linkage to FORECAST is well documented (see, for example (Seely, et al., 2004)). Detailed information on FPS-ATLAS can be found at www.forestry.ubc.ca/atlas-simfor/project/about.html.

Description of the Baseline Scenario Modeling

The selected baseline scenario applied to FPS-ATLAS assumes logging would have occurred over the first fifteen years of the project at a harvest level of 250,000 - 350,000 $m^3\ y^{-1}$. A lower level of harvest would then have been imposed over years 16-100 according the available standing stock.

The harvest method employed in the baseline scenario is clearcutting (the complete removal of all standing trees), a method with the lowest harvesting cost and maximum timber asset retrieval. Stands are assumed to regenerate naturally (i.e., no reforestation investment) in the baseline scenario since the costs of site preparation and planting would not be retrievable during a land re-sale. An overview of the baseline scenario assumptions is presented in Table 11.

Table 11 - Overview of the FPS-ATLAS simulation runs for the Baseline and Project scenarios.

Scenario	**Harvest Flow Target Years 1-15 ($m^3\ yr^{-1}$)**	**Harvest Flow Target years 16-100 ($m^3\ yr^{-1}$)**	**Minimum Harvest Criterion**	**Include EPA Area[17]**	**Regeneration Method[18]**
Baseline	300,000	maximum possible	150 $m^3\ ha^{-1}$	Y	Natural
Project case	2008-2010 based upon actual harvest; 2011 onward 10,000	10,000	150 $m^3\ ha^{-1}$	N	Planting

No harvest occurred in the inoperable area (outside the Timber Harvesting Land Base) or in Subalpine fir, Red cedar and Hemlock-leading stands that were $\geq$ 160 years old. Harvesting in Darkwoods Environmental Protected Areas (voluntary protection areas with no legal requirement) was permitted in the baseline scenario but not in project case. In the baseline scenario the mature pine-leading stands were harvested as priority (where economical) until 2010. After 2010 harvesting priority was determined based upon the

[17] Environmentally protected areas as defined in Section 4.1
[18] Natural regeneration causes stands to regenerate based upon the 300-series managed stand analysis units after harvesting while planting transitions to the 200-series

maximum difference between current age and minimum harvest age. For the project case, the simulated harvest priority from 2011 onward was random.

Both the baseline and project scenarios in FPS-ATLAS were run with annual time steps for 20 years, then 5-year periods thereafter, to 100 years.

Baseline Scenario GHG Emissions Calculation Summary

Total GHG emissions for the selected Baseline Scenario described in Section 2.4 were calculated using a suite of carbon accounting tools. The pools included in the accounting are described in Section 2.3. The basic equations employed for emissions accounting are based on the IPCC gain-loss method (IPCC, 2006b).

The FORECAST model (v8.4) and ATLAS model (v6.0.2.0) were used in combination with the initial (2008) spatial forest inventory data to calculate and track annual changes in both the biomass ($\Delta C_{BSL,LB,t}$) and dead organic matter pools ($\Delta C_{BSL,DOM,t}$) for the baseline scenario. Changes in storage in harvested wood products ($\Delta C_{BSI,HWP,t}$) and summarizing net carbon balances and buffer discounts were determined using the Darkwoods Carbon Model Microsoft Excel spreadsheet referenced in Appendix 5, using harvested wood volume data for the baseline scenario from FPS-ATLAS.

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

$$\Delta C_{BSL,t} = \Delta C_{BSL,P,t} \qquad (1)$$

where:

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

The annual change in carbon stocks in all pools in the baseline across the project activity area ($\Delta C_{BSL,P,t}$*;* $t\ C\ yr^{1}$*) was calculated as:*

$$\Delta C_{BSL,P,t} = \Delta C_{BSL,LB,t} + \Delta C_{BSL,DOM,t} + \Delta C_{BSI,HWP,t} \qquad (2)$$

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;* $t\ C\ yr^{1}$

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

The annual change in carbon stocks in living tree biomass (above- and belowground) in the baseline scenario ($\Delta C_{BSL,LB,t}$; t C yr^{-1}) was calculated as:

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

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}.*

The annual change in carbon stocks in dead organic matter (DOM) ($\Delta C_{BSL,DOM}$; t C yr^{-1}) in the baseline scenario was calculated as:

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

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 below-ground biomass carbon stock in year, t; t C yr^{-1}.*

The annual change in the carbon stored in harvested wood products (HWP), ($\Delta C_{BSl,HWP,t}$,; t C yr^{-1}) was calculated as:

$$\Delta C_{BSl,HWP,t} = \Delta C_{BSL,PERMHWP1,t} + \Delta C_{BSL,PERMHWP2,t} - \Delta C_{BSL,EMITFOSSIL,t,} \qquad (18)$$

where:

$\Delta C_{BSL,PERMHWP1,t}$ *= the annual harvested carbon that remains in permanent storage after conversion to wood products during primary processing (t C yr^{-1})*

$\Delta C_{BSL,PERMHWP2,t}$ *= carbon that remains in permanent storage after accounting for secondary processing of the residue carbon (biomass) generated from primary processing (t C yr^{-1})*

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

Equations for the derivation of the remaining variables, and a further discussion of the relationship of the models to equations 1 to 27 can be seen in Appendix 2.

Results from the Baseline Scenario Analysis

Results for the baseline scenario carbon calculations are shown in: annual harvest volumes (Table 13); growing stock volume (Figure 10); net ecosystem carbon storage for the selected carbon pools (Figure 11); wood products, manufacturing wastes and logging emissions (Table 14); and net baseline scenario emissions (Table 17).

Total emissions including changes in net ecosystem carbon storage as well as net storage and emissions associated with the harvesting and production of wood products for the baseline scenario are presented in Table 17 (calculated in the Darkwoods Carbon Model).

Note the short-term increase in emissions in both scenarios (year 4) is related to MPB-caused mortality in pine leading stand types and their subsequent shift to one of the MPB analysis units. During this transition a significant portion of the live biomass was converted to the litter pool, which is not included in the VCS carbon pool accounting (see Section 2.3), and is therefore assumed emitted immediately in both scenarios.

4.2. Project Emissions

Project Scenario Area Stratification

STEP 1 – Stratify to create homogeneous units

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 9 were also employed for the project scenario.

STEP 2 – Identify areas eligible for specific management activities

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.

Description of the Project Scenario Modeling

As in the baseline scenario, the stand-level model FORECAST was used to model all ecosystem carbon flows by analysis unit, and the landscape scale model FPS-ATLAS was used to create harvesting scenarios and track carbon biomass flows over time.

The project scenario applied to FPS-ATLAS uses the actual project harvest levels for 2008-2010[19], and then projects an ongoing project target harvest level of 10,000 $m^3 y^{-1}$. A

[19] To minimize the social and economic impact of the move to a lower level of harvesting, the NCC management plan included a ramp down period from the previous harvest levels to the target project level over the period 2008-2010.

detailed list of the harvesting activities by area is shown for the years 2008-2010 in Table 12. Harvesting activities for the remainder of the project duration (years 2011-2107) were selected randomly based on the criteria shown in Table 11.

The project harvest method employed is modeled as clear-cutting; which is conservative for the partial cutting undertaken in the 2008-2010 period (20-50% of the actual harvest areas were retained; however, accurate field data was not available so to be conservative, it is assumed that all of the area was harvested). For simplicity, the harvest volume is as modeled forward as a clear-cut annual volume, which is expected to reasonably represent the volume impact of future project activities which may actually employ variable harvesting techniques to achieve conservation objectives.

No project harvest occurred in the inoperable area (outside the Timber Harvesting Land Base) or in Subalpine fir, Red cedar and Hemlock-leading stands that were $\geq$ 160 years old. Harvesting in Darkwoods Environmental Protected Areas (voluntary protection areas with no legal requirement) was not permitted in project case. Project scenario stands are assumed to regenerate via planting.

Table 12 – Project harvest area and volumes for 2008, 2009 and 2010.

Year	AU	Area[20] (ha)	Volume[21] (m^3 ha^{-1})
2008	102	1.6	
2008	103	1.6	
2008	104	4.0	
2008	105	14.0	
2008	106	198.2	
2008	107	0.4	
2008	108	4.4	
2008	109	0.7	
2008	*Total*	*224.8*	*60,645*
2009	102	3.7	
2009	106	134.2	
2009	*Total*	*137.9*	*41,418*
2010	101	3.1	
2010	102	19.2	
2010	103	0.8	
2010	104	42.1	
2010	105	12.4	
2010	106	34.5	
2010	109	5.9	
2010	209	0.0	
2010	*Total*	*118.04*	*32,472*

Both the baseline and project scenarios in FPS-ATLAS were run with annual time steps for 20 years, then 5-year periods thereafter, to 100 years.

[20] Harvested area by year based on updates to the spatial inventory data for Darkwoods and simulated in FPS-ATLAS
[21] Simulated volume harvested from FPS-ATLAS

Determining Actual Ex-Post Onsite Carbon Stocks

The monitoring report will detail the data and calculations for ex-post onsite carbon stocks at the time of verification. However, as the project start date (2008) is prior to validation, the PDD has included the following summary of spatial inventory monitoring updates made over the period of 2008 to 2010. The GIS inventory database is updated to the end of 2010. Following steps from the methodology:

1) *Incorporating any new forest inventory data (including data from new or re-measured sampling plots and other monitored data, as outlined in Section 13 and 14) obtained during the previous year into the inventory estimate.*

As noted in Section 3.3, the Darkwoods carbon project does not have a carbon field plot network in place at the time of validation. Therefore, forest inventory data used in the calculations for this PDD are based on the starting inventory (updated as per #2 below) and has not yet incorporated any changes from field sampling plot data. The project will has begun plot installation as part of preparations for the project verification, and results from this field sampling will be reflected in the verification monitoring report.

2) *Updating the forest inventory for spatial monitoring results, including annual project activities and/or disturbances that have occurred during the monitoring period.*

The 2008 spatial inventory was updated for observed natural disturbances monitored during 2008 to 2010. The original Darkwoods spatial inventory data (reflecting conditions up to the end of 2007) was updated to show actual and specifically planned harvest activity through the 2010. The original Darkwoods spatial inventory for was updated to reflect MPB mortality (between 2008-2010) such that affected stands were identified to transition to new analysis units in 2011 (see Section 4.1).

3) *Using the selected model(s) to project prior-year data from the forest inventory to the current reporting year (as described in Section 9.3).*

The carbon accounting tools described in Section 4.1 were applied using the updated inventory to project forward prior-year data from forest inventory to the current reporting year.

4) *Comparing estimates of live biomass and dead organic matter in polygons and calculated from monitoring activities (Section 13 and 14) against current-year modeled values in the project scenario (see Section 9.2.2).*

As noted in #1 above, the carbon field sampling network is not installed yet, and hence directly comparative plot biomass data is not available. However, for the purposes of projecting ex-ante carbon stocks, the project has used 2 directly comparable data sources (see Appendix 4 for details) to test for expected model and inventory accuracy. No adjustments to inventory were made as a result of Appendix 4.

5) *Making calibration adjustments to models and/or parameters such that the fit between the equivalent modeled and measured variables meets targets (as per Section 9.2.2).*

No additional model calibrations have been identified as necessary or made from the updated forest inventory.

6) *If any changes are made to the model assumptions or parameters used in Section 9, the calculation of baseline emissions (from the current date forward) must be redone using the updated model(s) and parameter sets.*

The projected ex-ante calculations of the baseline and project scenarios include the most up to date inventory data and model parameter sets.

7) *Calculate the error terms for use in determining the uncertainty factor (Section 11.4).*

Prior to the field plot network, the error terms for the uncertainty factor have been estimated on a conservative basis from corroborating evidence (see Appendix 4) for the ex-ante projections.

The calculations for actual ex-post carbon stocks (methodology Equations 28a-e) will be undertaken at verification within the monitoring report as field plot sampling data becomes available. Ongoing calculations of ex-post carbon stocks are described in Section 3.4

Project Scenario GHG Emissions Calculation Summary

The FORECAST model (v8.4) and ATLAS model (v6.0.2.0) were used in combination with the initial (2008) spatial forest inventory data to calculate and track annual changes in both the biomass ($\Delta C_{PRJ,LB,t}$) and dead organic matter pools ($\Delta C_{PRJ,DOM,t}$) for the project scenario. Changes in storage in harvested wood products ($\Delta C_{PRJ,HWP,t}$) and summarizing net carbon balances were determined using the Darkwoods Carbon Model Microsoft Excel spreadsheet referenced in Appendix 5, using harvested wood volume and carbon pool output data for the project scenario from FPS-ATLAS.

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

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

where:

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

The annual change in carbon stocks in all pools in the project scenario across the project activity area ($\Delta C_{PRJ,P,t}$; t C yr^{1}) was calculated as:

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

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}.

The annual change in carbon stocks in living tree biomass (above- and belowground) in the project scenario ($\Delta C_{PRJ,LB,t}$; t C yr^{1}) was calculated as:

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

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}.

The annual change in carbon stocks in dead organic matter (DOM) ($\Delta C_{PRJ,DOM}$; t C yr^{1}) in the project scenario was calculated as:

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

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 below-ground carbon stock in year, t; t C yr^{1}.

The annual change in the carbon stored in harvested wood products (HWP), ($\Delta C_{PRJ,HWP,t}$; t C yr^{1}) in the project scenario was calculated as:

$$\Delta C_{PRJ,HWP,t} = \Delta C_{PRJ,PERMHWP1,t} + \Delta C_{PRJ,PERMHWP2,t} - \Delta C_{PRJ,EMITFOSSIL,t} \qquad (46)$$

where:

$\Delta C_{PRJ,PERMHWP1,t}$ = the annual harvested carbon that remains in permanent storage after conversion to wood products during primary processing ($t\ C\ yr^{-1}$)

$\Delta C_{PRJ,PERMHWP2,t}$ = carbon that remains in permanent storage after accounting for secondary processing of the residue carbon (biomass) generated from primary processing ($t\ C\ yr^{-1}$)

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

Equations for the derivation of the remaining variables, and a further discussion of the relationship of the models to equations 29 to 55 can be seen in Appendix 2.

Results from the Project Scenario Analysis

Results for the project scenario carbon calculations are shown in: annual harvest volumes (Table 13); growing stock volume (Figure 10); net ecosystem carbon storage for the selected carbon pools (Figure 11); wood products, manufacturing wastes and logging emissions (Table 14); and net project scenario emissions (Table 17).

Total emissions including changes in net ecosystem carbon storage as well as net storage and emissions associated with the harvesting and production of wood products for the project scenario are presented in Table 17.

Note the short-term increase observed in emissions in both scenarios (year 4) is related to MPB-caused mortality in pine leading stand types and their subsequent shift to one of the MPB analysis units. During this transition a significant portion of the live biomass was converted to the litter pool, which is not included in the VCS carbon pool accounting for the Darkwoods Project (see Section 2.3), and is therefore assumed emitted immediately in both scenarios.

Table 13- Projected Annual Harvest Area and Volume by Scenario (Year 1 = 2008). Data derived from FPS-ATLAS output.

Year	Baseline Harvest Volume (m^3)	Baseline Harvest Area (ha)	Project Harvest Volume (m^3)	Project Harvest Area (ha)
1	309,878	789	60,645	224
2	301,109	903	41,418	137
3	302,970	1,213	32,472	118
4	304,760	780	9,209	20
5	305,437	907	16,719	36
6	302,027	950	13,796	30
7	301,156	690	11,454	25
8	302,697	751	14,440	32
9	306,519	684	9,155	20
10	329,928	952	8,179	18
11	310,594	907	18,273	40
12	328,662	1,099	9,526	21
13	302,175	1,099	8,538	19
14	300,592	1,227	11,595	26
15	300,452	1,727	8,787	20
16	165,692	1,009	8,797	20
17	0	0	18,152	40
18	0	0	10,931	24
19	104,888	695	11,908	35
20	0	0	9,476	28
25	17,576	110	10,312	42
30	28,414	181	9,779	50
35	90,003	547	10,216	46
40	26,330	157	10,093	43
45	30,028	188	11,243	45
50	71,887	436	9,711	39
55	83,558	520	9,712	44
60	73,199	463	10,635	46
65	25,783	156	10,058	34
70	18,022	113	11,906	32
75	22,623	141	11,526	32
80	123,045	773	14,299	38
85	124,791	762	9,948	29
90	69,424	425	9,901	27
95	85,491	515	12,484	33
100	54,778	334	10,345	27

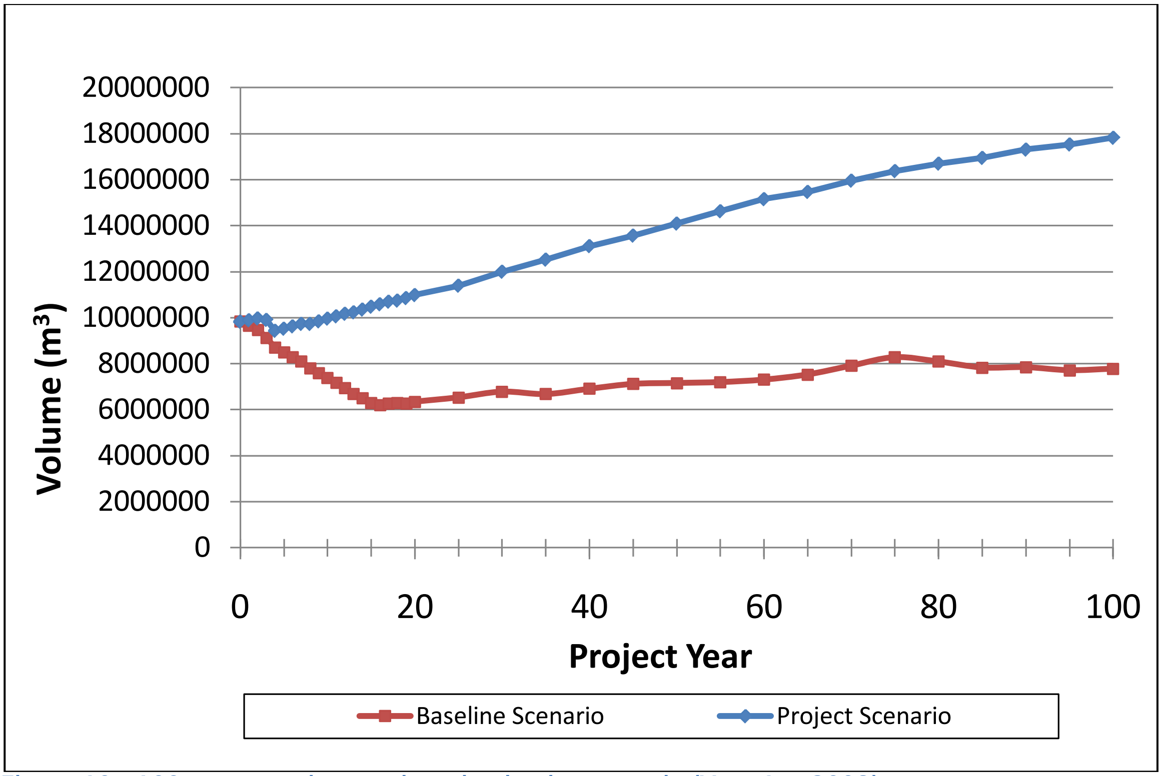

Figure 10 - 100-year growing stock projection by scenario (Year 1 = 2008).

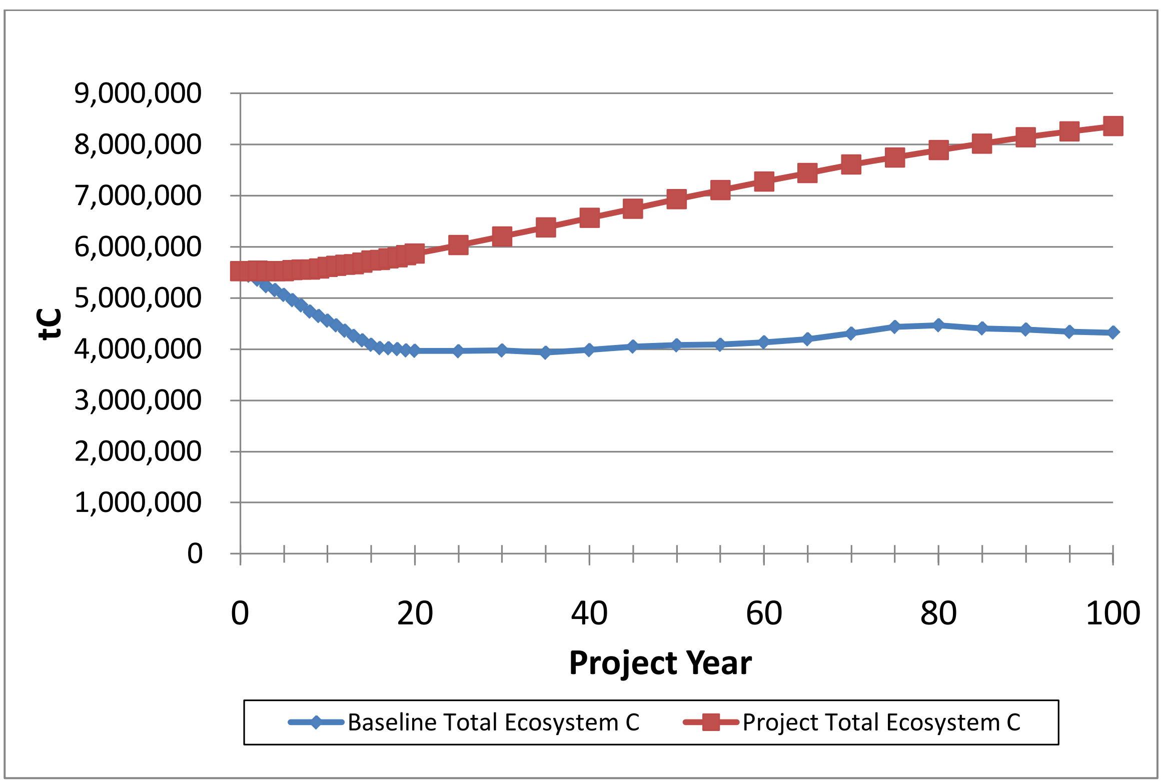

Figure 11 - Net Ecosystem Carbon Storage (Biomass + Deadwood + Belowground dead biomass) by Scenario (year 1 = 2008).

Table 14 - Calculated HWP, Manufacturing Wastes, and Equipment Emissions (Year 1 = 2008). Source: Darkwoods Carbon Model; worksheet: Summary Tables and Figures

Year	Baseline			Project		
	Storage	Storage	Emissions	Storage	Storage	Emissions
	HWP (tC)	Waste Products (tC)	Equipment & Production (tC)	HWP (tC)	Waste Products (tC)	Equipment & Production (tC)
0	0	0	0	0	0	0
1	3,952	1,273	(3,968)	773	249	(776)
2	3,840	1,237	(3,855)	528	170	(530)
3	3,864	1,245	(3,879)	414	133	(416)
4	3,887	1,252	(3,902)	117	38	(118)
5	3,896	1,255	(3,911)	213	69	(214)
6	3,852	1,241	(3,867)	176	57	(177)
7	3,841	1,237	(3,856)	146	47	(147)
8	3,861	1,244	(3,876)	184	59	(185)
9	3,909	1,259	(3,925)	117	38	(117)
10	4,208	1,356	(4,224)	104	34	(105)
11	3,961	1,276	(3,977)	233	75	(234)
12	4,192	1,350	(4,208)	121	39	(122)
13	3,854	1,242	(3,869)	109	35	(109)
14	3,834	1,235	(3,849)	148	48	(148)
15	3,832	1,234	(3,847)	112	36	(113)
16	2,113	681	(2,121)	112	36	(113)
17	0	0	0	232	75	(232)
18	0	0	0	139	45	(140)
19	1,338	431	(1,343)	152	49	(152)
20	0	0	0	121	39	(121)
25	1,121	361	(1,125)	132	42	(132)
30	1,812	584	(1,819)	125	40	(125)
35	5,740	1,849	(5,762)	130	42	(131)
40	1,679	541	(1,686)	129	41	(129)
45	1,915	617	(1,922)	143	46	(144)
50	4,584	1,477	(4,602)	124	40	(124)
55	5,329	1,717	(5,349)	124	40	(124)
60	4,668	1,504	(4,686)	136	44	(136)
65	1,644	530	(1,651)	128	41	(129)
70	1,149	370	(1,154)	152	49	(152)
75	1,443	465	(1,448)	147	47	(148)
80	7,847	2,528	(7,877)	182	59	(183)
85	7,958	2,564	(7,989)	127	41	(127)
90	4,427	1,426	(4,444)	126	41	(127)
95	5,452	1,756	(5,473)	159	51	(160)
100	3,493	1,125	(3,507)	132	43	(132)
Total	**122,494**	**39,462**	**(122,971)**	**6,449**	**2,078**	**(6,474)**

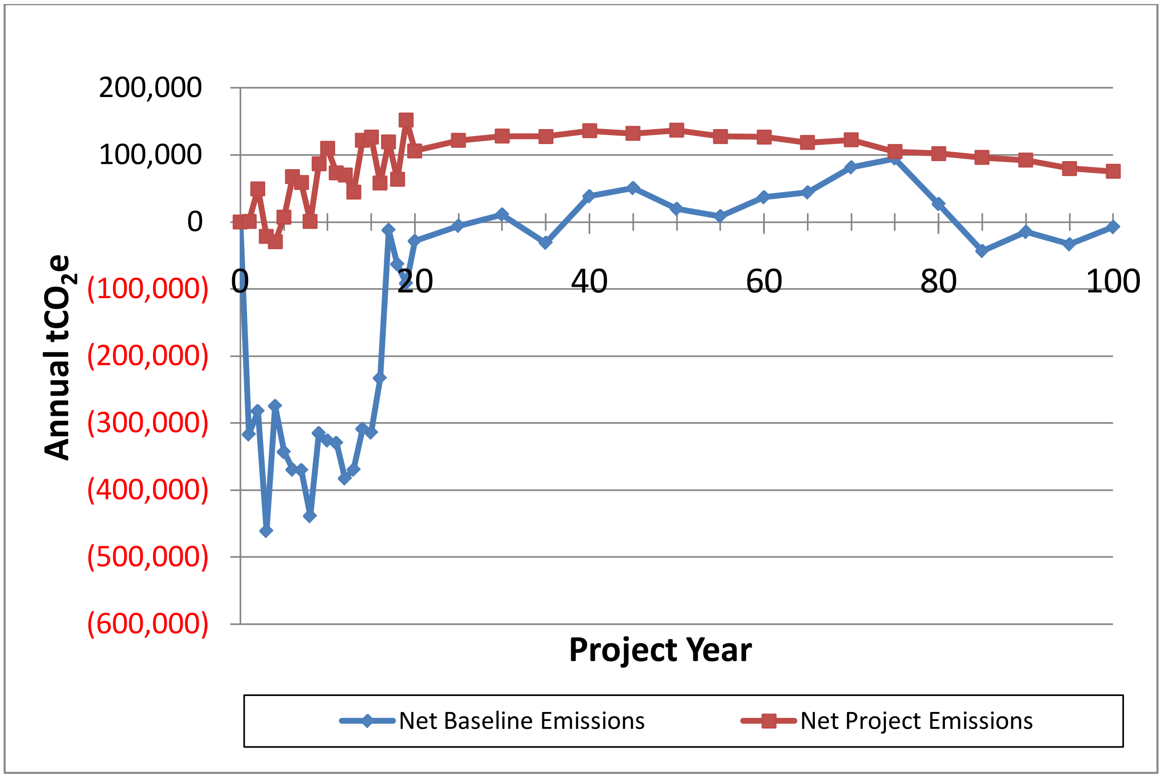

Figure 12 - Net Emissions/Sequestration Projection for the Baseline and Project Scenarios (Year 1 = 2008). Negative values indicate emissions and positive values indicated sequestration.

4.3. Leakage

Activity Shifting Leakage

NCC does hold 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 does not undertake ongoing commercial harvesting on other properties. 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.

More specifically, NCC has not undertaken any material level of timber harvesting on any owned or managed property outside Darkwoods for the period 2008 to 2010, and therefore there is no risk of starting activity shifting risk.

Table 15 - NCC Logging Activity on Other Properties (activity shifting risk)

Property	Year	Logging Volume (m^3)	Activity shifting evidence/comment
All NCC properties outside Darkwoods	2008	0.0	n/a – no harvest
All NCC properties outside Darkwoods	2009	0.0	n/a – no harvest
All NCC properties outside Darkwoods	2010	0.0	n/a – no harvest

Market Leakage

The methodology provides 3 options for market leakage. The Darkwoods property has selected Market Leakage Option 2 – using the CAR market leakage formula (Figure 13). This method is derived from CAR forestry protocol, which is developed specifically for the North American market context, appears to rationally represent the potential change in market supply of logs, and is widely accepted in the largest set of forest carbon projects in this market region.

Forest Project Protocol *Version 3.2, August 2010*

6.2.6 Quantifying Secondary Effects

For Improved Forest Management Projects, significant Secondary Effects can occur if a project reduces harvesting in the Project Area, resulting in an increase in harvesting on other properties. Changes in energy-related emissions, which could result from a Forest Project causing consumers of forest products to increase or decrease their use of alternative materials, are not accounted for because it is assumed that energy sector emissions will be capped in the relatively near future under a regulatory cap-and-trade system.

Equation 6.10 must be used to estimate Secondary Effects for Improved Forest Management Projects.

Equation 6.10. Secondary Effects Emissions

$$If \sum_{n=1}^{y-1} (AC_{hv,n} - BC_{hv,n}) > 0, then\ SE_y = 0$$

$$If \sum_{n=1}^{y-1} (AC_{hv,n} - BC_{hv,n}) < 0, then\ SE_y = (AC_{hv,y} - BC_{hv,y}) \times 20\%$$

Where,

SE_y	=	Estimated annual Secondary Effects (used in Equation 6.1)
$AC_{hv,n}$	=	Actual amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tonnes
$BC_{hv,n}$	=	Estimated average baseline amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tonnes, as determined in Step 1 of Section 6.2.3
y	=	The current year or reporting period

Figure 13 - Selected Market Leakage Method - CAR Forestry Protocol v.3.2 Market Leakage Process

For the Darkwoods project, the calculations for the Option 2 Leakage were derived from output annual timber harvest volume data from the Atlas/Forecast modeling (Table 12), and the leakage for each year (LE_y) was calculated as the annual net change in harvest volume between the baseline and project scenario, in tCO_2e, multiplied by 20% (as per Figure 2 in the methodology and the related calculations - shown in Figure 13 here) as follows:

Utilize the CAR formulas (Equation 6.10 – shown in Figure 13), with variables calculated as follows:

Note: for consistency, y = n = t.

$$BC_{hv,n} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,Other,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet 44/12 \qquad (56c.1)$$

As calculated using the *baseline scenario data*, and where:

$LBL_{BSL,FELLINGS,i,t}$ = annual removal of live tree biomass due to commercial felling in polygon, *i*; t d.m. yr^{-1} (equation 6)

$LBL_{BSL,OTHER,i,t}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1} (equation 6)

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

$1 - f_{BSL,BUCKINGLOSS,i,t}$ = the proportion of the log bole remaining after processing for quality, in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 12)

R_i = the root:shoot ratio in polygon, *i*

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

$$AC_{hv,n} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,Other,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet 44/12 \qquad (56c.2)$$

As calculated using the *project scenario data*, and where:

$LBL_{PRJ,FELLINGS,i,t}$ = annual removal of live tree biomass due to restoration felling in polygon, *i*; t d.m. yr^{-1} (equation 6)

$LBL_{PRJ,OTHER,i,t}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1} (equation 6)

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

$1 - f_{PRJ,BUCKINGLOSS,i,t}$ = the proportion of the log bole remaining after processing for quality, in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 12)

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

$SE_y = LE_y$ **(56c.3)**

Where,

SE_y = Secondary Effects in year 'y' (tCO_2e) calculated using equations in Figure 2 and equations 56c.1, 56c.2 and 56c.3.

LE_Y = Leakage in year y (in tonnes $CO_2e\ yr^{-1}$) – used in equation 58.

The outcome of this calculation (LE_y) is subtracted from the total net VCU's on an annual basis as per methodology in Equation 58.

The biomass calculations were obtained from FPS-ATLAS output (i.e. equation 56c.1 and 56c.2, with the conversion to tC (i.e. *CF) and tCO_2e (i.e. *44/12) made in the Darkwoods Carbon Model). Equation 56c.3 calculations (and the related calculations from Figure 13) were made for the Darkwoods project within the Darkwoods Carbon Model excel spreadsheet referenced in Appendix 5, and the annual results displayed in Table 16 and Table 18.

In summary, the leakage calculations result in an average annual leakage reduction factor of approximately 8.5% over the entire project duration, with a range of 0%-21.4% on an annualized basis as shown in Table 16[22].

[22] By way of comparison and context, this outcome is conservative in comparison on average with the robust forest carbon leakage analysis undertaken by the U.S. Environmental Protection Agency (U.S. EPA, 2005) which modeled an average U.S. leakage factor for logged to protected forests as *de minimis* (-2.8% leakage in Table 6-2) when looking across the U.S. and including the entire forest and agriculture sectors. They also refer to previous more constrained regional economic modeling (Murray, McCarl, & Lee, 2003) which showed a leakage rate of 7.9%-16% depending on ongoing forest activities (Table 6-4). This study also includes a brief review of other U.S. leakage studies, and in our opinion represents the most robust and complete economic modeling for leakage, and is therefore a rationale comparative data point for North American forest projects.

Table 16 - Projected Annual Leakage Risk Discounts

Year	Change Harvest Vol. (tCO_2e)	Discount (-20%) Change tCO_2e Harvested	Discount % of total VCU's
1	182,937	(36,587)	11.5%
2	190,613	(38,123)	11.5%
3	198,546	(39,709)	9.0%
4	216,934	(43,387)	17.8%
5	211,919	(42,384)	12.1%
6	211,562	(42,312)	9.7%
7	212,641	(42,528)	9.9%
8	211,581	(42,316)	9.6%
9	218,265	(43,653)	10.9%
10	236,164	(47,233)	10.9%
11	214,564	(42,913)	10.7%
12	234,246	(46,849)	10.4%
13	215,530	(43,106)	10.4%
14	212,124	(42,425)	9.9%
15	214,082	(42,816)	9.7%
16	115,161	(23,032)	7.9%
17	0	0	0.0%
18	0	0	0.0%
19	68,247	(13,649)	5.6%
20	0	0	0.0%
25	5,332	(1,066)	0.8%
30	13,678	(2,736)	2.3%
35	58,564	(11,713)	7.4%
40	11,918	(2,384)	2.4%
45	13,788	(2,758)	3.4%
50	45,637	(9,127)	7.8%
55	54,203	(10,841)	9.1%
60	45,921	(9,184)	10.2%
65	11,542	(2,308)	3.1%
70	4,489	(898)	2.2%
75	8,145	(1,629)	16.0%
80	79,819	(15,964)	21.2%
85	84,295	(16,859)	12.1%
90	43,690	(8,738)	8.2%
95	53,587	(10,717)	9.5%
100	32,614	(6,523)	7.9%
TOTAL:	**6,172,934**	**(1,240,247)**	**-8.5%**

4.4. Net GHG Emission Reductions and Removals

Calculation of Gross Emissions Reductions

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:

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

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

This calculation was undertaken in the Darkwoods Carbon Model excel spreadsheet. The gross emissions reductions calculated for the Darkwoods project are shown in Table 17.

Table 17 - Projected Emissions (Reductions) for the Darkwoods Project.

Year	Baseline (Emissions) Reductions (tCO2e)	Annualized[23] Baseline (Emissions) Reductions (tCO2e)	Project (Emissions) Reductions (tCO2e)	Annualized Project (Emissions) Reductions (tCO2e)	Net Change (Emissions) Reductions (tCO2e)	Annualized Net Change (Emissions) Reductions (tCO2e)
1	(316,806)	(316,806)	1,017	1,017	317,823	317,823
2	(281,998)	(281,998)	49,729	49,729	331,727	331,727
3	(460,747)	(460,747)	(21,287)	(21,287)	439,461	439,461
4	(274,442)	(274,442)	(29,803)	(29,803)	244,640	244,640
5	(342,937)	(342,937)	7,589	7,589	350,526	350,526
6	(369,400)	(369,400)	67,576	67,576	436,976	436,976
7	(370,089)	(370,089)	58,645	58,645	428,733	428,733
8	(438,621)	(438,621)	652	652	439,273	439,273
9	(314,885)	(314,885)	86,745	86,745	401,630	401,630
10	(325,881)	(325,881)	109,873	109,873	435,754	435,754
11	(329,490)	(329,490)	73,669	73,669	403,159	403,159
12	(382,417)	(382,417)	70,195	70,195	452,612	452,612
13	(369,428)	(369,428)	44,494	44,494	413,921	413,921
14	(308,474)	(308,474)	122,053	122,053	430,528	430,528
15	(314,055)	(314,055)	126,856	126,856	440,911	440,911
16	(232,863)	(232,863)	57,974	57,974	290,837	290,837
17	(12,104)	(12,104)	119,498	119,498	131,601	131,601
18	(62,981)	(62,981)	63,423	63,423	126,403	126,403
19	(91,622)	(91,622)	152,303	152,303	243,925	243,925
20	(28,505)	(28,505)	105,962	105,962	134,467	134,467
25	(29,038)	(5,808)	608,302	121,660	637,340	127,468
30	55,684	11,137	639,687	127,937	584,004	116,801
35	(155,283)	(31,057)	638,013	127,603	793,296	158,659
40	191,528	38,306	680,737	136,147	489,210	97,842
45	252,798	50,560	661,043	132,209	408,244	81,649
50	97,853	19,571	684,794	136,959	586,941	117,388
55	42,839	8,568	638,736	127,747	595,896	119,179
60	184,177	36,835	634,977	126,995	450,799	90,160
65	220,429	44,086	592,047	118,409	371,619	74,324
70	406,951	81,390	613,038	122,608	206,087	41,217
75	473,904	94,781	525,055	105,011	51,151	10,230
80	133,644	26,729	510,416	102,083	376,773	75,355
85	(216,528)	(43,306)	480,338	96,068	696,866	139,373
90	(74,710)	(14,942)	461,044	92,209	535,755	107,151
95	(166,662)	(33,332)	399,856	79,971	566,518	113,304
100	(38,092)	(7,618)	377,382	75,476	415,474	83,095
Total	(4,248,252)		10,412,628		14,660,880	

[23] Annualized for years 25-100 by dividing the 5-year simulation period amount by 5.

Calculation of Net Emissions Reductions

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:

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

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, using the data shown in Table 16 and Table 17.

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:

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

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 Tool for AFOLU Non-Permanence Risk Analysis and Buffer (Voluntary Carbon Standard, 2008c). 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 area as shown on p. 24 of the VCS Guidance for AFOLU Projects (Voluntary Carbon Standard, 2008a).

The VCS Buffer Discount Factor (BR_Y) was calculated as **10%**, as per the non-permanence risk assessment in Appendix 1. The BR factor will be re-assessed at each verification as necessary.

The uncertainty factor was conservatively estimated at **5%**, as per Appendix 4 and Section 4.5. The uncertainty factor will be re-calculated from field plot data at each verification.

Equation 59 is calculated in the Darkwoods Carbon Model spreadsheet)

Table 18 shows the calculated annual VCUs projected for the Darkwoods Project.

Table 18 - Calculated Annual VCUs for the Darkwoods Project. Source: Darkwoods Carbon Model: Summary Tables and Figures.

Year	**Annual Net Emissions Reductions (tCO_2e)**	Leakage Risk Discount (tCO_2e)	Uncertainty Risk Discount (tCO_2e)	Non-Perm. Buffer Contribution (tCO_2e)	Cumulative Non-Perm. Buffer Account (tCO_2e)	Non-Perm. Buffer Release (tCO_2e)	**Annual Saleable VCU's** (tCO_2e)
Rate		Varies	Est. 5%	10%		15.0%	
1	**317,823**	(36,587)	(14,062)	(31,463)	31,463		**235,711**
2	**331,727**	(38,123)	(14,680)	(32,840)	64,303		**246,084**
3	**439,461**	(39,709)	(19,988)	(43,600)	107,903		**336,164**
4	**244,640**	(43,387)	(10,063)	(24,086)	131,989		**167,105**
5	**350,526**	(42,384)	(15,407)	(34,683)	141,671	25,001	**283,053**
6	**436,976**	(42,312)	(19,733)	(43,329)	184,999		**331,602**
7	**428,733**	(42,528)	(19,310)	(42,502)	227,502		**324,392**
8	**439,273**	(42,316)	(19,848)	(43,558)	271,060		**333,551**
9	**401,630**	(43,653)	(17,899)	(39,782)	310,842		**300,296**
10	**435,754**	(47,233)	(19,426)	(43,163)	300,905	53,101	**379,032**
11	**403,159**	(42,913)	(18,012)	(39,942)	340,846		**302,292**
12	**452,612**	(46,849)	(20,288)	(44,853)	385,699		**340,622**
13	**413,921**	(43,106)	(18,541)	(41,016)	426,715		**311,259**
14	**430,528**	(42,425)	(19,405)	(42,683)	469,398		**326,015**
15	**440,911**	(42,816)	(19,905)	(43,718)	436,148	76,967	**411,439**
16	**290,837**	(23,032)	(13,390)	(28,883)	465,031		**225,532**
17	**131,601**	0	(6,580)	(13,183)	478,214		**111,838**
18	**126,403**	0	(6,320)	(12,654)	490,869		**107,429**
19	**243,925**	(13,649)	(11,514)	(24,273)	515,142		**194,488**
20	**134,467**	0	(6,723)	(13,459)	449,311	79,290	**193,575**
25	**127,468**	(1,066)	(6,320)	(12,647)	435,666	15,376	**122,810**
30	**116,801**	(2,736)	(5,703)	(11,511)	419,237	14,797	**111,648**
35	**158,659**	(11,713)	(7,347)	(15,303)	421,388	14,873	**139,169**
40	**97,842**	(2,384)	(4,773)	(9,629)	399,101	14,086	**95,143**
45	**81,649**	(2,758)	(3,945)	(7,987)	373,181	13,171	**80,131**
50	**117,388**	(9,127)	(5,413)	(11,291)	365,191	12,889	**104,446**
55	**119,179**	(10,841)	(5,417)	(11,395)	358,843	12,665	**104,191**
60	**90,160**	(9,184)	(4,049)	(8,561)	341,401	12,049	**80,415**
65	**74,324**	(2,308)	(3,601)	(7,280)	321,131	11,334	**72,468**
70	**41,217**	(898)	(2,016)	(4,022)	290,053	10,237	**44,519**
75	**10,230**	(1,629)	(430)	(893)	250,340	8,836	**16,114**
80	**75,355**	(15,964)	(2,970)	(6,766)	241,545	8,525	**58,180**
85	**139,373**	(16,859)	(6,126)	(13,151)	261,206	9,219	**112,456**
90	**107,151**	(8,738)	(4,921)	(10,283)	265,729	9,379	**92,588**
95	**113,304**	(10,717)	(5,129)	(10,799)	271,766	9,592	**96,250**
100	**83,095**	(6,523)	(3,829)	(7,972)	264,882	9,349	**74,120**
Total	14,660,880	(1,240,247)	(671,032)		(264,882)		12,484,719

4.5. Calculation of the Uncertainty Factor

As noted elsewhere, the actual ex-post plot network has not been installed prior to validation, and therefore the uncertainty factor has not been calculated from actual ex-post data. For the ex-ante carbon projections in the PDD, an initial conservative estimate of the model and inventory error has been calculated from other applicable project data, as outlined in the next section below and Appendix 4.

Prior to verification, the uncertainty factor will be updated using plot sampling data and the procedure from the methodology for projects using analysis units:

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.

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

Where,

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

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

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.

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

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[24]

1.654 = the 90% confidence interval t-value

All other terms as defined in equation 60a.

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

Where,

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.

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

[24] 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).

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 $y_{d,h,i}$

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.

$$E_P = E_M + E_I \qquad (60f)$$

Step 4 – Compare the result of Step 3 against Table 19 to determine the uncertainty factor:

Table 19 - Uncertainty Factor Calculation

Estimated Project Error, E_P (%)	Uncertainty Factor (=$ER_{Y,ERR}$)
0 – 10%	= 1.5%[25]
>10%	= 1.5% + E_P – 10%

The uncertainty factor is calculated at each verification and applied annually until the next verification.

Initial Ex-Ante Estimate of Uncertainty

Given the fact that no permanent sample plots have been established for measuring carbon storage within the Darkwoods property to date, an ex-ante estimate of the uncertainty factor ($ER_{Y,ERR}$) was calculated using measures of model error and inventory error.

The ex-ante model error term (E_M) was calculated to be 1.1% by comparing model outputs of timber volume harvested in the project scenario (for the 2008 & 2009 project years) against actual reported assessment timber volumes reported for the Darkwoods property by the BC Assessment Authority[26].

The estimate of model error based on total harvested volume captures error coming from both the stand-level model FORECAST (simulates stand productivity) and the linked landscape-scale model FPS-ATLAS (simulates the volume generated through the harvesting of specific inventory polygons). The error for volume projection should be consistent with that for carbon storage as the two have a direct, proportional relationship.

[25] 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.
[26] Available upon request

The ex-ante inventory error term (E_I) was calculated to be 6.5% by taking the average error measured in two inventory audits, one conducted within the Darkwoods property (Kleine, 1992); (Pluto Darkwoods Corp., 1992); and one conducted for the larger, adjacent Kootenay Lake Timber Supply Area (BC MOF, 2005); (also see Appendix 4). As shown in Equation 60f , the project error term (E_P) was calculated as the sum of E_M and E_I to be 7.6%.

Using the calculation method shown in Section 4.5 and Appendix 4, the **ex-ante uncertainty factor ($ER_{Y,ERR}$) is calculated to be 1.5% (however, note adjustment below)**.

The data from previous inventory and the quality of directly comparable reference data used provide a good level of confidence about the calculated uncertainty factor; however, because the Darkwoods monitoring permanent plot network is not in yet in place to provide up to date direct measured ex-post plot level data for the years at initial validation and verification (2008-2010), **the project will initially increase the ex-ante estimate of $ER_{Y,ERR}$ to 5% to be conservative** (as shown in Table 18).

This additional uncertainty factor will be re-assessed at verification and adjusted annually to reflect improved field data from the Darkwoods monitoring plot network.

5. Environmental Impact:

There are no known environmental impacts to assess for the retention of natural forest. This carbon project enhances all aspects of biodiversity, water, and other environmental attributes by retaining and protecting the existing forest in an intact, fully functioning ecosystem. Project scenario management activities will be minimal, low impact operations focused on salvage, restoration, or preventative management activities on a small areas annually.

6. Stakeholders Comments:

NCC has undertaken extensive stakeholder engagement during and after the Darkwoods acquisition process. These have included targeted meetings with all relevant stakeholders, including local government, local industry, local recreational use groups, and general public meetings in all local communities.

It should be noted that the primary topic of all such engagements has been about the acquisition and the project scenario property management activities. NCC has chosen, so far, simply to mention carbon as a possible action, but not to explicitly hold stakeholder discussions specifically regarding the carbon project until there was a level of certainty in the validation and verification process.

Over the period of 2008-2010, the following is a non-exhaustive list of stakeholders meetings:

Table 20 - Darkwoods Stakeholders Meetings

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	

7. Ownership:

7.1. Proof of Title:

The Nature Conservancy of Canada holds clear title on the Darkwoods property. Title documentation is available for review upon request.

7.2. Emissions Trading Program:

Not Applicable – Canada is an Annex I country with binding GHG reduction commitments under Kyoto. However, Canada chose not to include managed forests as a carbon tracking and reporting element under Section 3.4. Therefore Canada has not counted credits associated with forest management such as this Darkwoods project at this time.

In addition, Canada has strong private property rights laws and precedents, and it is extremely unlikely that Canada would be able to report emissions changes from fee-simple private land forests without the participation of landowners.

Canada does not currently have national GHG emissions regulations or other binding emissions targets. A federal GHG emissions reduction program (cap and trade) has begun first drafts, and is expected to roll out first drafts of the program in the fall of 2009. Current materials identify forest-based carbon projects as viable offset creation vehicles.

Provincial, Federal, and International government activities relating to GHG emissions will be monitored closely on an ongoing basis to identify regulatory or other agreements that affect the emission reductions claimed by this project.

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Appendix 1 – NON-PERMANENCE RISK ASSESSMENTS

The methodology requires the use the latest VCS permanence risk rating tool. The Darkwoods Forest Carbon project has used the currently approved 2008 VCS risk assessment tool to determine the project permanence risk rating.

However, as reference and supporting evidence, the project has also used the draft 2011 VCS non-permanence risk tool to calibrate the selection of the risk rating from within the range provided by the 2008 tool (i.e. the outcome of the 2008 tool is a range of values – the project uses a combination of assessing the level of risks in the 2008 tool with the quantitative outcome of the 2011 draft tool as calibration to select a single value from within the range).

VCS 2008 Non-Permanence Risk Analysis and Buffer Determination:

The 2008 Non-Permanence Risk Tool requires two sections – risk factors applying to all project types and risk factors applying to IFM project types (Table 1 and Table 6, respectively in (Voluntary Carbon Standard, 2008c)).

Table 21- VCS 2008 Tool - Risk Factors Applying to All Project Types

Project risk	
Risk of unclear land tenure and potential for disputes	**VERY LOW** – This is fee-simple land, with clear title in the possession of NCC.
Risk of financial failure	**LOW** – NCC is one of the largest not-for-profit conservation organizations in Canada, with a 45 year history and a portfolio of over 800,000ha of protected lands nationally. A robust and complete financial analysis of the Darkwoods carbon project has been completed, which demonstrates the project has substantial margins at conservative VCU prices. Most importantly, these projected carbon finance returns can fund the remaining acquisition financing and property operations. Although clearly needing carbon finance to support the property and project, NCC is a large, financially stable company, with considerable fundraising capabilities, which mean there is a low risk of failing to meet the obligations of the carbon project. Low ownership and operating costs create substantial margin flexibility to sustain the project under unanticipated conditions. A risk assessment determined cash flow breakeven at VCU price levels of <\$2.00/tCO_2e. NCC has unique access to research partners and funding which can supplement monitoring costs in the case of reduced returns

	from carbon. Detailed financial projections are available confidentially upon validator request.
Risk of technical failure	**VERY LOW** – the project involves primarily the avoidance of operational activities other than property monitoring, which means the risk of technical failure is virtually non-existent. NCC has extensive in-house and contract conservation land management expertise. Field staff located at the property are highly experienced forest managers, including BC Registered Professional Foresters, who have clearly demonstrated experience in managing all necessary project activities. Previous ownership management and staff have been retained to provide over 30 years of Darkwoods property management knowledge.
Management risk: Risk of management failure	**LOW** –the project proponents include deep managerial and land management experience. The business management plans are robust, and the operational execution requirements relatively straight forward, all of which serve to limit risks of management failure. NCC has employees or contractors with leading carbon management, land management, conservation science, and forest management expertise.
Economic risk Risk of rising land opportunity costs that cause reversal of sequestration and/or protection	**LOW** – NCC has a strong history of acquiring and maintaining over 800,000 hectares of land across Canada. As a not-for-profit, NCC has a clear and legal mission and objectives of retaining land for conservation purposes, which is well aligned with the goal of retaining sequestered carbon. The NCC business model is generally driven by donations and other funding specific to the conservation mission and therefore rising land opportunity costs are not considered a significant element affecting NCC's decision-making, and in particular not threatening to carbon sequestered in conservation lands.
Regulatory and social risk Risk of political instability Risk of social instability	**LOW** – British Columbia has a stable and refined forest and land management legal and regulatory system. Private property rights are well protected. Although B.C. and Canada are currently developing regulatory carbon management plans, it is extremely unlikely that any change would affect private property rights around retaining timber and other biomass. So the only scenario which could occur would be a change to forest management rules for private forest land in BC. Although no discussions are known to be pending regarding this, even in the case that new rules are enacted, they would primarily affect

	the forward looking baseline (by requiring more protections in the harvesting scenario), which is very low risk and the project could adapt in the future as necessary. These new rules would not affect retroactive activities in the project or baseline scenario, and therefore create very limited risk to permanence on ex-post emission credits.
Natural disturbance risk	
Risk of devastating fire	**LOW** – Fire does plays a role in most B.C. forests, however, this region of B.C. is known as an 'interior wet belt' and the property contains a highly diverse set of micro and macro-site conditions which reduce catastrophic fire risk. The fire return interval for the ICH (Interior Cedar-Hemlock) is 150-200 years, and ESSF (Engelmann Spruce–Subalpine Fir) 150-350 years (B.C. Ministry of Forests, 2003). Devastating fires are rare, with forest diversity and complexity limiting campaign type fires (Wong, 2003). The Darkwoods property has a history of successful fire protection under previous management, with <400ha of fire disturbance over the previous 30 years. NCC has undertaken significant fire risk mitigation steps, by entering into a fire protection agreement with the B.C. government (who have initial attack fire fighting resource permanently stationed in adjacent Creston, BC), and by re-opening a manned fire tower on the property. The adjacent and embedded properties are mostly either crown lands or hold similar crown fire protection agreements. NCC employs forestry staff and resources near the site at the Darkwoods office in Nelson, B.C. It is expected that ongoing monitoring and conservation science work will provide increased management presence across the property for enhanced fire monitoring capacity on an ongoing basis. Stand fire hazard risk management is one of the activities to be undertaken by NCC with the harvesting operations in the carbon project scenario. NCC intends to retain and maintain the major access roads into each area of the property for monitoring and natural disturbance management purposes. Property access is strictly controlled with gates and an NCC managed user permitting process. Overall, the diversity of climatic, terrain, and forest site types on the property; in combination with active on-site fire monitoring and management, excellent property access routes, and

	proximal fire fighting resources mean this property has a low risk of catastrophic fire. A note on climate change: the effects of climate change on ecosystems and forest types in B.C. are not well understood, particularly in more complex and diverse landscapes such as Darkwoods. In general, most climate modeling indicates that temperature and precipitation will increase across southern B.C., and generally, stands should see increased productivity. However, snow pack is expected to decline (warmer winters), which may affect seasonal water supply negatively, but increase growing days for trees. On the negative side, summer water stress occurrences may increase, and the incidence of stronger storms may increase. However, analyzing the current information on the effects of climate change in B.C. do not lead to conclusive indication of any particular change – just simply that things may change in multiple and complex ways (many interlinked, some offsetting, etc.). Most relevant studies seem to indicate diverse natural stands will be better adapted than strongly managed stands, and diverse areas with multiple ecosystem types may be best able to adapt over time (due to a higher presence of more species and niche ecosystems which can adapt and fill ecosystem changes more rapidly). Further, the significant effects appear to be focused on mid- to long-term timeframes (i.e. >2030, >2050, >2080), and not specifically relevant to this project duration. The project and baseline scenario carbon flow modeling includes a 4% loss every 20 years to reflect endemic natural disturbance loss. The carbon project scenario includes annual forest management activities to manage habitat, restoration, risk protection, and/or salvage, which provides an operational tool to begin to manage for adapting to climate change as the science improves over time. The project proponents will endeavour to continue to monitor the state of knowledge about climate change and adapt the project and baseline scenarios as appropriate in future years. More information: (Black, Jassal, & Fredeen, 2008), (Columbia Mountains Institute of Applied Ecology, 2005)
Risk of pest and disease attacks	**LOW** – This property is located in a transition zone between wet and dry climates, and such has a high level of stand and tree diversity. Even the worst pest outbreak in B.C. recorded history,

	the Mountain Pine Beetle epidemic, has had a relatively minor impact on the standing stock of the property simply because there is a limited amount of suitable pine. On crown land in the Kootenay Lake TSA, pine makes up about 22% of the harvestable forest, with less than 10% of the pine infected in 2007. The outbreak is expected to reach 68% of the pine stocks by 2015, when the outbreak is expected to be 'over' (Schrier, 2009). On the Darkwoods property specifically, pine makes up <6% of the of the forest area, and has been a focus of harvest over the past decade to the point that limited mature pine remains at risk to MPB. However, the remaining pine stocks are heavily affected by MPB. The emissions from these infected stands are included in ex-ante modeling under both the baseline and project scenarios, as detailed in the emissions calculations sections. The Darkwoods forests are diverse, and therefore most pest/disease outbreaks in the Darkwoods forests will be dispersed endemic levels with low property-level impact. *Armallaria spp.* root rot is the most significant disease in the area, primarily in the ICH - BCMOFR estimates low level timber supply impacts beginning past year 50 in managed stand conditions (B.C. Ministry of Forests, 2002). Pests include mountain pine beetle, Douglas-fir beetle, spruce beetle, and western hemlock looper, western spruce budworm, Douglas-fir tussock moth. The Darkwoods property has a low risk of catastrophic pest outbreaks, partially because of these are typically localized endemic outbreaks with low overall mortality, and more importantly because the diversity and distribution of stand types reduces the risk of catastrophic outbreaks affecting a significant portion of the properties biomass. The stand data and modeling undertaken for the baseline and project scenarios includes typical operational adjustment factors to reflect average stand level tree losses due to pests, disease, and natural mortality on an annual basis. In addition, an additional 4% stand loss every 20 years has been included to conservatively reflect additional endemic natural disturbances, including pests and disease. Further, the active management plans for NCC in the carbon project scenario account provide tools which can be used to prevent or manage pest or disease outbreaks on the land base. Ongoing project monitoring forest health and taking proactive

	management actions will reduce the risks of any catastrophic outbreaks. A detailed discussion of disturbance regimes can be found in (Wong, 2003), (Cirque Resource Associates Ltd., 2007).
Risk of extreme weather events (e.g. floods, drought, winds)	LOW – as mountainous terrain, the property has little threat of flooding other than on a localized stream bed basis. The diverse forest types and ages provide substantial property level resilience to wind and other extreme weather events. As noted, the FORECAST carbon modeling accounted for an additional 4% natural disturbance loss every 20 years. Drought is a potential threat on a stand or regional basis; and although this property does sit on the edge of an interior wet belt, it is possible droughts could extend the dry zones into the wet transition zone on this property. The diversity of tree species provides a long-term resilience to drought, particularly in robust natural stands. Further, the baseline scenario and the project scenario would face the same issues regarding at least minimum natural levels of natural disturbance (i.e. a drought would affect both). The baseline may see an increased risk of damage from blow down and land slide activity due to the harvesting operations disturbing and opening new areas, along with an increased risk of drought impacts on significant areas of regenerating stands (which are more at risk than mature stands). Although the project scenario may see some positive and negative effects from extreme weather events over time, and/or during the limited forest management activities; it is expected these risks are *de minimis* in nature, and generally lower than the baseline risks.
Geological risk (e.g. volcanoes, earthquakes, landslides)	VERY LOW - There are no known major geological risks associated with this property.
All Projects Risk Rating:	LOW

Table 22 – 2008 VCS Permanence Risk Assessment Tool, Risk Factors Applicable to IFM Projects.

Risk Factor	Comments	LtPF Rating
Devastating Fire Potential	LOW – As detailed in Table 21, fire does plays a role in most B.C. forests, however, this region of B.C. is known as an 'interior wet belt' and the property contains a highly diverse set of micro and macro-site conditions which	LOW

	reduce catastrophic fire risk. NCC has undertaken significant fire risk mitigation steps, including a fire protection agreement with the B.C. government, re-opening the manned fire tower on the property, maintaining main access roads, employing on-site staff, and undertaking stand fire hazard risk management activities in the project scenario as necessary. Overall, the diversity of climatic, terrain, and forest site types on the property; in combination with active on-site fire monitoring and management, excellent property access routes, and proximal fire fighting resources mean this property has a low risk of catastrophic fire. The project and baseline scenario carbon flow modeling includes a 4% loss every 20 years to reflect natural disturbance loss.	
High Timber Value	**LOW** – NCC has a strong history of acquiring and maintaining over 800,000 hectares of land across Canada. As a not-for-profit, NCC has a clear mission and objectives of retaining land for conservation purposes, which is well aligned with the goal of retaining sequestered carbon. The NCC business model is generally driven by donations and other funding specific to the conservation mission and therefore timber opportunity costs are not considered a significant element affecting NCC's decision-making, and in particular not threatening to carbon sequestered in conservation lands. The Darkwoods property does have some valuable timber; however not on an individual tree basis as would be the case on the B.C. coast, PNW, or tropical forests. The value is generally at a stand level, and relates to volume-based removals by significant harvesting operations. Without the carbon revenue, NCC might be forced to consider significant ongoing harvesting and/or sub-dividing for divestment to complete the acquisition funding and fund operating costs. In the presence of carbon finance, however, harvesting for economic reasons is not consistent with NCC mission and objectives and has a very low risk.	LOW
Illegal Logging Potential	**V. LOW** – B.C. has an excellent timber tracking regulations, and strong illegal harvesting enforcement. All timber sales require physical timber marking with government issued hammer stamps, which permits identification and tracking of all wood.	V. LOW

	NCC is developing an access management plan, which currently requires all property users to have a private permit to be on the property. All roads are, or will be, gated and usage monitored. NCC has property management staff located at the Darkwoods field office in Nelson, B.C. who provide ongoing direct presence and monitoring of the property.	
Unemployment Potential	**V. LOW -** Generally, the southern interior of B.C. is well developed, with efficient labour markets, excellent forest law enforcement and robust diversified local economies. Unemployment levels are on par with regional/national levels and work mobility to alternative livelihoods is excellent. The communities surrounding the Darkwoods properties (i.e. Creston, Nelson) are among the most diversified and least dependant on the forest industry in the Southern Interior of B.C.(Cirque Resource Associates Ltd., 2007)	V. LOW
	IFM Project Risk Rating:	LOW

Non-Permanence Risk Assessment Summary and Buffer Determination:

The risk analysis results in a rating of "LOW" for both the All Projects assessment elements and the IFM Projects elements. Based on these risk ratings, and a qualitative assessment of the number of risk elements which provide very little material risk to the project offset permanence, the project selects a **Non-Permanence Buffer of 10%**.

For comparative purposes, the project also undertook the pending 2011 VCS Non-Permanence Risk Assessment, which provides a more quantitative assessment method. As shown below for reference/comparative purposes, this proposed tool as results in a non-permanence buffer of 7.5% (which would default to the minimum of 10%).

Appendix 1.1 – VCS 2011 Draft Risk Tool Assessment (for reference only):

Table 23 - Darkwoods Permanence Risk Rating (2011 VCS Tool) – for reference only.

Risk Criteria	Darkwoods Risk Rating	Comment
INTERNAL RISKS		
1. Technical Complexity		
a) Management practices undertaken, technologies	LOW - Proven to be effective, well established or native in the	Conservation forest management is well

applied, or species planted (where applicable) in project activity	agro-ecological zone in which the project is located, as evidenced by publications in scientific journals, technical reports from government agencies, NGOs or research groups or other projects registered under the VCS or an approved GHG program.	established, well researched, and published. NCC has extensive experience in forest conservation property management similar to the project activities.
b) Number of project activities	LOW - One to four distinct activities (e.g. activities to reduce deforestation or degradation by distinct classes of deforestation agents such as illegal loggers or collection of fuel wood by communities, or management activities such as conversion to no-till or rangeland management) required for the ongoing protection of carbon stocks.	Fundamentally there is one activity required to implement the project: acquisition of the land. Sub-activities such as access control, conservation management logging, and monitoring are not listed, but still fall within the 1-4 activities category
c) Ongoing enforcement	LOW - No ongoing enforcement required to prevent encroachment by outside actors is required to protect stocks on which credits have previously been issued.	No ongoing enforcement is required on Darkwoods.
d) Project size and accessibility	Less than five separate parcels, totaling less than 100,000 ha, and all reachable within one day of travel by those employed by the project.	
Sub-total, Technical Complexity (TC) = [a + b + c + d]	**TC = 0 + 0 + 0 + 0 = 0**	
2. Management Capacity		
a) Management team (implementing entity) experience	High - Experienced: Management team includes individuals with significant (more than five years) experience, including in AFOLU project design and	The project developers and project managers are experienced with all of the tools and management practices required for the implementation of the project.

	implementation, carbon accounting and reporting under the VCS or other approved GHG program, and other skills necessary to undertake all project activities.	
b) Management team (implementing entity) proximity	High - Full time management team is located on-site (within half a day of travel from the project location), for the management of ongoing project activities.	Darkwoods property management team is located in Nelson, BC, within 30 minutes of property.
Sub-total, Management Capacity (MC) = [a + b]	MC = 5 + 5 = 10	
TOTAL, TCM = TC × (1 – MC ⁄ 10)	TCM = 0 * (1-10/10) = 0%	
3. Financial Viability		
	Base - Project has not secured medium- and long-term funding (defined as >5 years) to reach operational breakeven after conservatively estimating GHG credit sales. Mitigation - For the next five years, project has secured revenue equal to forecasted expenses via an executed forward purchasing agreement for future GHG credits, and/or other funding sources.	NCC has the financial capability to cover property management costs for >5 years. NCC has secured initial sales agreements capable of funding > 5 years project implementation. Details confidential, but available for inspection.
	FV = 10% - 5% = 5%	
4. IFM Project Longevity		
	Long-Term - Crediting Period 75-100 years	Darkwoods crediting period is 100 years. Darkwoods has agreements with Environment Canada to manage for ecological integrity in perpetuity.
	Total Project Longevity = Long	

	Term **TPL = 0%**	
	TOTAL INTERNAL RISKS **= 0% + 5% +0% = 5%**	
EXTERNAL RISKS		
a) Ownership	Private = 0%	
b) Disputes	None = 0%	
Total [(a, b or c) + (as applicable, d + e + f)]	**Ownership Risks = 0 + 0 = 0%**	
c) Community Engagement	N/A = 0%	The local communities are not reliant on the project area (no material effect on local economics or community usage) and the area does not include areas of significance to local communities. NCC has, however, an extensive community engagement process, and an access permit program for all interested local parties to use the land for appropriate activities.
	Community Engagement = 0%	
d) Political Risk	Canada = 1.61 Rating >1.5 = 2% Mitigating: -2% Canada/BC does not appear to participate in the listed programs; however, B.C. has enacted a GHG Gas Emissions legislation which supports the development of forestry related projects. Therefore, the mitigation % is deemed to be applicable.	Voice & Accountability = +1.44 Political Stability = +1.02 Govn't Effectiveness = +1.78 Regulatory Quality = +1.64 Rule of Law = +1.78 Control of Corruption = +2.04 Avg. = 1.62

	Political Risk = 2% - 2% **Political Risk = 0%**	
	TOTAL EXTERNAL RISKS **= 0% + 0% + 0% = 0%**	
NATURAL RISKS		
a) Likelihood	<10 years (primarily fire starts) Likelihood = 2	Darkwoods does encounter incidents of fire generally on an annual basis.
b) Significance	Insignificant (<5% of biomass) Significance = 0	On a property scale, fire incidents do not affect >5% of the biomass on an annual basis averaged over 10 years.
c) Mitigation	a) Project implements prevention measures applicable to the risk factor (e.g., for fire risk, project includes fuel removal, fire breaks, fire towers and fire-fighting equipment) b) Project proponent has proven history of effectively containing natural risk Both conditions apply = 0.25%	Darkwoods implements prevention measures including: road access, active fire tower, local
	TOTAL NATURAL RISK = 2% + 0% + 0.25% **= 2.5%**	
TOTAL RISK RATING		
	Internal Risk = 5%	
	External Risk = 0%	
	Natural Risk = 2.5%	
	TOTAL RISK RATING = 7.5% **APPLY MINIMUM PERMANENCE BUFFER RISK RATING OF 10%**	

Appendix 2 – Methodology Equations Usage

The following sections provide a listing of equations described in the VCS methodology document, and used to calculate the carbon balance in the baseline and project case, for the Darkwoods property. Estimated values for all parameters are listed either in Table 7 of the PDD, two tables provided in this Appendix for HWP, or directly specified within the models being used. Selection of parameter (and input) values requires a balance between accuracy and conservativeness. Accuracy should always prevail except when alternative values are of equivalent accuracy, in which case the more conservative value is used. Details regarding model selection (i.e., FORECAST, FPS-ATLAS, and growth and yield models used to derive input values to FORECAST) and their appropriateness are provided in section 4 of the PDD.

As noted in the PDD (section 4.1), the project area was stratified into a total of 17 homogeneous analysis units. In practice, the biomass dynamics of each ecosystem pool for a given analysis unit were simulated in FORECAST, and converted into its carbon equivalent. The resulting output was then assembled into a library database. This database was used by FPS-ATLAS to track the carbon stored in all of the inventory polygons to which an analysis unit is assigned. A schematic representation of model interactions is presented in Figure 7 of the PDD and further details are described in section 4.1. The equation list in this Appendix represents the summarized carbon or biomass pools by polygon. At relevant points, reference is provided to summary documents of the actual calculations reported in the PDD.

In each section below a description of how the equations are represented within the modelling tools used in the project. These sections are highlighted in non-italics & green text, while the quoted methodology text is in italics, black text.

All equation and section numbering and cross-referencing is related to the methodology document unless otherwise noted:

Calculating the Baseline Carbon Balance

The total annual carbon balance for each inventory polygon within the project landbase is tracked using the FPS-ATLAS model in combination with the ecosystem carbon storage curves generated using FORECAST for each analysis unit. The annual carbon content (tracked for each ecosystem pool) is then summed each year for the whole landbase in baseline scenario by FPS-ATLAS and reported in the output table (see Appendix 3), and then summarized in the Darkwoods Carbon Model spreadsheet ((Equations 1-3, 10). The annual change in harvested wood products storage (Equations 2, 18) is calculated in the Darkwoods Carbon Model sheet (see below) using the annual simulated harvested wood volume output from FPS-ATLAS to drive the calculations.

This methodology employs the IPCC gain-loss method (IPCC, 2006a), *which requires the biomass carbon loss be subtracted from the biomass carbon increment for the reporting year. This method is particularly appropriate for areas with a mix of stands of different forest types, and/or where biomass change is very small compared to the total amount of biomass. Further details can be found in* (IPCC, 2006a) *(Ch. 4).*

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

$$\Delta C_{BSL,t} = \Delta C_{BSL,P,t} \qquad (1)$$

where:

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

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

$\Delta C_{BSL,LB,t}$ *= 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}*

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

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

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.

Live Biomass Gain

The total annual live biomass gain for each polygon, *i* within the project landbase is tracked using the FPS-ATLAS model in combination with the ecosystem carbon storage curves generated using FORECAST for each analysis unit. FPS-ATLAS determines the amount of C storage in each inventory polygon using its tracked age to lookup the live biomass value from the carbon curve assigned to the polygon (based upon its assigned analysis unit). The FORECAST carbon table provides values in t ha-1 which are then converted to total tons by FPS-ATLAS by multiplying by the area of the polygon (Equation 4). The amount carbon stored in above and below ground live biomass is calculated by

FORECAST (Equations 5a-b) based upon the age dependent root shoot ratio (R_i) represented in the model. (see Table 7)

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

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

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).

$$G_{BSL,i,t} = G_{BSL,AG,i,t} + G_{BSL,BG,i,t} \tag{5a}$$

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

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

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

Live Biomass Loss

The total annual live biomass loss for each polygon, *i* within the project landbase (Equations 6-8) is tracked using the FPS-ATLAS model in combination with the ecosystem carbon storage curves generated using FORECAST for each analysis unit. Within-stand losses related to natural mortality and stand-self thinning are captured within the carbon storage curves generated by FORECSAST for each analysis unit. Live biomass loss through harvesting is represented using the harvest schedule determined by FPS-ATLAS to determine when a specific inventory polygon is harvested. When this occurs, the polygon has its age reset to 1 and switches to the associated managed stand analysis unit. For example, if a polygon with an age of 150y that was assigned as AU = 101 is selected for harvesting, it age would be reset to 1 and the polygon would be reassigned to AU = 301. In this example AU 301 was simulated to reflect the dead organic matter conditions created after a clearcut harvest (of AU 101) where 90% of the stemwood biomass (present in AU 101, age 150y before the harvest) has been removed as harvested wood. Losses through road construction and landings (Equation 9) are conservatively assumed to be 0 in the baseline scenario because of the existing road network on the Darkwoods property.

The annual decrease in live biomass tree carbon from live biomass loss ($\Delta C_{BSL,L,t}$; t C yr^{-1}) is the sum of losses from:

1. *Natural mortality (i.e. insects, disease, competition, wind, etc.)*

2. *Commercial round wood felling*
3. *Incidental sources.*

Losses must be specific to a given polygon ; each polygon must be summed in order to calculate total annual loss across the project activity area. The live biomass losses are not emitted directly, but rather are transferred to dead organic matter pools.

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

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).*

$$LBL_{BSL,NATURALi,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,NATURAL,i,t} \qquad (7)$$[27]

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. Tree mortality is an ongoing process during stand development. Trees die as a consequence of insect attack, disease, competition, or some combination thereof. Hence, mortality can be highly variable between years. This parameter can be applied uniformly across an analysis unit , or individually to a given polygon. Sources for mortality estimates include permanent sample plots in similar stand types, literature reports, and inventory data.*

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

where:

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

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

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

Incidental loss ($LBL_{BSL,OTHER,i,t}$; t d.m. yr^{1}) is the additional live tree biomass removed for road and landing construction in the polygon, i, and is calculated as a proportion of biomass removed by harvesting:

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

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 by for road and landing construction in polygon, i, year, t (unitless; $0 \leq f_{BSL,DAMAGE,i,t} \leq 1$)[28]. Data for this variable should be based on regional and local comparative studies and experiential information derived from the local forest industry[29].

Dead Organic Matter Dynamics ($\Delta C_{BSL,DOM}$)

Dead organic matter dynamics including dead wood and snag creation and decay have been simulated using FORECAST for each analysis unit. Thus, Equations 10-17 are captured within the carbon curves generated by FORECAST for each analysis unit and tracked on the landbase using FPS-ATLAS in conjunction with the spatial inventory data.

Dead organic matter (DOM) included in this methodology comprises three components: standing dead wood (minimum $\geq$ 5 cm DBH and 1.3 m height; termed snags), lying dead wood (minimum $\geq$ 5 cm DBH; LDW), and belowground dead wood (i.e., dead roots). Standing dead wood is < 45º of vertical, while lying dead wood is $\geq$ 45º of vertical.

The annual change in carbon stocks in DOM ($\Delta C_{BSL,DOM}$; t C yr^{1}) is calculated as:

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

[28] Projecting ex-ante road and landing removals beyond a few years is difficult and complex. As described, $f_{BSL,DAMAGE,i,t}$ functions as a proxy for estimating biomass impacts of all new roads and landings associated with annual harvesting in polygon, i. Project proponents can simulate $LBL_{BSL,OTHER,i,t}$ directly, if appropriate models are available.

[29] $f_{BSL,DAMAGE,i,t}$ may be zero or de minimis in cases where a polygon is already roaded.

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 below-ground biomass carbon stock in year, t; t C yr^{1}.

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

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

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).

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

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; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$). Ex ante estimates shall be derived preferably from regional reports in similar forest types.

$f_{BSL,BRANCH,i,t}$ = the annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, i (unitless; $0 \leq f_{BSL,BRANCH,i,t} \leq 1$). Ex ante data are available from allometric equations and models (for example, (Kurz & Apps, 2006) *for Canada;* (Smith, Miles, Vissage, & Pugh, 2004) *for the U.S.). In the event slash burning was undertaken as part of regular management activities, this parameter should be reduced accordingly to reflect the proportion of biomass remaining. Estimates should be obtained from expert opinion; as a default, assume 100% consumption if slash burning occurs.*

$f_{BSL,BUCKINGLOSS,i,t}$ = 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; $0 \leq f_{BSL,BUCKINGLOSS,i,t} \leq 1$). Preferably, data for this variable shall be based on regional and local comparative studies and experiential information derived from the local forest industry. Otherwise, an average default value of 21% can be used, based on US national summary statistics(Smith, Miles, Vissage, & Pugh, 2004)*.*

$SNAG_{BSL,,i,t}$ = the total mass of the snag pool in polygon, i, year, t (see equation 14b).

$f_{BSL,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, i, year, t, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{SNAGFALLDOWN,i,t} \leq 1$). Ex ante estimates for this parameter can be derived from peer reviewed literature (for example, (Parish, Antos, Ott, & Di Lucca, 2010) *and forest carbon accounting models that track the rates of input and losses from dead organic matter pools (for example,* (Kurz & et al, 2009)*.*

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

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; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$). A common approach to ex ante estimation of $f_{BSL,lwDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with a single exponential model, of the general form:

$$Y_t = Y_o\, e^{-kt}$$

where Y_o is the initial quantity of material, Y_t the amount left at time t, and k is a decay constant (Harmon, et al., 1986)*. Other types of exponential models are available (reviewed in* (Harmon, et al., 1986)*) and may be more appropriate to particular forest types (to be described and justified by the project proponent, if used). Ex ante estimates for the decay parameter appropriate for the project should be derived from peer-reviewed literature (for example,* (Harmon, et al., 1986)*;* (Laiho & and Prescott, 2004)*;* (Harmon et al, 2008)*).*

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

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

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

where:

$SNAG_{BSL,i,t}$ = The total mass of snags accumulated inpolygon 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.

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

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; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$). Ex ante default estimates for this calculation can be derived from literature values (for example (Harmon, et al., 1986)*;* (Runkle, 2000)*;* (Harmon et al, 2008)*) and should be matched to the ecosystems that most closely characterize the project area.*

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

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; $0 \leq f_{BSL,SWDECAY,i,t} \leq 1$). As with lying dead wood, a common approach to estimating $f_{BSL,SWDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with a single exponential model (see equation 13). Ex ante estimates for this parameter should be derived from peer reviewed literature appropriate for the project site (for example, Vanderwel et al. 2006a) and forest carbon accounting models that track the rates of input and losses from dead organic matter pools for each forest type, productivity, and age-class (see, for example, Vanderwel et al., 2006b; (Kurz & et al, 2009)*).*

$f_{BSL,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, i, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{BSL,SNAGFALLDOWN,i,t} \leq 1$). See equation 12 for parameter estimates.

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 per equation 17a. Calculation of $\Delta C_{BSL,DBG,t}$ is specific to a given polygon; each polygon must therefore be summed in order to calculate total annual loss across the project activity area.

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

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

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).

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

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 by for road and landing construction in polygon, i (unitless; $0 \leq f_{DAMAGE,i,t} \leq 1$), year, t (see equation 9)

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

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; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$). The ex ante estimation of the decay of dead belowground biomass should be done using a similar single exponent decay function as that described above for lying deadwood biomass. Estimates for the decay parameter appropriate for specific project should be derived from peer-reviewed literature (see for example: (Moore, Trofymow, Siltanen, Prescott, & CIDET, 2005)*); Melin et al. (2009);* (Melin, Petersson, & Nordfjell, 2009)*).*

Harvested Wood Products

All harvested wood products calculations are made within the Darkwoods Carbon Model; worksheet: Summary Tables and Figures (see references, Appendix 5), using key output data from FPS-ATLAS. Key assumptions used for the Darkwoods project in the Darkwoods Carbon Model spreadsheet are summarized Appendix 2, Table 1 and Appendix 2, Table 2 below. Additional assumptions and variables not described here are found in the Darkwoods Carbon Model spreadsheet.

The annual change in the carbon stored in harvested wood products (HWP), $\Delta C_{BSl,HWP,t}$, is calculated as:

$$\Delta C_{BSl,HWP,t} = \Delta C_{BSL,PERMHWP1,t} + \Delta C_{BSL,PERMHWP2,t} - \Delta C_{BSL,EMITFOSSIL,t,} \quad (18)$$

$\Delta C_{BSL,PERMHWP1,t}$ = the annual harvested carbon that remains in permanent storage after conversion to wood products during primary processing ($t\ C\ yr^{-1}$)

$\Delta C_{BSL,PERMHWP2,t}$ = carbon that remains in permanent storage after accounting for secondary processing of the residue carbon (biomass) generated from primary processing ($t\ C\ yr^{-1}$)

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

1.4.1 Permanent carbon storage from primary processing ($\Delta C_{BSL,PERMHWP1,t}$)

The IPCC LUCF Sector Good Practice Guideline(IPCC, 2003) *for country calculations recommends estimating changes in current stocks of carbon in products-in-use. This approach is not well suited at the project level, however, because of the necessity and difficulty of assembling historical production data, estimating current stocks, and then calculating their relative decay rates. The recommended method is therefore to calculate the long-term storage in HWP stocks attributable to current production. This approach avoids any post-project calculation of carbon emissions associated with product decay,* *and accounts only for the fraction of wood products in permanent storage over a defined period (100 years is the time frame acceptable to the IPCC) (IPCC, 2000). Application of this 100-year method involves five steps (detailed in* (Miner, 2006)*):*

1. *Identify the types and amounts of biomass-based products that are made in the year of interest and end up in a final product.*
2. *Express this annual production in terms of the amount of biomass carbon per year for each product.*
3. *Divide the products into categories based on function and allocate the carbon to the functional categories.*
4. *Use decay curves or other time-in-use information to estimate the fraction of the carbon in each functional category, expected to remain in use for 100 years.*
5. *Multiply the amount of carbon in annual production in products in each functional category by the fraction remaining at 100 years. The result is the amount of sequestered carbon in the products in each functional category attributable to this year's production.*

A variety of equations are available to apply this method (Miner, 2006)*; see below). Results are sensitive to the selection of time-in-use distributions. Existing time-in-use distributions, many of which have been created to develop national carbon inventories, should be used in the 100-year method only after their suitability for making long-term projections has been established. In some cases, this can be done with available data. Data for U.S. housing, for instance, have been analyzed to confirm that time-in-use information from the U.S. national inventory can be used in the 100-year method without over estimating carbon sequestration*(Miner, 2006)*.*

The total carbon in permanent storage from primary processing in year t ($\Delta C_{BSL,PERMHWP1,t}$; t C yr^{-1}) is:

$$\Delta C_{BSL,PERMHWP1,t} = \Sigma[\,(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet \Sigma(RE_{BSL,k} \bullet f_{BSL,PERMHWPk}) \bullet CF \qquad (19)$$

where:

$LBL_{BSL,FELLINGS,i,t}$ = annual removal of live tree biomass due to commercial felling in polygon, i; t d.m. yr^{-1} (equation 8)

$LBL_{BSL,OTHER,i,t}$ = annual removal of live tree biomass from incidental sources in polygon, i; t d.m. yr^{-1} (equation 9)

$1 - f_{BSL,BRANCH,i,t}$ 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)

$1 - f_{BSL,BUCKINGLOSS,i,t}$ = the proportion of the log bole remaining after processing for quality, in polygon, i (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 12)

$RE_{BSL,k}$ = the recovery efficiency for each product type, k (unitless; $0 \leq RE_{BSL,k} < 1$).

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

$$RE_{BSL,k} = f_{BSL,PRODUCTk} \bullet f_{BSL,PROCESSk} \qquad (20)$$

where:

$f_{BSL,PRODUCTk}$, and $f_{BSL,PROCESSk}$, are the respective fractions allocated to a given forest product type, k, and its associated processing efficiency (unitless; $0 \leq f_{BSL,PRODUCTk}$, $f_{BSL,PROCESSk} < 1$).

Bucking loss (see equation 12), product allocation, and primary processing efficiency estimates are project specific and may be derived from local or regional average harvesting operations and wood processing facilities when available. Alternatively, project proponents shall select local or regionally appropriate primary processing efficiencies for milling based on published data. One source of information is the CAR Forestry Protocol 3.2, Appendix C (Climate Action Reserve, 2010)*; national and regional published sources are also available (see for example,*(Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005), (Smith, Miles, Vissage, & Pugh, 2004)*, and references therein).*

$f_{BSL,PERMHWPk}$ = the fraction of biomass allocated to permanent storage after a 100-year time period, for each product type, k (unitless; $0 \leq f_{BSLPERMHWPk} < 1$). The simplest (i.e., default) approach is to use a first order decay function, of the following form (Miner, 2006)*:*

$$f_{BSLPERMHWPk} = (1 / (1 + (Ln(2) / HL_k)))\text{^}Y \qquad (21)$$

where:

HL_k is the half-life of a given product type, k (years), and Y is the elapsed time (i.e, 100 years). A number of other more complex decay functions are available (reviewed in (Miner, 2006)*). See Appendix 2, Table 1 for default values.*

Table 1 - Darkwoods Wood Product Allocation Assumptions (Source: Darkwoods historical data), Processing Efficiency ((Briggs, 1994), (CAR, 2010)), and Product Half-Life (Miner, 2006).

Product	Allocation	Processing efficiency	Half life (yrs)
Sawnwood	0.58	0.637	35
Veneer, plywood, structural panels	0.26	0.445	30
Non-structural panels	0.0	0.501	20
Paper	0.16	0.50	2

Secondary processing of the residue carbon (biomass) generated from primary processing ($\Delta C_{BSL,PERMHWP2,t}$)

Primary timber processing mills (facilities that convert roundwood into products such as lumber, plywood, and wood pulp) generate residues that are used for secondary processing. These residues fall into three categories — bark, coarse residues (chunks and slabs), and fine residues (shavings and sawdust). For paper production, Kraft (or sulfate) pulping is the most common processing technology. In Kraft pulping about half the wood is converted into fiber and other half becomes black liquor, a by-product containing unutilized wood fiber and valuable chemicals. Pulp and paper facilities combust black liquor in recovery boilers to produce energy (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*.*

The total residual biomass remaining in year t after primary product processing ($B_{BSL,RESIDUAl,t}$; t d.m. yr^{-1}) is:

$$B_{BSL,RESIDUAl,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet \Sigma(f_{BSL,PRODUCTk} - RE_{BSL,k}) \qquad (22)$$

where:

$f_{BSL,PRODUCTk}$ is as defined in equation 20; all other terms are defined in equation 19.

For purposes of secondary manufacturing, it is assumed that any residual biomass derived from paper production (i.e., black liquor) is combusted at 100% efficiency (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*, a conservative assumption. Hence, the final summation term in $B_{RESIDUAl,t}$ is therefore calculated for all product types, except paper.*

Let f_{BARK}, f_{COARSE}, and f_{FINE}, be the proportions of bark, coarse, and fine residual biomass, respectively, (unitless; $0 \leq f_{BARKt}$, $f_{COARSEt}$, $f_{FINEt} < 1$) that comprise $B_{BSL,RESIDUAl,t}$. In addition, let $f_{BARKUSE}$, $f_{COARSEUSE}$, and $f_{FINEUSE}$ be the proportions of each of these biomass categories that are allocated to secondary manufacturing (unitless; $0 \leq f_{BARKUSE}$, $f_{COARSEUSE}$, $f_{FINEUSE} < 1$).

The biomass allocated to secondary processing of bark, and coarse and fine residuals, in year, t (t d.m. yr^{-1}), is therefore:

$$B_{BSL,BARK,t} = B_{BSL,RESIDUAl,t} \bullet f_{BSL,BARK} \bullet f_{BSL,BARKUSE} \qquad (23a)$$

$$B_{BSL,COARSE,t} = B_{BSL,RESIDUAl,t} \bullet f_{BSL,COARSE} \bullet f_{BSL,COARSEUSE} \qquad (23b)$$

$$B_{BSL,FINE,t} = B_{BSL,RESIDUAl,t} \bullet f_{BSL,FINE} \bullet f_{BSL,FINEUSE} \qquad (23c)$$

Default values are 26.5%, 42.9%, and 30.6%, for f_{BARK}, f_{COARSE}, and f_{FINE}, respectively (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*. Default values are 85%,* *and 42%, for $f_{COARSEUSE}$, and $f_{FINEUSE}$, respective* (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*). Evidence indicates that on average 80% of bark is combusted for energy, with the remainder used principally as mulch* (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*. Decay rates for mulch are difficult to estimate. Hence, as a default, all bark is assumed to be 100% combusted, a conservative assumption. Local data should be used for all variables, if available.*

$B_{COARSE,t}$ and $B_{FINE,t}$ must now be allocated to particular product classes in order to derive estimates of permanence from secondary manufacturing using the 100-year method ($\Delta C_{BSL,PERMHWP2,t}$).

$$\Delta C_{BSL,PERMHWP2,t} = B_{BSL,COARSE,t} \bullet f_{BSL,PROCESSc} \bullet f_{BSL,PERMHWPc} + B_{BSL,FINE,t} \bullet f_{BSL,PROCESSf} \bullet f_{BSL,PERMHWPf} \quad (24)$$

Processing efficiencies of coarse and fine residuals ($f_{BSL,PROCESSc}$ and $f_{BSL,PROCESSf}$, respectively) in secondary manufacturing are typically much higher than primary manufacturing. A default value of 85 % can be used (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005) *if project-specific values are not available. With respect to calculating permanent storage, the default approach is to assume that $B_{BSL,COARSE,t}$ has a half-life equivalent to sawnwood, and $B_{BSL,FINE,t}$ has a half-life equivalent to non-structural panels (see Appendix 2, Table 2). These values are then used in equation 24 to calculate the fraction of biomass allocated to permanent storage after a 100-year time period, for the coarse and fine material. Alternative half-lives (see* (Miner, 2006)*) can be used if justified from industry-specific information.*

Fossil fuel emissions associated with logging, transport, and manufacture

Annual fossil fuel emissions from harvesting and processing of the various wood products ($C_{BSL,EMITDIRECT,t}$) are calculated as:

$$C_{BSL,EMITFOSSIL,t} = \Delta C_{BSL,EMITHARVEST,t} + \Delta C_{BSL,EMITMANUFACTURE,t} + \Delta C_{BSL,EMITTRANSPORT,t} \quad (25)$$

where:

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

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

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

The simplest approach to calculating $C_{BSL,EMITFOSSIL,t}$ is to use published or derived carbon emission intensity factors. In the case of harvesting, $\Delta_{BSL,}C_{EMITHARVEST,t}$; t C yr^{-1}), can be calculated as:

$$\Delta C_{BSL,EMITHARVEST,t} = \Sigma[\,(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet c_{HARVEST} \quad (26a)$$

where:

$c_{HARVEST}$ is the carbon emission intensity factor (t C emitted/t C raw material) associated with harvesting (see Appendix 2, Table 2 for default values); ; all other terms are as defined in equation 19.

$\Delta C_{BSL,EMITTRANSPORT,t}$ must be calculated after consideration of the transport distance from harvest to processing facility, and the means of transportation. This term can be calculated as follows (after (Heath, et al., 2010)*):*

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

where:

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

$d_{TRANSPORTk} =$ 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 (see Appendix 2, Table 2 for default values); all other terms are as defined in equation 19.

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

$c_{MANUFACTUREk}$ 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 19.

(Heath, et al., 2010) Darkwoods estimates for $c_{MANUFACTUREk}$ are provided in Appendix 2,Table 2.

Table 2 – Carbon emission intensity factors for harvesting, manufacture, and transportation associated with different product categories

Activity	Value	Reference
Harvesting ($c_{HARVEST}$) (t C emitted/t C raw material)		
Clearcut harvest	0.016	(Zhang, Cormier, Lyng, Mabee, Ogino, & McLean, 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

Ex Post Calculations of Carbon Stocks

The calculation of actual (ex post) carbon stocks is undertaken using field plot sampling data. At the time of validation, the Darkwoods carbon project had not completed the initial field plots, and had not undertaken the following calculations. These calculation will be undertaken with Darkwoods field data at verification.

Actual (ex post) annual net carbon stocks are calculated using the equations in this section.

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

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

Average aboveground biomass for measured polygon, i, in year, t ($B_{AG,i,t}$) is determined by converting the aboveground, tree-level measurements (kg biomass per tree) described in Section 13.2 to area-based, stand-level measurements (t ha^{-1}). This is achieved by summing the aboveground biomass of all the trees within a sample plot, converting kg to t, and then dividing the sum by the plot area in ha. All plots within a particular polygon should be averaged to get an average estimate of stand-level aboveground biomass (t ha^{-1}). Once the average aboveground biomass has been determined for each measured polygon, belowground biomass is estimated by multiplying the aboveground biomass by the root:shoot ratio, R_i (equation 28d) and the two are summed to determine total stand-level live biomass for measured polygon i, time t, ($B_{TOTAL,i,t}$). R_i is described in Section 8.2.1. Finally, the average measured carbon stock in living tree biomass for measured polygon i, time t, ($C_{LB,i,t}$) is calculated as shown in equation 28c. This value of $C_{LB,i,t}$ must be compared to the equivalent calculation of live biomass ($LB_{PRJ,i,t}$) calculated in the project scenario (Section 9.3) (see comparison method and steps below).

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

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

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

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

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 in Section 13.2. The value of $DOM_{LDW,i,t}$ must be compared to the equivalent calculation of lying dead wood mass ($LDW_{PRJ,i,t}$) in the project scenario (Section 9.3.3) (see comparison method and steps below).

The average quantity of dead organic matter contained in standing snags for measured polygon, i, in year, t ($DOM_{SNAG,i,t}$ is calculated by summing the mass (aboveground only) of all the measured standing dead trees within a sample plot (converting kg to t) and dividing the sum by the plot area in ha (See Section 13.2). The belowground component of snags is treated as dead below ground biomass (See Section 9.3.3) and is not directly measured. All plots within a particular polygon should be averaged to get an average estimate of $DOM_{SNAG,i,t}$. The value of $DOM_{SNAG,i,t}$ must be compared to the equivalent calculation of standing dead tree mass ($SNAG_{PRJ,i,t}$) in the project scenario (Section 9.3.3) (see comparison method and steps below).

Calculating the Project Carbon Balance

The total annual carbon balance for each inventory polygon within the project landbase is tracked using the FPS-ATLAS model in combination with the ecosystem carbon storage curves generated using FORECAST for each analysis unit. The annual carbon content (tracked for each ecosystem pool) is then summed each year for the whole landbase in baseline scenario by FPS-ATLAS and reported in the output table (see Appendix 3), and then summarized in the Darkwoods Carbon Model spreadsheet ((Equations 29-31, 38). The annual change in harvested wood products storage (Equations 30, 46) is calculated in the Darkwoods Carbon Model sheet (see below) using the annual simulated harvested wood volume output from FPS-ATLAS to drive the calculations.

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} .

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

$\Delta C_{PRJ,LB,t}$ = 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}.

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

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.

Live Biomass Gain

The total annual live biomass gain for each polygon, *i* within the project landbase is tracked using the FPS-ATLAS model in combination with the ecosystem carbon storage curves generated using FORECAST for each analysis unit. FPS-ATLAS determines the amount of C storage in each inventory polygon using its tracked age to lookup the live biomass value from the carbon curve assigned to the polygon (based upon its assigned analysis unit). The FORECAST carbon table provides values in t ha-1 which are then converted to total tons by FPS-ATLAS by multiplying by the area of the polygon (Equation 32). The amount carbon stored in above and below ground live biomass is calculated by FORECAST (Equations 33a-b) based upon the age dependent root shoot ratio (R_i) represented in the model. (see Table 7)

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

$$\Delta C_{PRJ,G,t} = \Sigma(A_{PRJ,i} \bullet G_{PRJ,i,t}) \bullet CF \quad (32)$$

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).

$$G_{PRJ,i,t} = G_{PRJ,AG,i,t} + G_{PRJ,BG,i,t} \quad (33a)$$

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

$$G_{PRJ,BG,i,t} = G_{PRJ,AG,i,t} \bullet R_i \qquad (33b)$$

where R_i is the root:shoot ratio in polygon, i. R_i should ideally be estimated for each polygon, but these data are difficult to derive empirically. Hence, general relationships are acceptable (Cairns, 1997).

Equations 32 and 33 can be used directly to calculate $\Delta C_{PRJ,G,t}$ when all tree cover within a polygon is removed by harvesting (i.e., clearfelling) and no residual structure is retained. In cases of partial harvesting and/or multiple entries into a polygon, these equations must be applied separately to each of the resulting sub-polygons (the different age classes that are created). This ensures that growth rates reflect the difference in forest age between the sub-polygons.

Live Biomass Loss

The total annual live biomass loss for each polygon, *i* within the project landbase (Equations 34-36) is tracked using the FPS-ATLAS model in combination with the ecosystem carbon storage curves generated using FORECAST for each analysis unit. Within-stand losses related to natural mortality and stand-self thinning are captured within the carbon storage curves generated by FORECSAST for each analysis unit. Live biomass loss through harvesting is represented using the harvest schedule determined by FPS-ATLAS to determine when a specific inventory polygon is harvested. When this occurs, the polygon has its age reset to 1 and switches to the associated managed stand analysis unit. For example, if a polygon with an age of 150y that was assigned as AU = 101 is selected for harvesting, it age would be reset to 1 and the polygon would be reassigned to AU = 201. In this example AU 201 was simulated to reflect the dead organic matter conditions created after a clearcut harvest (of AU 101) where 90% of the stemwood biomass (present in AU 101, age 150y before the harvest) has been removed as harvested wood. Losses through road construction and landings (Equation 37) will be assessed through monitoring activities in the project scenario. Any losses of area due to management activities will be updated in the spatial inventory. However, we expect this term to be minor because of the existing road network on the Darkwoods property.

The annual decrease in aboveground tree carbon from live biomass loss ($\Delta C_{PRJ,L,t}$; t C yr^{-1}) is the sum of losses from:

1. *Natural mortality (i.e. insects, disease, competition, wind, etc.)*
2. *Commercial round wood felling*
3. *Incidental sources.*

Losses must be specific to a given polygon; each polygon must be summed in order to calculate total annual loss across the project activity area. The live biomass losses are not emitted directly, but rather are transferred to dead organic matter pools.

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

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).

$$LBL_{PRJ,NATURALi,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,NATURAL,i,t} \quad (35)$$[30]

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. Tree mortality is an ongoing process during stand development. Trees die as a consequence of insect attack, disease, competition, or some combination thereof. Hence, mortality can be highly variable between years. This parameter can be applied uniformly across an analysis unit, or individually to a given polygon. Ex post estimates from regional data sources in corresponding stand types are preferred. Sources for mortality estimates include permanent sample plots in similar stand types, literature reports, and inventory data. Some models (the FORECAST model, for example) simulate annual background mortality rates directly and can accommodate variable age structures following partial harvesting.

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

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).

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[30] Note, for Equation 35, 36, and 37: $(f_{PRJ,NATURAL,i,t} + f_{PRJ,HARVEST,i,t} + f_{PRJ,DAMAGE,i,t}) \leq 1.0$

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, i, (unitless; 0 $\leq f_{PRJ,HARVESTi} \leq 1$), in year, t. Data for this variable should be obtained from harvest schedule information. Values may be constrained by (a) the value of $f_{PRJ,NATURAL,i,t}$ (i.e., $f_{PRJ,HARVEST,i,t} < 1- f_{PRJ,NATURAL,i,t}$), and/or (b) the area of timber available for commercial harvest.

Incidental loss ($LBL_{PRJ,OTHER,i,t}$; t d.m. yr^{-1}) is the additional live tree biomass removed for road and landing construction in the polygon, i, and is calculated as a proportion of biomass removed by harvesting:

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

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; $0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$)[31]. Data for this variable should be based on regional and local comparative studies and experiential information derived from the local forest industry[32].

Dead Organic Matter Dynamics ($\Delta C_{PRJ,DOM,t}$)

Dead organic matter dynamics including dead wood and snag creation and decay have been simulated using FORECAST for each analysis unit. Thus, Equations 38-45 are captured within the carbon curves generated by FORECAST for each analysis unit and tracked on the landbase using FPS-ATLAS in conjunction with the spatial inventory data.

Dead organic matter (DOM) included in this methodology comprises three components: standing dead wood (minimum $\geq$ 5 cm DBH and 1.3 m height; termed snags), lying dead wood (minimum $\geq$ 5 cm DBH; LDW), and belowground dead wood (i.e., dead roots). Standing dead wood is < 45º of vertical, while lying dead wood is $\geq$ 45º of vertical.

The annual change in carbon stocks in DOM ($\Delta C_{PRJ,DOM}$; t C yr^{-1}) is calculated as:

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

where:

[31] Projecting ex-ante road and landing removals beyond a few years is difficult and complex. As described, $f_{PRJ,DAMAGE,i,t}$ functions as a proxy for estimating biomass impacts of all new roads and landings associated with annual harvesting in polygon, i. Project proponents can simulate $LBL_{PRJ,OTHER,i,t}$ directly, if appropriate models are available.

[32] $f_{PRJ,DAMAGE,i,t}$ may be zero or de minimis in cases where a polygon is already roaded.

$\Delta C_{PRJ,LDW,t}$ = 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 below-ground carbon stock in year, t; t C yr^{-1}.

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

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

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).

$$\begin{aligned} LDW_{PRJ,IN,i,t} = {} & (LBL_{PRJ,NATURALi,t} - LBL_{PRJ,NATURALi,t} \bullet R_i) \bullet f_{PRJ,BLOWDOWN,i,t} + \\ & ((LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i) + \\ & (LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i)) \bullet f_{PRJ,BRANCH,i,t} + \\ & ((LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i) + \\ & (LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i)) \bullet \\ & (1 - f_{PRJ,BRANCH,i,t}) \bullet f_{PRJ,BUCKINGLOSS,i,t} + SNAG_{PRJ,,i,t} \bullet f_{PRJ,SNAGFALLDOWN,i,t} \qquad (40) \end{aligned}$$

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; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$). Ex ante estimates shall be derived preferably from regional reports in similar forest types.

$f_{PRJ,BRANCH,i,t}$ = the annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, i (unitless; $0 \leq f_{PRJ,BRANCH,i,t} \leq 1$). Ex ante data are available from *allometric equations and models (for example,* (Kurz & Apps, 2006) *for Canada;* (Smith, Miles, Vissage, & Pugh, 2004) *for the U.S.). In the event slash burning is undertaken, this parameter should be reduced accordingly to reflect the proportion of biomass remaining. Estimates should be obtained from expert opinion; as a default, assume 100% consumption.*

$f_{PRJ,BUCKINGLOSS,i,t}$ *= 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;* $0 \leq f_{PRJ,BUCKINGLOSS,i,t} \leq 1$*). Preferably, data for this variable shall be based on regional and local comparative studies and experiential information derived from the local forest industry. Otherwise, an average default value of 21% can be used, based on US national summary statistics*(Smith, Miles, Vissage, & Pugh, 2004)*.*

$SNAG_{PRJ,i,t}$ *= 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;* $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$*). Ex ante estimates for this parameter can be derived from peer reviewed literature (for example,* (Parish, Antos, Ott, & Di Lucca, 2010) *and forest carbon accounting models that track the rates of input and losses from dead organic matter pools (for example,* (Kurz & et al, 2009)*.*

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

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; ;* $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$*). A common approach to ex ante estimation of* $f_{PRJ,lwDECAY,i,t}$ *is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with an a single exponential model, of the general form:*

$Y_t = Y_o e^{-kt}$

where Y_o *is the initial quantity of material,* Y_t *the amount left at time t, and k is a decay constant* (Harmon, et al., 1986)*. Other types of exponential models are available (reviewed in* (Harmon, et al., 1986)*) and may be more appropriate to particular forest types (to be described and justified by the project proponent, if used). Ex ante estimates for the decay parameter appropriate for the project should be derived from peer-reviewed literature (for example,* (Harmon, et al., 1986)*;* (Laiho & and Prescott, 2004)*;* (Harmon et al, 2008)*).*

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

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

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

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 biomass develops as a result of natural mortality. In cases where snags are created through management activities, these should be accounted for here.

$SNAG_{PRJ,OUT,i,t}$ = 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.

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

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; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$). Ex ante default estimates for this calculation can be derived from literature values (for example (Harmon, et al., 1986)*;* (Runkle, 2000)*;* (Harmon et al, 2008)*) and should be matched to the ecosystems that most closely characterize the project area.*

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

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; $0 \leq f_{PRJ,SWDECAY,i,t} \leq 1$). As with lying dead wood, a common approach to estimating $f_{PRJ,SWDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with an a single exponential model (see equation 41). Ex ante estimates for this parameter can be derived from peer reviewed literature appropriate for the project site (for example, Vanderwel et al. 2006a) and forest carbon accounting models that track the rates of input and losses from dead organic matter pools for each forest type, productivity, and age-class (see, for example, Vanderwel et al., 2006b; (Kurz & et al, 2009)*).*

$f_{PRJ,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, i, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$). See equation 40 for parameter estimates.

The annual change in DOM derived from dead belowground biomass ($\Delta C_{PRJ,DBG,,t}$; t C yr^{-1}) is calculated for each polygon as per equation 45a. Calculation of $\Delta C_{PRJ,DBG,t}$ is specific to a given polygon; each polygon must therefore be summed in order to calculate total annual loss across the project activity area.

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

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

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}). Dead belowground biomass develops as a result of mortality through natural causes or through harvesting activities.

$DBG_{PRJ,OUT,i,t}$ = 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).

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

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; $0 \leq f_{PRJ,HARVESTi} \leq 1$), 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),

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

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; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$). The ex ante estimation of the decay of dead belowground biomass should be done using a similar single exponent decay function as that described above for lying deadwood biomass. Estimates for the decay parameter appropriate for specific project should be derived from peer-reviewed literature (see for example: (Moore, Trofymow, Siltanen, Prescott, & CIDET, 2005)*;* (Melin, Petersson, & Nordfjell, 2009).

Harvested Wood Products

All harvested wood products calculations are made within the Darkwoods Carbon Model; worksheet: Summary Tables and Figures (see references, Appendix 5), using key output data from FPS-ATLAS. Key assumptions used for the Darkwoods project in the Darkwoods Carbon Model spreadsheet are summarized Appendix 2, Table 1 and Appendix 2, Table 2 below. Additional assumptions and variables not described here are found in the Darkwoods Carbon Model spreadsheet.

See Section 8.4 (equivalent baseline calculations) for various discussion and background on HWP calculations.

The annual change in the carbon stored in harvested wood products (HWP), $\Delta C_{PRJ,HWP,t}$, is calculated as:

$$\Delta C_{PRJ,HWP,t} = \Delta C_{PRJ,PERMHWP1,t} + \Delta C_{PRJ,PERMHWP2,t} - \Delta C_{PRJ,EMITFOSSIL,t} \qquad (46)$$

$\Delta C_{PRJ,PERMHWP1,t}$ = the annual harvested carbon that remains in permanent storage after conversion to wood products during primary processing ($t\ C\ yr^{-1}$)

$\Delta C_{PRJ,PERMHWP2,t}$ = carbon that remains in permanent storage after accounting for secondary processing of the residue carbon (biomass) generated from primary processing ($t\ C\ yr^{-1}$)

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

Permanent carbon storage from primary processing ($\Delta C_{PRJ,PERMHWP1,t}$)

If harvesting is occurring in the project case, see section 8.3 for a discussion of key issues.

$$\Delta C_{PRJ,PERMHWP1,t} = \Sigma[\,(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJBUCKINGLOSS,i,t})] \bullet \Sigma(RE_{PRJk} \bullet f_{PRJ,PERMHWPk}) \bullet CF \qquad (47)$$

where:

$LBL_{PRJ,FELLINGS,i,t}$ = annual removal of aboveground live tree biomass due to commercial felling in polygon, i; $t\ d.m.\ yr^{-1}$ (equation 36)

$LBL_{PRJ,OTHER,i,t}$ = annual removal of live tree biomass from incidental sources in polygon, i; t d.m. yr^{1} (equation 37)

1 - $f_{PRJ,BRANCH,i,t}$ the proportion of aboveground live tree biomass remaining after netting out branch biomass, in polygon i (unitless; $0 \leq f_{PRJ,BRANCH,i,t} \leq 1$)(see equation 40)

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

$RE_{PRJ,k}$ = the recovery efficiency for each product type, k (unitless; $0 \leq RE_{PRJ,k} < 1$).

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

$$RE_{PRJ,k} = f_{PRJ,PRODUCTk} \bullet f_{PRJ,PROCESSk} \quad (48)$$

where:

$f_{PRJ,PRODUCTk}$, and $f_{PRJ,PROCESSk}$, are the respective fractions allocated to a given forest product type, k, and its associated processing efficiency (unitless; $0 \leq f_{PRJ,PRODUCTk}, f_{PRJ,PROCESSk} < 1$).

Bucking loss, product allocation, and primary processing efficiency estimates are project specific and may be derived from local or regional average harvesting operations and wood processing facilities when available. Alternatively, project proponents shall select local or regionally appropriate primary processing efficiencies for milling based on published data. One source of information is the CAR Forestry Protocol 3.2, Appendix C (Climate Action Reserve, 2010)*; national and regional published sources are also available (see for example,*(Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*,* (Smith, Miles, Vissage, & Pugh, 2004)*, and references therein).*

$f_{PRJ,PERMHWPk}$ = the fraction of biomass allocated to permanent storage after a 100-year time period, for each product type, k (unitless; $0 \leq f_{PRJ,PERMHWPk} < 1$). The simplest (i.e. default) approach is to use a first order decay function, of the following form (Miner, 2006)*:*

$$f_{PRJ,PERMHWPk} = (1 / (1 + (Ln(2) / HL_k)))^{\wedge}Y \quad (49)$$

where:

HL_k is the half-life of a given product type, k (years), and Y is the elapsed time (i.e, 100 years). A number of other more complex decay functions are available (reviewed in (Miner, 2006)*). Selection of any particular function other than the default should be justified in the PDD. If a first order function is employed, use* (IPCC, 2003a) *for default values unless national or sub-national values are available.*

Secondary processing of the residue carbon (biomass) generated from primary processing ($\Delta C_{PRJ,PERMHWP2,t}$)

See Section 8 for further discussion on residual manufacturing waste

The total residual biomass remaining in year t after primary product processing ($B_{PRJ,RESIDUAl,t}$; t d.m. yr^{1}) is:

$$B_{PRJRESIDUAl,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet \Sigma(f_{PRJ,PRODUCTk} - RE_{PRJ,k}) \quad (50)$$

where:

$RE_{PRJ,k}$ is as defined in equation 48; all other terms are defined in equation 47.

For purposes of secondary manufacturing, it is assumed that any residual biomass derived from paper production (i.e., black liquor) is combusted at 100% efficiency (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*, a conservative assumption. Hence, the final summation term in $B_{PRJ,RESIDUAl,t}$ is therefore calculated for all product types, except paper.*

Let $f_{PRJ,BARK}$, $f_{PRJ,COARSE}$, and $f_{PRJ,FINE}$, be the proportions of bark, coarse, and fine residual biomass, respectively, (unitless; $0 \leq f_{PRJ,BARKt}$, $f_{PRJ,COARSEt}$, $f_{PRJ,FINEt} < 1$) that comprise $B_{PRJ,RESIDUAl,t}$. In addition, let $f_{PRJ,BARKUSE}$, $f_{PRJ,COARSEUSE}$, and $f_{PRJ,FINEUSE}$ be the proportions of each of these biomass categories that are allocated to secondary manufacturing (unitless; $0 \leq f_{PRJ,BARKUSE}$, $f_{PRJ,COARSEUSE}$, $f_{PRJ,FINEUSE} < 1$).

The biomass allocated to secondary processing of bark, and coarse and fine residuals, in year, t (t d.m. yr^{1}), is therefore:

$$B_{PRJ,BARK,t} = B_{PRJ,RESIDUAl,t} \bullet f_{PRJ,BARK} \bullet f_{PRJ,BARKUSE} \quad (51a)$$

$$B_{PRJ,COARSE,t} = B_{PRJ,RESIDUAl,t} \bullet f_{PRJ,COARSE} \bullet f_{PRJ,COARSEUSE} \quad (51b)$$

$$B_{PRJ,FINE,t} = B_{PRJ,RESIDUAl,t} \bullet f_{PRJ,FINE} \bullet f_{PRJ,FINEUSE} \quad (51c)$$

Default values are 26.5%, 42.9%, and 30.6%, for $f_{PRJ,BARK}$, $f_{PRJ,COARSE}$, and $f_{PRJ,FINE}$, respectively (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*. Default values are 85%, and 42%, for $f_{PRJ,COARSEUSE}$, and $f_{PRJ,FINEUSE}$, respective* (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*). Evidence indicates that on average 80% of bark is combusted for energy, with the remainder used principally as mulch (Perlack et al. 2005). Decay rates for mulch are difficult to estimate. Hence, as a default, all bark is assumed to be 100% combusted, a conservative assumption. Local data should be used for all variables, if available.*

$B_{PRJ,COARSE,t}$ and $B_{PRJ,FINE,t}$ must now be allocated to particular product classes in order to derive estimates of permanence from secondary manufacturing using the 100-year method ($\Delta C_{PRJ,PERMHWP2,t}$).

$$\Delta C_{PRJ,PERMHWP2,t} = B_{PRJ,COARSE,t} \bullet f_{PRJ,PROCESSc} \bullet f_{PRJ,PERMHWPc} + B_{PRJ,FINE,t} \bullet f_{PRJ,PROCESSf}$$

$\bullet\ f_{PRJ,PERMHWPf}$ **(52)**

Processing efficiencies ($f_{PRJ,PROCESSc}$ and $f_{PRJ,PROCESSf}$) in secondary manufacturing are typically much higher than primary manufacturing. Hence, a default value of 85 % can be used (Perlack, Wright, Turhollow, Graham, Stodkes, & Erback, 2005)*. With respect to calculating permanent storage, the default approach is to assume that $B_{PRJ,COARSE,t}$ has a half-life equivalent to sawnwood, and $B_{PRJ,FINE,t}$ has a half-life equivalent to non-structural panels. These values are then used in equation 20 to calculate the fraction of biomass allocated to permanent storage after a 100-year time period, for the coarse and fine material. Alternative half-lives (see* (Miner, 2006)*) can be used if justified from industry-specific information.*

Fossil fuel emissions associated with logging, transport, and manufacture

Annual fossil fuel emissions from harvesting and processing of the various wood products ($C_{PRJ,EMITDIRECT,t}$) are calculated as:

$$C_{PRJ,EMITFOSSIL,t} = \Delta C_{PRJ,EMITHARVEST,t} + \Delta C_{PRJ,EMITMANUFACTURE,t} + \Delta C_{PRJ,EMITTRANSPORT,t} \qquad (53)$$

Where

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

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

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

The simplest approach to calculating $C_{PRJ,EMITFOSSIL,t}$ is to use published or derived carbon emission intensity factors. In the case of harvesting, $\Delta_{PRJ,}C_{EMITHARVEST,t}$; t C yr^{1}), can be calculated as:

$$\Delta C_{PRJ,EMITHARVEST,t} = \Sigma[\,(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet c_{HARVEST} \qquad (54a)$$

where:

$c_{HARVEST}$ is the carbon emission intensity factor (t C emitted/t C raw material) associated with harvesting (see Appendix 2, Table 2); all other terms are as defined in equation 19.

$\Delta C_{PRJ,EMITTRANSPORT,t}$ must be calculated after consideration of the transport distance from harvest to processing facility, and the means of transportation. This term can be calculated as follows (after (Heath, et al., 2010)*):*

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

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);

$c_{TRANSPORTk}$ is the carbon emission intensity factor (kg C emitted/t C raw material) associated with transportation type; all other terms are as defined in equation 19.

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

$c_{MANUFACTUREk}$ 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 19.

(Heath, et al., 2010)(Heath, et al., 2010)Estimates for $c_{MANUFACTUREk}$ are provided in Appendix 2, Table 2.

Note: Equations and calculations for Leakage, Gross Emissions Reductions, Net Emissions Reductions, and Project VCU's are covered in the main document in detail.

Appendix 3 – Output from FPS-ATLAS model

Table 24 - FPS-ATLAS model output showing total C storage (t C) in each of the modeled ecosystem pools for each simulation year in the baseline scenario. Net Ecosystem C, used in the calculation of VCUs, includes Tree C, Deadwood C and Dead Belowground biomass (BG) C.

Baseline Scenario							
Year	Tree C	Plant C	Deadwood C	Litter C	Dead BG C	Soil C	Net Ecosystem C
0	4,173,005	28,329	665,724	216,967	683,879	3,201,485	5,522,608
1	4,096,566	28,551	643,064	217,549	695,397	3,203,984	5,435,027
2	4,029,312	28,642	618,912	218,334	708,742	3,203,094	5,356,966
3	3,869,060	28,634	627,120	221,283	734,012	3,204,578	5,230,192
4	3,637,747	30,633	694,783	237,519	821,645	3,211,218	5,154,175
5	3,551,524	31,703	683,370	239,233	824,598	3,211,488	5,059,492
6	3,470,858	31,193	662,221	236,183	824,533	3,208,201	4,957,612
7	3,398,697	32,562	642,308	232,030	814,543	3,206,076	4,855,548
8	3,283,908	33,705	643,258	229,286	807,638	3,208,163	4,734,804
9	3,212,169	35,095	628,106	231,530	807,485	3,210,067	4,647,760
10	3,132,050	35,115	617,245	230,263	808,330	3,212,381	4,557,625
11	3,060,685	34,707	600,535	230,503	805,365	3,213,600	4,466,585
12	2,973,963	34,891	584,604	230,425	802,483	3,215,699	4,361,050
13	2,883,415	35,362	582,688	229,991	793,059	3,218,002	4,259,162
14	2,791,451	35,877	575,389	232,112	807,049	3,218,977	4,173,889
15	2,695,087	35,224	564,671	234,461	827,338	3,222,085	4,087,096
16	2,651,502	38,441	551,823	233,688	819,648	3,226,547	4,022,973
17	2,687,205	40,263	546,675	226,077	785,795	3,227,410	4,019,675
18	2,699,060	42,434	553,458	221,394	749,996	3,229,182	4,002,514
19	2,686,001	41,459	544,981	224,887	746,141	3,235,085	3,977,123
20	2,720,148	42,635	532,800	222,054	716,408	3,233,631	3,969,356
25	2,816,540	45,815	523,514	216,375	621,033	3,236,846	3,961,087
30	2,946,579	54,633	474,655	207,123	554,449	3,242,713	3,975,683
35	2,906,654	56,780	454,288	219,561	570,603	3,255,714	3,931,545
40	3,026,970	56,822	425,515	221,441	530,713	3,252,890	3,983,198
45	3,130,557	57,077	407,258	223,531	513,656	3,245,490	4,051,471
50	3,140,454	57,950	394,840	230,452	541,381	3,233,499	4,076,675
55	3,145,186	57,389	370,757	229,733	570,709	3,218,570	4,086,652
60	3,151,836	56,371	363,306	230,338	620,209	3,214,338	4,135,351
65	3,234,794	55,690	374,444	225,784	585,652	3,205,768	4,194,890
70	3,393,248	51,509	356,717	218,828	555,445	3,199,293	4,305,410
75	3,540,585	47,552	345,969	224,165	547,526	3,196,770	4,434,080
80	3,440,528	41,567	360,057	245,637	667,413	3,206,615	4,467,998
85	3,318,161	41,758	375,547	248,322	712,758	3,210,012	4,406,466
90	3,329,619	44,612	379,499	242,769	675,582	3,222,897	4,384,700
95	3,278,268	47,540	396,700	251,151	662,585	3,236,587	4,337,553
100	3,312,366	48,132	392,284	243,880	621,412	3,236,176	4,326,062

Table 25 - FPS-ATLAS model output showing total C storage (t C) in each of the modeled ecosystem pools for each simulation year in the project scenario. Net Ecosystem C, used in the calculation of VCUs, includes Tree C, Deadwood C and Dead Belowground biomass (BG) C.

Project Scenario							
Year	Tree C	Plant C	Deadwood C	Litter C	Dead BG C	Soil C	Net Ecosystem C
0	4,173,005	28,329	665,724	216,967	683,879	3,201,485	5,522,608
1	4,193,551	28,651	645,189	217,214	683,899	3,205,771	5,522,639
2	4,232,162	28,858	623,278	216,301	680,581	3,206,790	5,536,021
3	4,198,756	28,881	650,442	215,769	680,891	3,208,363	5,530,089
4	3,930,802	31,059	809,019	239,381	782,110	3,214,947	5,521,931
5	3,962,464	32,085	796,397	239,767	765,070	3,215,665	5,523,931
6	4,010,486	31,294	779,647	236,524	752,155	3,215,550	5,542,288
7	4,052,456	31,889	763,527	234,162	742,238	3,215,272	5,558,221
8	4,056,041	31,698	771,429	233,551	730,870	3,217,331	5,558,340
9	4,097,524	32,117	753,555	236,459	730,860	3,218,803	5,581,939
10	4,144,672	32,192	743,302	234,309	723,870	3,219,685	5,611,844
11	4,190,496	31,741	722,926	235,862	718,421	3,220,113	5,631,843
12	4,234,426	31,658	705,165	234,766	711,340	3,222,252	5,650,931
13	4,259,056	31,358	704,487	235,720	699,477	3,225,143	5,663,020
14	4,301,315	31,313	692,583	236,896	702,332	3,224,332	5,696,230
15	4,349,600	31,121	681,496	236,958	699,664	3,226,610	5,730,760
16	4,393,225	34,680	663,015	237,076	690,281	3,230,459	5,746,521
17	4,437,116	34,845	651,728	234,970	690,164	3,232,258	5,779,008
18	4,448,414	33,776	659,491	235,194	688,340	3,233,428	5,796,245
19	4,500,406	30,607	644,740	241,418	692,550	3,238,747	5,837,696
20	4,546,984	30,261	628,279	241,279	691,267	3,237,782	5,866,530
25	4,698,534	26,063	619,609	249,739	714,095	3,237,906	6,032,238
30	4,927,460	26,418	561,400	243,807	717,640	3,239,800	6,206,500
35	5,109,691	23,669	532,135	251,376	738,478	3,244,667	6,380,304
40	5,313,126	20,549	497,633	256,908	754,991	3,243,256	6,565,750
45	5,462,225	16,974	501,731	260,227	781,869	3,235,182	6,745,825
50	5,637,952	15,915	491,598	266,171	802,828	3,233,884	6,932,378
55	5,814,697	15,223	476,965	268,075	814,719	3,237,024	7,106,381
60	5,990,545	14,616	464,136	269,814	824,675	3,243,101	7,279,356
65	6,089,888	12,625	506,268	278,461	844,480	3,244,578	7,440,636
70	6,262,674	12,651	497,563	279,346	847,391	3,247,885	7,607,628
75	6,407,978	11,140	495,917	281,908	846,753	3,258,378	7,750,648
80	6,524,842	9,445	511,767	289,072	853,059	3,262,588	7,889,668
85	6,611,409	7,873	547,891	294,783	861,210	3,267,158	8,020,510
90	6,751,728	7,077	542,828	293,237	851,539	3,275,448	8,146,095
95	6,835,509	6,864	563,975	300,851	855,513	3,282,574	8,254,997
100	6,949,254	6,511	564,854	301,159	843,676	3,290,100	8,357,784

Appendix 4 – Ex-Ante Uncertainty Error Estimation Calculations

This appendix provides supporting data and calculations used to calculate the uncertainty factor in Section 4.5.

Model error was estimated based upon volumes reported for the Darkwoods area by the BC Assessment Authority (BCAA)[33] compared against modeled harvested volumes for the project scenario (Table 26). Some of the small differences between the specific years are related to the use of different year-ends for each measure of annual harvest volumes. For example the BCAA uses a year-end of Dec. 31, while the Darkwoods year-end reporting (used to drive the models) is actually set as Mar. 31 of the following year. However, over the two-year period, much of the difference related to the year-end timing is cancelled out. The 2010 data from BCAA were not yet available at the time this document was prepared. An adjustment to the total area harvested in the model was made to account for the fact that some of the stands harvested during 2008 and 2009 (determined as 174.5 ha using the Darkwoods spatial inventory data) were selectively harvested with an average of 20% retention. However, the harvesting for the project scenario was modeled as clearcut harvesting in all cases to be conservative in the calculation of net ecosystem carbon storage. Thus, to facilitate a fair comparison of the model volume harvested against the BCAA measured values the area harvested by the model was reduced by (174.5 ha* 20% = 34.9 ha) and the total volume recalculated using the average volume per hectare from the model (281.4) (See Table 26). The area-corrected modeled value of volume production on a per hectare basis was very close to the measured value (Table 26)

Table 26 - Area (ha) and volume harvested in the Darkwoods landbase from 2008-2010 as reported by the BC Assessment Authority (BCAA) and from model output for the project scenario.

	BCAA			Models (Project Scenario)		
Year	Area	Volume	Vol/ha	Area	Volume	Vol/ha
2008	174.5	50,763	290.9	224.8	60,645	269.7
2009	150.1	40,433	269.4	137.9	41,418	300.4
2010	n/a	n/a	n/a	136.6	38,927	285.0
2008 +2009	**324.6**	**91,196**	**280.9**	362.7	102,063	281.4
Corrected area project area and volume for the years 2008+2009 considering that 174.5 ha were selectively harvested with an average of 20% retention				**327.8**	**92,242**	**281.4**
Average model error (E_M) based on total volume					**1.1%**	

[33] Data tables available upon request.

Inventory error was estimated based upon inventory audit documents for the Kootenay Lake TSA (BC MOF, 2005) and the Darkwoods Property (Pluto Darkwoods Corp., 1992); (Kleine, 1992); (Table 27). To be conservative, the error for the Darkwoods forest inventory was estimated as the average between the older regional inventory and the more recent local inventory audit conducted on the Darkwoods property.

Table 27 - Calculated average error (at a 90% confidence limit) in forest inventory data for the Darkwoods property based on two inventory audits.

Inventory Error Kootenay Lake TSA Audit				
Mean Vol	SD	SE	n	% error @ 90%CI
285	108.3	17.08	40	9.9%
Inventory Error Darkwoods Audit				
Mean Vol	SD	SE	n	% error @ 90%CI
170.5	50.9	3.32	235	3.2%
Average inventory error (E_I)				**6.5%**

Appendix 5 - Supporting Data files

The following table includes the key data files used in the PDD. The Darkwoods Carbon Model v8.2 is included as part of the PDD. The remaining files were provided to auditors as evidence documentation.

Table 28 - List of supporting data files used in the creation of the Darkwoods project description document.

Description	Filename	Format	Date
Spatial inventory data for the Darkwoods landbase. Used to support the landscape-scale modeling with FPS-ATLAS	forest_cover2010v3.2.mdb	Microsoft Access Database with shapefile	06/01/2011
Stand-level carbon database for each analysis unit generated from FORECAST for use in FPS-ATLAS	FORECAST carbon & volume 1-year time step.xls	MS Excel	07/01/2011
Example of the use of the allometric biomass equations (Standish et al. 1985) to generate biomass data from growth and yield data	TIPSY Fd 18 output with Standish equations.xls	MS Excel	03/11/2010
Spreadsheet model used to calculate storage and emissions from harvested wood products and to calculate to project VCUs from model output on emissions considering leakage, uncertainty, and buffers etc..	Darkwoods Carbon Model v8.7a.xlsx	MS Excel	04/20/2011
FORECAST Calibration data set with AU run details for the low elevation forest types	KL ICH v8.4.fds	FORECAST Dataset file	15/07/2009
FORECAST Calibration data set with AU run details for the high elevation forest types	KL ESSF v8.4.fds	FORECAST Dataset file	31/08/2010
ATLAS Carbon output	ATLAS Runs Updated Mar 2011.xlsx	MS Excel	31/03/2011
ATLAS Harvest area by AU during 2008-2010	Area_by AU_by_Period_Mar_2011.xlsx	MS Excel	31/03/2011
An example of the FORECAST calibration dataset used for Douglas-fir showing the use of BEFs from Li et al. 2003 and as modified by Lehtonen et al. 2004.	FORECAST Fd data.xls	MS Excel	03/11/2010