Forest Carbon Stewardship at the Site Level

Prepared for: **Forest Enhancement Society of BC**
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Executive Summary

British Columbia has committed to reduce its greenhouse gas emissions by 40% by 2030 and 80% by 2050 compared to 2007 levels through the *Climate Change Accountability Act*. Therefore, mitigation and management strategies will be required to reduce carbon emissions. The forests of BC present a large variety of opportunities for carbon management; however, BC's forest policy framework, for the most part, has not been changed to empower forest carbon mitigation opportunities (Hoberg et. al., 2016).

As emphasized in Hoberg et. al. (2016), a mix of strategies at all levels of forestry will provide the greatest carbon benefit: from site-specific to province wide, and from corporate to legal. The intent of this project is to identify a range of actions with carbon benefits at the operational level, and associated and enabling corporate, policy and legal actions.

The project was divided into two phases. The first phase of the project was previously presented in the Interim Progress Report which summarized a non-statistical sampling of site plans to identify (a) existing activities or prescriptions that manage for carbon, whether intentionally or otherwise, and (b) activities or prescriptions that with adjustment could result in a carbon benefit. The Interim Progress Report also included a backgrounder on forests in the context of climate change in Canada and BC; and a summary of regulatory influences at the site level.

The second phase of the project is summarized in this Final Report. Based on the review of sample site plans and existing literature, a range of site level actions that may have carbon benefits were explored. This rather extensive list was narrowed down to nine actions that are expected to have the largest carbon benefits, along with the enabling actions necessary to support the implementation of those activities.

The nine site level actions are:

1. Utilize continuous cover forestry (e.g. partial cutting systems like single tree selection), prescribing spacing wide enough to promote regeneration of crop trees in layers 3 and 4.
2. Promote partial cutting where ecologically appropriate.
3. Avoid short rotation (pre-culmination) clearcut harvesting.
4. Decrease road density, i.e. shorten roads, narrow road widths, or preferentially build snow roads where possible.
5. Require rehabilitation and planting of roads where possible.
6. Accept modified form or vigour stems in layers 1 or 2.
7. Increase retention beyond wildlife tree retention area (WTRA) defaults or create temporary retention features (related to 6 above).
8. Accept trees in retention areas that are not necessarily representative of the rest of the stand (related to 6 above).
9. Employ treatments to avoid burning, including lop and/or scatter, grinding and chipping of residuals or decking to leave.

Providing information on the benefits or extent of application of these nine actions at the level of the biogeoclimatic zone or natural resource district will be complex and multifaceted, and is beyond the scope of this project. To provide general context of the possible carbon benefits of these actions, rough estimates were carried out and are presented in an Appendix to this report. The numbers indicate that there could be significant benefits associated with the actions but they should be taken as preliminary estimates only and further verification and modelling is required to gain a more accurate accounting. Assuming executive direction is provided to manage for carbon, it will be important to identify and

quantify the benefits at the scale of natural resource districts and biogeoclimatic ecosystem classification (BEC) zones/ subzones to ensure ecologically appropriate variations of the operational actions.

Full implementation of these actions will require changes at the legal, policy and corporate level. At the legal level, changes are suggested to the *Forest Act's Cut Control Regulation*, the *Forest and Range Practices Act*, and the *Forest Planning and Practices Regulation*. Under those acts, changes are also suggested for forest stewardship plans, silviculture stocking standards, and site plans. In addition, policy changes are suggested for the Interior and Coast Appraisal Manuals, and the Provincial Logging Residue and Waste Procedures Manual. Finally, senior policy direction will be necessary to begin the process of making these changes. Corporate buy-in from BC Timber Sales and forest licensees will also be necessary.

Further work to synthesize or model the carbon effects of various site level activities would help to inform the most appropriate on-the-ground and policy actions. Development of carbon strategy implementation and measurement guidelines may be helpful and would ensure consistency in reporting. Consideration of regional and ecological variations across the province will also be necessary.

The suggested actions, supported by legal, policy, and corporate support, have the potential for a significant carbon benefit. Some preliminary estimations of these benefits have been made, and indications are that they may be in the order of millions of tonnes of CO_2e; however, these estimates **are unverified**. Therefore, it is strongly suggested that verification - including carbon modelling – be undertaken for the strategies and actions identified in this report.

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Acronyms

AAC	Allowable annual cut
BC	British Columbia
BCTS	BC Timber Sales
BMPs	Beneficial/ Best Management Practices
CBM-CFS3	Carbon Budget Model of the Canadian Forest Sector
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CWH	Coastal Western Hemlock biogeoclimatic zone
dbh	Diameter at Breast Height
ECE	Engineering Cost Estimate
FCI	Forest Carbon Initiative
FESBC	Forest Enhancement Society of British Columbia
FLNRORD	(Ministry of) Forests Lands Natural Resource Operations and Rural Development
FPPR	Forest Planning and Practices Regulation
FRPA	Forest and Range Practices Act
FSP	Forest Stewardship Plan
GBS	Ground-Based System
GHG	Greenhouse Gas
ICH	Interior Cedar Hemlock
MAI	Mean Annual Increment
N_2O	Nitrous oxide
OSBG	Objective Set by Government
P.Ag.	Professional Agrologist
RESULTS	Reporting Silviculture Updates and Land Status Tracking System
RFT	Registered Forest Technologist
RPBio	Registered Professional Biologist
RPF	Registered Professional Forester
SBS	Sub-Boreal Spruce biogeoclimatic zone
SOPs	Standard Operating Procedures
SORTIE	An individual tree, spatially explicit model of forest dynamics (acronym not defined in literature)
sph	Stems per hectare
TASS	Tree and Stand Simulator
TIPSY	Table Interpolation for Stand Yields
VDYP	Variable Density Yield Projection
WTRA	Wildlife tree retention area

1. Project Description

Westland Resources Limited (Westland), in partnership with BC Timber Sales (BCTS) and the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), conducted a project to review opportunities and barriers related to carbon management at the site level. British Columbia's Forest Carbon Initiative (FCI) and the Forest Enhancement Society of BC (FESBC) provided funding for the project.

British Columbia has committed to reduce its greenhouse gas emissions by 40% by 2030 and 80% by 2050 compared to 2007 levels through the *Climate Change Accountability Act*. In addition, BC is a participant in the Pan-Canadian framework on Clean Growth and Climate Change (Government of Canada, 2019). Therefore, mitigation and management strategies will be required to reduce carbon emissions. The forests of BC present a large variety of opportunities for carbon management, however, BC's forest policy framework, for the most part, has not been changed to empower forest carbon mitigation opportunities (Hoberg et. al., 2016).

As emphasized in Hoberg et. al. (2016), a mix of strategies at all levels of forestry will provide the greatest carbon benefit: from site-specific to province wide, and from corporate to regulatory. The intent of this project is to identify a range of actions with carbon benefits at the operational level, and associated and enabling corporate, policy and legal actions.

The project was divided into two phases. The first phase of the project was previously presented in the Interim Progress Report which summarized a non-statistical sampling of site plans to identify (a) existing activities or prescriptions that manage for carbon, whether intentionally or otherwise, and (b) activities or prescriptions that with adjustment could result in a carbon benefit. The Interim Progress Report also included a backgrounder on forests in the context of climate change in Canada and BC; and a summary of regulatory influences at the site level.

The second phase of the project is summarized in this Final Report. Based on the review of sample site plans and existing literature, a range of site level actions that may have carbon benefits were explored. This rather extensive list was narrowed down to nine actions that are expected to have the largest carbon benefits, along with the enabling actions necessary to support the implementation of those activities. Potential carbon budget modelling case studies were considered (Appendix D), and while some preliminary information was developed that contributed to quantitative carbon benefit estimations for a site level action, time and budget constraints did not allow modelling to be completed for this project. The authors feel that modelling is essential to confirming the carbon benefits of the proposed strategies. Results from modelling may also provide support for proposed changes to the legal and policy framework.

The Appendices to this report provide additional information that was gathered or produced in the preparation of this report, including:

- Appendix A: Complete example site plans incorporating wording related to the actions presented in Section 2.
- Appendix B: The complete list of actions considered for their carbon benefit. A subset of this list was selected for further development and is presented in Section 2.
- Appendix C: Descriptions and unverified estimation of the carbon benefits provided in Section 2.1.1.
- Appendix D: Carbon budget modelling case studies that were considered but not modelled as part of this project. They are provided as options for future modelling work.
- Appendix E: The Interim Progress Report for this project.

2. Actions

To put carbon management into real action, activities must change on the ground, i.e. at the operational level. In some cases, the regulatory regime needs to be visited and updated to allow those operational actions to occur. This section describes the on-the-ground actions recommended for carbon management in Section 2.1, and the activities and enabling actions necessary to support the implementation of those activities in Sections 2.2 and 2.3.

There are several ways operational actions can manage for carbon in the forested environment. **Maintain** existing stored carbon, i.e. keep it where it is already stored, and thereby preventing it from being released to the atmosphere. **Avoid** releasing carbon over the short term by not burning it, or by avoiding accelerated decomposition. Improve **utilization** of the carbon into products resulting in a storage or substitution benefit. Promote additional **sequestration** of carbon.

Each action described in Section 2.1 below will have a different impact on the carbon equation. In some cases, there is relatively good information on the expected or predicted carbon benefit, but in other cases, the extent of the carbon benefit cannot be confidently stated. As a result, we did not try to develop or define exact numbers regarding the potential carbon benefit, but instead utilized existing research and carbon modelling results to draw out conclusions regarding relative carbon benefit. Therefore, the authors wish to note that more work is needed to confidently quantify the carbon benefits of specific actions.

It is important to note that strategies and actions aimed at reducing carbon emissions at the site level may have to be reconciled with other priorities: for instance, careful consideration of the impacts on wildfire management from carbon strategies or actions is necessary before implementation. Some of these implications are discussed in this report; however, we recognise that fire management policy is rapidly evolving and all influences may not be captured.

The regulatory regime consists of legal, policy, and corporate aspects.

Legal:

- *Acts, regulations, and high-level documents are the Legal part of the regime, and are intended to be difficult to change.*

Policy

- *Forest Stewardship Plans, Policies, Manuals and contracts are the Policy part of the regime: they can be changed, but not without some effort.*

Corporate

- *Guidelines, SOPs, BMPs and environmental conditions are considered to be the Corporate part of the regime: they can change relatively quickly*.

2.1. Site Level – Operational actions that will impact carbon

A range of potential operational or tactical actions have been identified and reviewed, with the full list provided in Appendix B. Nine of these actions were identified as having more than a small carbon benefit, and/or being readily implementable and are discussed further below:

- Actions 1, 2, and 3 all relate to silviculture system selection.
- Actions 4 through 8 relate to block planning.
- Action 9 relates to post-harvest treatments, or the avoidance thereof.

Information provided regarding each action includes a discussion of the carbon benefit compared to the status-quo, and in some cases the interaction with other forest values and opportunities or barriers to implementation.

Appendix B provides additional information for all potential actions including: where it applies within the range of operational activities, and what is necessary for its implementation.

1. *Utilize continuous cover forestry (e.g. partial cutting systems like single tree selection), prescribing spacing wide enough to promote regeneration of crop trees in layers 3 and 4.*
   - When compared to the status quo of clearcutting, continuous cover forestry will allow continued fixing of carbon in retained stems, while promoting commercial harvesting.
   - Slash piles at the road side may be avoided (as per action 9 below) through the use of current technologies like single-grip harvesters which could prevent the felling of poor-quality standing trees to waste; or by reducing the concentration of woody residue through lop and scatter of the tops and limbs. In some regions, lop and scatter can be suitable for fire hazard abatement due to the dispersed nature of harvesting (Brouwer, pers. comm.).
   - Avoiding the need for burning of slash piles may also allow the use of the waste to benefit other forest values. For example, licensees in the Coast Mountains Forest District have been utilizing fallen waste to create small piles in openings harvested by group selection that are suitable for small mammal denning (Brouwer, pers. comm.).
   - On a landscape level, continuous cover forestry can allow access to areas that are constrained from status quo clearcutting, e.g. areas with a Visual Quality Objective of retention or preservation; some wildlife habitat areas or riparian management areas; areas subject to spatial or temporal constraints.
   - In the short-term, continuous cover forestry might be expected to require more road development to allow the same level of cutting as for clearcutting. This is not necessarily true and will be landscape-specific. For instance, areas with large amounts of second growth will already have the primary road systems established. Additionally, since continuous cover forestry does not have to follow the cut and leave pattern of clearcuts in old growth, increased area (per kilometer of new road) is available for harvest under continuous cover forestry in the short-term.
2. *Promote partial cutting (e.g. commercial thinning and shelterwoods) where ecologically appropriate.*
   - Like 1 above, these systems will allow the continued capture of carbon into residual stems, and again can avoid the creation of slash piles.
   - The carbon accounting for commercial thinning is complex. Modelling carried out under the Forest Carbon Initiative has indicated that commercial thinning does not produce a carbon benefit (Watson, pers. comm.). However, commercial thinning has the potential to reduce the rotation for sawlogs and improve stem quality allowing the timber to be used for longer-lived wood products (Colombo et. al., 2005), and also reduces residual waste. If modelling were to account for the potential carbon storage in longer lived wood products, commercial thinning may prove to have carbon benefits.
   - Commercial thinning also can also be used to reduce fuels in fire prone forests and may be one management strategy to reduce fire hazards, though the net carbon benefit of this management approach is dependent on many factors and is therefore unknown (Daigle and Dymond, 2010).
   - The final harvest, which would be a clearcut, would result in less debris and slash as the logs in the stand will generally be larger with fewer sub-merchantable stems when compared to a status-quo clearcut.
3. *Avoid short rotation (pre-culmination) clearcut harvesting.*
   - This action can be looked upon as the other side of the coin compared to 1 above; i.e. early clearcutting before culmination means that areas that are currently fixing carbon at high rates are turned back to areas that for several decades - even with prompt reforestation- will be fixing carbon at very low rates.

- In addition, early clearcutting can result in large amounts of sub-merchantable tops and stems. In the status quo environment, unless there is a fibre processing facility nearby, these stems will very likely be piled and burned.

4. *Decrease road density, i.e. shorten roads, narrow road widths, or preferentially build snow roads where possible.*
   - Shortening or narrowing roads will reduce soil exposure and decrease the amount of deforested land. In other words, this action prevents land alienation and the associated permanent carbon losses.
   - Reducing road lengths may cause higher logging costs, due to longer skidding distances. Depending on the location, this may be countered by reduced road construction costs. However, working from the premise that the forest industry operates efficiently, the overall cost for logging will likely rise, and this tension between cost and carbon will need to be addressed.
   - This action is consistent with, and supports BC's *Zero Net Deforestation Act*, though this Act is not yet in force (Hoberg et. al., 2016).
5. *Require rehabilitation and planting of roads where possible.*
   - As noted in Hoberg et. al. (2016), deforestation is a significant form of carbon leakage. Planning and constructing roads and trails so that they can be rehabilitated back to carbon-absorbing forests is a relatively straightforward and simple action.
   - Road rehabilitation and reforestation comes at a cost: since carbon currently is not valued or recognized in the regulatory system, it is expected that this added cost burden will not be willingly embraced by the forest industry.
6. *Accept modified form or vigour stems in layers 1 or 2.*
   - In many parts of the province, standing trees do not make sawlog or pulplog grades: currently, this means that such stems are felled and left as waste. The resulting accumulations can be such that they create a fire hazard as per a Fire Hazard Assessment required under the *Wildfire Act*. The results of such assessments are often prescriptions for burning to abate the hazard, resulting in a rapid release of carbon.
   - Allowing a portion of those standing trees to remain standing would reduce carbon release from burning (Hall and Dymond, 2012), and may also reduce release from rotting, as standing stems may rot more slowly than felled stems (Lewis and Harley, 2005).
   - Concerns with this approach include the occupancy of regeneration space or retaining stems with forest health issues that then present a risk to understory regeneration. This would cause concern that retained stems are creating an undue impact on timber supply, which is not consistent with objectives set by government in the *Forest Planning and Practices Regulation* (FPPR). Therefore, modified expectations around retained stems and crop trees will have to strike a balance with the FPPR Objectives.
7. *Increase retention beyond wildlife tree retention area (WTRA) defaults or create temporary retention features (related to 6 above).*
   - In the *Forest and Range Practices Act* (FRPA), retention of wildlife trees is one way to achieve consistency with the FPPR Objectives for wildlife and biodiversity. Designation of additional trees within WTRAs or within other reserves beyond the default amounts will maintain carbon stores while also contributing to wildlife and biodiversity values.
   - Inclusion of temporary retention features in FPPR would allow the conservation of trees for carbon purposes and other valued features.

- Like WTRAs, such additional retention will need to be long-term for it to be accepted and accountable within carbon management.

8. *Accept trees in retention areas that are not necessarily representative of the rest of the stand (related to 6 above).*
   - The current guidance for WTRAs is that retained trees should be representative of the pre-harvest stand (BC Government, 2006). This guidance could be altered to support the retention of non-merchantable trees, thereby avoiding the creation of logging waste.
   - Retention of larger stems also has a disproportionately higher impact on carbon storage as most above-ground carbon is stored in the boles of the biggest trees (Daigle and Dymond, 2010).
   - This action is consistent with an emerging position amongst some wildlife biologists that wildlife trees do not necessarily have to be similar to the surrounding stands but should instead be focused on providing or promoting wildlife habitat (Doyle, pers. comm.).
   - Alternatively to WTRAs, additional retention areas could also be identified for carbon retention (or to address other FRPA values).

9. *Employ treatments to avoid burning, including lop and/or scatter, grinding and chipping of residuals or decking to leave.*
   - Burning of logging waste and residue creates an immediate carbon release. Avoidance of this will delay the release. Additionally, Hall (2011) notes that decomposition produces less greenhouse gas (GHG) emissions than burning, so there is not just a delay, but an actual carbon benefit by not burning. Therefore, actions that treat, distribute or reduce logging waste so that burning is not required are beneficial from a carbon perspective.
   - There are hazard abatement treatments that can be undertaken without any change to the *Wildfire Act* or the *Wildfire Regulation*:
     - Begin hazard assessment and abatement evaluation and considerations before operations commence, and then adapt as necessary to reflect actual conditions: this requires qualified professionals with appropriate knowledge, education, and experience.
     - Extend the period within which hazards must be abated, to encourage drying so fibre can be used for other products – do this in non-critical hazard areas.
     - Extend time frames for non-forest industry operators to be the same as for forest industry if a qualified professional is involved in the hazard assessment and planning.
     - Discourage burning by incenting other forms of abatement, such as access restriction (where appropriate) and utilization incentives
   - The significance of the 2017 and 2018 wildfire seasons has ensured that forest fuel hazard reduction using fire as a tool will be an emphasis and focus of the Wildfire Branch. This will put prescriptions for carbon reduction through avoiding burning of woody waste in conflict with public safety imperatives. Conversely, smart and strategic fire and forest fuel management (for example, as described in Daigle and Dymond 2010) may result in benefits and prevent or reduce future "firestorm" seasons, which will have a significant carbon benefit, albeit likely not measurable.
   - While not a focus of this report, another significant way to reduce burning of logging debris will be by promoting utilization of that material through product research and market development (Daigle and Dymond, 2010; Jobb, pers. comm.).

2.2. Site Level - Activities to support carbon actions

The previous section describes actions that in and of themselves will have a carbon benefit. This section discusses administrative actions required to support, validate, monitor or directly incent those carbon benefit actions.

The regulatory actions necessary to implement carbon management within the forestry regime, and that will give rise to the site level carbon actions and support activities, are discussed in Section 2.3.

Activities B through D are compatible with the BC Fibre Action Plan (2015) and recent provincial policy around residual fibre recovery including fibre recovery zones, and the concurrent residual harvesting system (BC Government, 2019).

A. *Have a stumpage assessment for downed waste wood that is much higher than for standing waste*

Operational activity: Retain waste in standing form; Appraisal system; Waste Manual

Rationale/ reasoning:

- Currently, once forest harvesting is completed there is a requirement to assess the logged area for the amount of woody material that should have been removed from the site. This "waste" can be either logs (or parts of logs) on the ground, or trees that should have been felled and removed. Stumpage is charged on this waste.
- In several cases, many logs have been felled and then not removed, creating fire hazards or rotting material, neither of which is desirable from a carbon standpoint. If the stumpage charged for the felled waste were to be higher, then the operator would think twice about "felling trees to waste", and if trees stay standing their carbon release will be much reduced.

B. *Increase stumpage rates for waste left on-site versus waste brought to a facility*

Operational activity: Utilizing downed waste and avoiding burning; Appraisal system; Waste Manual

Rationale/ reasoning:

- Similar to A above, the intention is to prevent waste material in the forest from being burned or left to rot. The thought behind this action is to increase the penalty for waste such that it becomes worthwhile for the operator to remove the waste to a facility.
- The expectation is that this penalty could only apply where biomass processing facility exists.
- While others have recommended this action (or a close variation), it adds cost to the forest operator, and would have to be carefully implemented, perhaps with some form of incentive through the stumpage appraisal system (Hoberg et. al. 2011, ANON 2012).
- The Concurrent Residual Harvest System (CRHS) being rolled out by the province provides a mechanism to reduce the administrative burden related to scaling of low quality timber (MFLNRORD, 2019). Changes to stumpage rates to incent better utilisation will not create any inconsistency with the CRHS

C. *Lower waste benchmarks where carbon (fibre) users are in the area*

Operational activity: Utilizing downed waste and avoiding burning; Appraisal system

Rationale/ reasoning:

- Normal logging operations will result in some small amounts of waste. Currently there is a benchmark level of waste that is applied before stumpage penalties will be applied. This benchmark varies to reflect the conditions of different parts of the province, but it does not change in areas where there are biomass processing facilities. Therefore, it may be reasonable

to expect the benchmark to be lower in areas where such facilities exist as an incentive to encourage operators to send waste to the facility.
- This activity could potentially be implemented under the umbrella of the MFLNRORD Fibre Action Plan/ Fibre Recovery Process (BC Government, 2015 and 2019).

D. Utilize sub-merchantable volume with no concern about allowable annual cut impact

Operational activity: Utilizing downed waste and avoiding burning; Cut control

Rationale/ reasoning:
- When a forest tenure holder moves wood to a biomass facility, the volume moved is counted against the allowable annual cut (AAC) for that tenure. Often, the price that the tenure holder receives for this wood is lower than to a sawmill or pulp mill, and therefore the tenure holder would rather not give up a portion of its AAC to products with low profits.
- If we want to move material to biomass facilities instead of seeing it burned, an approach that does not see that wood counted against the tenure holders' AAC would be a positive incentive.
- This activity is not currently consistent with the Concurrent Residual Harvest System, which is intended to be cut control neutral (MFLNRORD, 2019).

E. Extend period to encourage drying so fibre can be used for other products – do this in non-critical hazard times/ areas

Operational activity: Avoiding burning of woody waste; Hazard assessment

Rationale/ reasoning:
- Some biomass facilities do not want wet woody material, i.e. material that does not meet the moisture content requirements of the facility. In many cases, natural air-drying of material can bring woody waste within the required moisture content range. However, fire hazard abatement requirements often dictate the disposal of the material before it has reached that moisture content. As allowed by the *Wildfire Regulation*, and where safe to do so, modifying the period within which abatement must occur may address this issue, and prevent the burning and carbon release of the waste material
- There are no legal barriers to implementing this activity. However, there may be resistance to this action due to concerns about fire hazard or liability, so corporate or policy direction encouraging innovative approaches to removing woody material would be beneficial.
- Access management may help to address the fire risk associated with this action. For example, restricting public access via barriers may limit the risk of human-caused fire starts in areas set aside for extended drying periods.

F. Extend time frames for non-forest industry operators to be the same as for forest industry if a qualified professional is involved in the hazard assessment and planning

Operational activity: Avoiding burning of woody waste; Hazard assessment

Rationale/ reasoning:
- Communities and non-forest industry operators are required to abate fire hazards from clearing operations earlier than forest operators. This is due to the expected proximity of these activities to homes and infrastructure. However, like E above, this may prevent the opportunity for air drying and subsequent delivery of material to a biomass facility. Therefore, as allowed in the *Wildfire Regulation,* an operation may be assessed by a qualified professional who can make a determination regarding extension of the time frame for abatement (if safe to do so), or an

exemption can be requested. This could again prevent the burning and carbon release of the waste material.
- There is no legal barrier to doing this, corporate and policy direction is all that is needed.

G. *Discourage burning by incenting other forms of abatement (access restriction, utilization incentives)*

Operational activity: Avoiding burning of woody waste; Hazard assessment

Rationale/ reasoning:
- This action is straightforward: if fire hazard can be abated by means other than burning, then carbon release will be reduced.
- As noted by Daigle and Dymond (2010) and Jobb (pers. comm.), the best way to reduce fire hazard and carbon inputs from burning is to remove the burnable material from the site.
- Non-operational methods to remove material by improving utilization through actions like product development or marketing are important and beneficial; however, they are beyond the scope of this report.

H. *Adjust appraisal system to economically stimulate utilization through implementing fair costing/ stumpage. For Example:*
- *reflect transportation costs to fibre facility (not just sawmill); i.e. allow multiple Points of Appraisal,*
- *allow fire hazard reduction activities as Engineered Cost Estimates,*
- *allow appraisal averaging, and*
- *modify how stumpage is charged on waste material.*

Operational activity: Appraisal system

Rationale/ reasoning:
- Penalties can change habits, but generally this occurs under protest. Incentives, on the other hand are willingly embraced. The intent of this action is to provide means for forest operators to willingly reduce the production of carbon.
- The stumpage appraisal system generally uses a “least cost” methodology, expecting use of the cheapest possible method to meet obligations. This means that forest operators are effectively discouraged from undertaking the more expensive activities that avoid burning. Adjusting the appraisal system to remove that barrier will act as an incentive for improved utilization.

2.3. Actions at the Regulatory level

The following are regulatory actions that will be necessary to provide the regime that will give rise to the site level carbon actions and support activities identified above. They are split into legal, policy, and corporate actions. Some of the changes are dependent on which direction is taken regarding management for carbon. For example, if government elects to establish a legal Objective for carbon through the *Forest Planning and Practices Regulation*, then some of the corporate changes will be redundant.

Operational forestry activities in British Columbia are primarily regulated by three statutes: the *Forest Act*, the *Forest and Range Practices Act*, and the *Wildfire Act*. These acts and their associated regulations (such as the FPPR, the *Cut Control Regulation*, or the *Wildfire Regulation*) provide direction to regulators and to licensees as to requirements and responsibilities for activities on public forest lands.

Additional high-level documents can be developed and approved under the authority of the statutes, and these become binding on the regulated users of the forest. Examples of high-level documents

include Sustainable Resource Management Plans, Land and Resource Management Plans, Wildlife Habitat Areas, and Ungulate Winter Ranges.

The acts, regulations, and high-level documents are the Legal part of the regulatory structure, and are intended to be difficult to change.

Licensees develop a Forest Stewardship Plan (FSP) to describe and demonstrate how their operations will be consistent with the requirements of the statutes and the legal objectives set in the high-level documents.

In some cases, regulators provide additional interpretation or guidance, so that licensees have clarity on how aspects of the statutes or plans are applied. This information can be in the form of Policies or Manuals, and often takes on a quasi-legal status. Policies come from government's executive levels and can include notification, guidance and expectations from the Deputy Minister and Chief Forester, Regional Executive Directors, or District Managers. Manuals include documents such as the Interior and Coast Appraisal Manuals, the Provincial Logging Residue and Waste Measurement Manual, the Scaling Manual and the Silviculture Surveys Procedure Manual. Contracts can also be set with licensees and forest operators.

The FSP, Policies, Manuals and contracts are the Policy part of the regulatory structure: they can be changed, but not without some effort.

Guidelines can be developed by regulators, forest licensees or field operators to provide additional information on how to implement or carry out plans or activities. Standard operating procedures (SOPs) are a special form of guidance for oft-repeated items, or where consequences can be of special concern, e.g. safety or environmental damage. Beneficial Management Practices (also sometimes called Best Management Practices), or BMPs, are similar to SOPs but are generally more advisory than SOPs. SOPs and BMPs can be created as part of environmental and resource management planning carried out by licensees, though this is not always necessary. They could also be incorporated as standards of practice within forest certification systems. Environmental conditions, whether physical, economic, or cultural, can have an impact on operational activities.

Guidelines, SOPs, BMPs and environmental conditions are considered to be the Corporate part of the regulatory structure: they can change relatively quickly.

2.3.1. Changes to the Legal portion of the regulatory framework

At the legal level, carbon could be identified as an objective set by government in the *Forest and Range Practices Act*, and the *Forest Planning and Practices Regulation*. Also, within the FPPR, site plan content requirements could be modified to include the discussion and reporting of carbon. The effective time frames for at least the carbon management portion of site plans should also be modified so that they can apply through an entire rotation, thereby allowing carbon retention strategies to have efficacy. This would be similar to the Stand Management Prescriptions that were in place under the Forest Practices Code regime prior to FRPA. Currently, a licensee's legal obligations for a cut block are met once free growing is declared. If carbon management actions were made effective in site plans, this would extend the legal obligation for the licensee past free growing. Additionally, such actions – and their results - would require tracking, possibly through RESULTS (Reporting Silviculture Updates and Land Status Tracking System).

This section provides possible changes that could be made to the applicable Acts and Regulations and the examples of how these changes would be addressed in Forest Stewardship Plans and Site Plans.

Forest Act - Cut Control Regulation

Incent utilization of slash (i.e. avoidance of burning) by introducing a change to the *Cut Control Regulation* section 17 by adding a section so that all grade code 4 (interior) and U or X (coast) delivered to a fibre facility that is not a pulp mill is "adjusted downward by 100%". This change would be independent of the Concurrent Residual Harvest System currently being rolled out by the Province, which is meant to be cut-control neutral (MFLNRORD, 2019)

Example wording:

Reduction in volume of timber harvested
…
17(6.5) Despite subsection (3) (d), (4) (d), (5) or (6), the volume of timber harvested attributed to a licence in cut control statements is adjusted downward by 100% for grade code 4 (interior) or grade code U or X (coast) if the timber is sold or delivered to a facility that produces products from timber other than lumber, veneer, or pulp.

Forest and Range Practices Act

- Inclusion of carbon as a forest value in the FRPA

  Example wording:

  Objectives set by government
  149(1) …
  (i) carbon sequestration and retention.

  Carbon
  150.6 The Lieutenant Governor in Council may make regulations establishing criteria for measuring or reporting carbon sequestration or retention.

- Allowing Site Plans to apply for the term necessary to manage carbon

  Example wording:

  Site plans for cutblocks and roads
  10(2) …
  *(c) identify how the intended results or strategies described in the forest stewardship plan apply to the site**, and***
  (d) indicate the period of time within which (c) will apply.

- Though not directly related to one of the site-level actions proposed in Section 2.1 of this report, government could consider using **FRPA section 27** more broadly to require more proactive management of forest health issues by licensees. In other words, by preferentially requiring the harvest of forest stands impacted or infected by forest health agents, utilisation of timber could potentially be increased with a commensurate decrease in wood waste and residues.

Forest Planning and Practices Regulation

- Inclusion of Carbon Sequestration and Retention as an Objective Set by Government (OSBG) in the FPPR. Though not specifically stated in the objective, work would need to be done to determine regional base case scenarios from which to measure carbon benefits.

  Example wording:

  Objectives set by government for carbon
  6.1 The objectives set by government for carbon are, without unduly reducing the supply of timber from British Columbia's forests, to
  (a) enhance carbon retention or sequestration on British Columbia's forests, and

(b) develop, promote, or apply opportunities for utilization of cut trees into products that provide carbon retention, sequestration or substitution benefits.

- Inclusion of Temporary Retention Features in the FPPR, as a mechanism that can be used within a Site Plan to conserve a Resource Feature, Cultural Heritage Feature, or an OSBG, or a factor specifically identified by the Chief Forester. With respect to carbon management, the idea would be that trees that may otherwise be felled to waste could be instead retained in a temporary retention feature. A possible concern is that this could result in high-grading; however, professional reliance would require that there is a rationale stating how the temporary retention feature meets the definition. Require annual reporting of this item.

  Example wording:

  Definitions
  1 (1) In this regulation:
  …
  "temporary retention feature" means a tree or group of trees, or an area, retained for the purposes of conserving a Resource Feature, Cultural Heritage Feature, or to address an Objective Set by Government or other factor specifically identified by the Chief Forester.

  Annual reports
  *86 (3)(b) the location of any resource feature**, temporary retention feature** or wildlife habitat feature in or contiguous to a cutblock or road of which feature the holder is aware during the reporting period if*
  …, and
  (f) a summary of any carbon benefits attributable to temporary retention features or site level planning.

- An addition to the Factors relating to stocking specification in **section 6 of Schedule 1** may be appropriate, i.e. changing "commercially valuable and ecologically suitable species" in 6(3) to "***species valuable for commercial, ecological or carbon purposes***".
- Reduce permanent access structure limits from 7% to 6%.This will require licensees to reduce total road area, narrow up roads, or rehabilitate roads. Alternatively, add this as another section specifically tied to government's expectations for carbon management. Eventually, analysis of the actual permanent access structure averages in a region could be carried out to determine if the limit could be further reduced by region, sub-region, or district.

  Example wording:

  Permanent access structure limits
  *36(1) An agreement holder must ensure that the area in a cutblock that is occupied by permanent access structures built by the holder or used by the holder does not exceed **6%** of the cutblock, unless*
  …

- Change road deactivation requirements to "road must be fail-safe", to allow for future use of roads, e.g. for fibre companies' access to fibre or licensee re-entries without putting environmental safety at risk.

  Example wording:

  Road deactivation
  *82**(2.5) for the purposes of this subsection, "fail-safe condition" means a condition where a qualified professional can reasonably attest that the hazard and consequence of environmental or public safety failure for a road or section of road is very low, and the road surface, subgrade, and any remaining structures will not be subject to erosion or***

sedimentation exceeding that to be expected from a road deactivated in accordance with subsection (1).

(a) A person may submit to the district manager, in writing, a request for an exemption from the requirements of subsection (1) if a qualified professional certifies the road or section of road is in fail-safe condition.

(3) The minister, in a notice given to a person who submits a request under subsection (2) ***or (2.5)****, may exempt …*

Wildfire Act (or Regulation)

The site level actions presented in Section 2.1 can be implemented without changes to the *Wildfire Act or Wildfire Regulations; therefore,* no changes to the *Wildfire Act* or *Wildfire Regulation* are suggested.

As stated in the introduction to this section, actions aimed at reducing carbon emissions at the site level may be at odds with wildfire management, especially considering the severity of recent fire seasons. A recent investigation by the Forest Practices Board in response to a complaint alleging that logging debris piles contributed to the spread of a fire in 2018 has brought the timing requirements of abatement under review (Forest Practices Board, 2019). This could lead to the shortening of abatement timing making it hard to implement carbon management actions. Careful consideration of the fire risk implications of any action will be required before implementation.

Forest Stewardship Plans

- Include carbon-related Results and/or Strategies into FSPs if there is a carbon OSBG. Note that the example Result below would also demonstrate a commitment to business to business relationships between licensees and fibre users.

  Example wording:

  Result: ***For each cutblock harvested within the FSP Holder's Forest Development Unit by the FSP Holder or its contractors, the FSP Holder will offer fibre that does not meet current utilization levels to local consumers of fibre. This offer will occur prior to the FSP Holder scheduling the fibre for disposal. (For the purposes of this Result, "local" means within XX hours haul time from the cutblock.)***

  Comment: The haul time would be specified and committed to by the licensee in their FSP, making it measurable and verifiable. The distance that licensees/fibre users would actually be willing to transport fibre would vary based on market conditions; however, this result only requires that an offer is made for fibre within the specified distance. The result does not require that the offer is accepted.

  Comment: If the Fibre Recovery Strategy and Fibre Recovery Zones which began implementation in 2018 by the Ministry of FLNRORD in certain Natural Resource Districts is successful, the need for the above Result would likely be diminished.

  Strategy: ***When developing a cutblock, stems that are known to have limited timber value may be retained for carbon storage purposes. Carbon retention stems are to be preferentially located in WTRAs, in riparian management areas, in visual retention areas, and where safe to do so, may be dispersed throughout the stand. Site Plans will describe carbon retention stem characteristics.***

<u>Strategy:</u> During the period of this FSP, roads that are not required for silviculture or access to additional harvesting opportunities and are practicable to rehabilitate will be rehabilitated and reforested to the appropriate stocking standard.

- Change the definition of "acceptable form and vigour" in FSP stocking standards to allow retention of trees for the retention of carbon

  Example wording:

  <u>Stocking Standards:</u> Carbon Stocking Standards are identical to existing Stocking Standards with the exception that Carbon Retention Stems can comprise up to 200 stems per ha of preferred and acceptable species. Carbon Retention Stems must be layer 1 or layer 2 trees and be a minimum 1m horizontal distance from other well-spaced trees.

  <u>Criteria for Carbon Retention Stems in Layers 1 and 2</u>
  For Carbon Retention Stems in layers 1 or 2 the criteria for good health, form, and vigour are:
  - ***trees must not exceed the damage criteria of Table A of the Free Growing Damage Criteria for Multi-Layered Stands in British Columbia (February 2007), except as noted below:***
    - ***A maximum of one Porodaedalea pini conk per tree is allowed on layer 1 trees***
    - ***Frost cracks, rotten branches, forks and crooks are allowed, and***
  - ***trees must have at least 20% continuous live crown.***

Site Plans

Sample Site Plans have been prepared that include examples of the wording changes below as well as legal obligations. These site plans are included in Appendix A. The expected carbon benefits could be calculated and documented within the Site Plan and also reported, possibly into RESULTS. For the carbon benefit calculations to be valid, there would likely have to be standardized calculation methods (likely supported by underlying carbon modelling) specific to a region.

Modifications or additions to Site Plans could include:

- Addition of wording related to timber/ log quality and carbon benefits vs other objectives (e.g. wildlife)

  Example wording:

  Biodiversity Emphasis/L.U. Comments

  TEsw049 is located within the Skeena River Kalum Landscape Unit. 8.8% of the cutblock area has been designated as WTRA which exceeds the minimum wildlife tree retention requirements of 5% (CWH) for the Skeena River Kalum Landscape Unit listed in the Table 6 of the Kalum SRMP. ***The extra WTRA over the 5% target contributes to biodiversity and wildlife objectives as well as to carbon Objectives and represents XXX $tC0_2e$ of additional carbon storage. In addition, 100 stems per ha of Carbon Retention Stems will be retained scattered across the block. These trees represent XXX $tC0_2e$ of additional carbon storage. The Carbon Retention Stems also contribute to biodiversity and wildlife objectives.*** *Tesw049 is located within the Little Oliver-Skeena River East Grizzly Bear Identified Watershed (GBIW). The block does not contain a significant amount of identifiable and stratifiable Grizzly site series (06/11 ecosystems).*

  Carbon Management Comments

  Carbon Strategies employed on TEsw049 include additional WTRA, retention of 100 Carbon Retention Stems per ha, rehabilitation and reforestation of 0.3ha of road not required for future access, additional retention of non-merchantable understory stems within the RMA of streams and processing piling residual material such that it

can be utilized if a future market occurs.

- Road density, deactivation, rehabilitation requirements

  Example wording:

Result or Strategy Description	***A1-TSK-KA-ABS During the period of this FSP roads that are not required for silviculture or access to additional harvesting opportunities and are practicable to rehabilitate will be rehabilitated and reforested to the appropriate stocking standard.***
Applies:	***YES***
How Result or Strategy Applies to the Site (or Rationale if it does not apply)	***Stubs 2 and 4 are not required for silviculture access and do not access additional timber. Following completion of harvesting, Stubs 2 and 4 will be rehabilitated and reforested. Stubs 2 and 4 total 0.3ha, the 0.3ha of road reforested within 6 years represent approximately XXX $tC0_2e$ of additional carbon sequestration at 2030 and XXX $tC0_2e$ of additional carbon sequestration at 2050.***

- Measurement/ assessment of carbon benefits from treatments. The following table is one suggested approach, but a table providing more detailed accounting by activity and standard unit could also be incorporated into the Site Plan and reported into RESULTS. As noted previously, carbon calculations would have to be supported by standardized methods and underlying modelling.

  Example wording:

GROUP WTRA / WTP AND SITE DEG. CALCULATION (to be retained on the first block of the Permit only), ***CARBON BENEFIT SUMMARY***

Block	*Gross Cutblock Area*	*WTRA / WTP*	*%*	*BEC*	*Perm Access*	*%*	***Carbon Benefit from Carbon Results and Strategies at time of harvest 2020***	***Carbon Benefit from Carbon Results and Strategies 2030***	***Carbon Benefit from Carbon Results and Strategies 2050***	***Carbon Benefit from Carbon Results and Strategies at rotation 2110***
TEsw049	*63.2*	*5.5*	*8.8*	*CWH/ ws/1*	*2.8*	*4.4*	***XXX tCO_2e***	***XXX tCO_2e***	***XXX tCO_2e***	***XXX tCO_2e***
Total # of Blocks: 1	*63.2*	*5.5*	*8.8*		*2.8*	*4.4*	***XXX tCO_2e***	***XXX tCO_2e***	***XXX tCO_2e***	***XXX tCO_2e***

- Modified description of retained stems/ leave tree characteristics within Site Plan

  Example wording:

A target of 100 stems/ha of Carbon Retention Stems has been selected. A range of 50 to 150 Carbon Retention Stems is considered acceptable. Carbon Retention Stems must be Layer 1 or Layer 2 trees and must not exceed the damage criteria of Table A of the Free Growing Damage Criteria for Multi-Layered Stands in British Columbia (February 2007), except as noted: a maximum of one Porodaedalea pini conk per tree is allowed on layer 1 trees; and frost cracks, rotten branches, forks and crooks are allowed. Selection of Carbon Retention Stems should consider windthrow hazard. Preferentially select Carbon Retention Stems growing on well drained microsites and that have good live crown and height to diameter ratios (trees with lots of taper).

2.3.2. Changes to the Policy portion of the regulatory framework

Direction to require management and consideration of carbon can be made based on the legal changes above and subsequent direction from the Ministry[1] Executive. Within the current Policy framework, this direction would lead to Ministry staff making changes to guidelines and manuals. Additionally, if carbon were to become part of the utilization requirements for licensees, then tenure documents and permits would have to reflect this additional forest product, and make provisions requiring its measurement and reporting. In other words, carbon management will likely require government to implement legislation and policy changes to guide licensees. Actual reporting would then be done by licensees.

Government Executive directions related to carbon

It is suggested this direction should come from the Deputy Minister and Chief Forester and be copied to the Premier and Minister. The letter or memo should be directed to Assistant Deputy Ministers, Regional Executive Directors, District Managers, and copied to all other Ministry staff.

This letter or memo should also be forwarded to forest licensees, or a separate letter could be sent providing the same directions (as appropriate for licensees).

The direction should cover:

- Indication that government is committed to its climate goals, and that carbon management is therefore intended for inclusion as an OSBG.
- Confirmation that Ministry staff are expected to prepare for carbon management consistent with the directions of this letter.
- Direction to Delegated Decision Makers and Ministry staff regarding encouragement and acceptance of carbon-related initiatives within FSPs and/or SPs until such time as carbon is legally established as an OSBG.
- Provide government instruction to develop and incorporate carbon BMPs into field activities.
- Provide guidance that carbon sequestration or retention is an acceptable purpose within Site Plans, and within WTRAs until such time as Temporary Retention Features are legally established.
- Policy direction that treatments that reduce slash or diminish fire hazard are to be encouraged, e.g. to disperse slash and reduce fire hazard, dirty woody debris to be piled and kept separate from clean waste logs, with the added benefit of allowing possible future utilization of waste logs.
- Direction to encourage partial cutting to
  - recover mortality volume
  - contribute to mid-term timber supply
  - allow continued carbon storage
  - promote growing longer lived wood products.
- Direction to include carbon in forest management, particularly in appraising carbon management activities, utilization standards, and forest measurements such as cruising and waste and residue assessments.
- Direction to develop a Carbon Measurement Guidelines document
  - The processes and methods for carbon measurement could be tested through contracts or agreements with organizations like FPInnovations; this would then be followed by revisions to the process.

[1] In this section, the term 'Ministry/Minister' refers to the Ministry/Minister of Forests Lands Natural Resource Operations and Rural Development.

- Creation of a carbon measurement guidelines document would also be beneficial so that reporting methods are understood and standardized. This could then be followed by a requirement to implement standardized measurement and reporting.

Interior Appraisal Manual

The following changes to the Appraisal Manual are in keeping with the idea that the appraisal system is an economic cost accounting system, reflecting the concept of recognizing costs for an average efficient operator. At this time, the authors have avoided suggesting changes to incent certain behaviours through appraisal mechanisms that are not reflective of efficient economic costs (e.g. allowances to incent long skidding over road construction; allowances to incent road rehabilitation instead of just deactivation; enabling higher planting cost allowances to accelerate carbon crop establishment). This would change if government establishes direction for carbon within a clear regulatory and policy environment.

Section 1.1 Definitions:

- Change "Applicable Volume" to only include sawlog volume, thereby incenting greater utilization by making total stumpage lower. Costs will be attributed to a lower volume, resulting in a higher cost per cubic metre in the appraisal system. In other words, if fibre volume is not included in appraisal calculations, then operating costs do not get watered down, which equals an incentive to use fibre. This can be used as a rationale (quid pro quo) for applying increased penalties for poor utilization or slash burning.

Section 1.3 Points of Appraisal:

- Change to allow multiple destinations, to incent actual deliveries of fibre to its best and highest use (from a carbon perspective). Appraisal haul cost will be weighted by volume of log sort/ type to destination. This would effectively provide recognition of costs to move residual fibre to a non-traditional facility.

Section 1.4.2 Maximum Area

- Delete the maximum area constraint for cutting authority areas; alternatively, increase the maximum area to be equivalent to the management unit within which the cutting authority is to be issued. This could support appraisal averaging over a broader area as suggested for Section 5.2 below.

Sections 4.3.1 Development Cost, and 4.3.6 Engineering Cost Estimates (subsection 8):

- Allow the cost of road rehabilitation as an Engineering Cost Estimate (ECE), to incent reduced permanent access structure % to reduce permanent withdrawal of growing stock.
- Allow the cost of non-fire hazard abatement (e.g. lop & scatter, grind & spread, woody debris separation) as an ECE, to incent reduced slash or pile burning.

Section 5.2 Stumpage Rate Determination

- Allow appraisal averaging. When appraised for stumpage, stands with a lower quality timber profile or stands of average quality with high development costs often have a negative stumpage rate indicated[2]. In these cases, the stumpage rate is set at a minimum level ($0.25/m^3). This means that cost allowances within the stumpage appraisal system that are intended to incent better utilization

[2] This is currently the case in certain areas, e.g. northwest BC, but is likely to become more common throughout the province as stand values diminish in areas that have been affected by insects, disease and wildfires.

will not be effective. Appraisal averaging will allow the negative portion of an appraisal to be recognized in the calculation for stumpage on other stands within a management unit. This should only be applied using rates from actual billed volume, thereby avoiding the potential for manipulation of the system. This can be implemented by using the Indicated Rate and billing history.

Example wording:

5.2.1.1 Accumulated Indicated Rate

1. ***The Accumulated Indicated Rate (AIR) is the difference of the total stumpage paid on a license within its cut control period (TSPCC) divided by total volume billed for that period (TVBCC), less the sum of the IR for each cutting authority (IR_{CA}) under that license multiplied by the billed volume for each cutting authority (BV_{CA}), and divided by the total volume billed for that period.***
2. ***Expressed as an equation:***

   $$AIR = (TSPCC / TVBCC) – (sum[(IR_{CA1} X\ BV_{CA1}) + (IR_{CA2} X\ BV_{CA2}) + …] / TVBCC)$$
3. ***In the case where there are no previous cutting authorities within a cut control period, then the AIR = IR.***

5.2.2 Reserve Stumpage

The reserve stumpage for a cutting authority is determined by selecting:

1. *The greater of:*
   a. ***the AIR, or***
   b. *the minimum stumpage rate.*

Section 6.6 Miscellaneous Stumpage Rates (*Note: this could also be done through the Waste Manual, section 1.2.4)*

- Apply a stumpage assessment for downed waste wood that is much higher than for standing waste.

Example wording:

Table 6-7: Miscellaneous Stumpage Rates

Species	*Code*	*Product*	*Reserve Stumpage Rate*
All species	***tbd***	***Felled grades 1 and 2 of avoidable waste left on-site above waste benchmarks, after a waste assessment has been made***	***2.0 X the cutting authority stumpage rate*** *(note 1)*
All species	***tbd***	***Standing grades 1 and 2 left on-site, after a waste assessment has been made***	***0.5 X the cutting authority stumpage rate*** *(note 2)*

Note 1: Higher stumpage to penalize poor utilization/ incent better utilization, and to prevent operators from "falling to waste".

Note 2: Lower stumpage to incent operators to not "fall to waste". Minimum stumpage of $0.25/m^3 would still apply.

Coast Appraisal Manual

While section numbers or wording will not be the same, similar actions as identified above for the Interior Appraisal Manual should be applied to the Coast Appraisal Manual.

Provincial Logging Residue and Waste Measurement Procedures Manual

Section 1.2.1 Purpose

- Change Table 1-3 so that Measure/Record for grades Dry Y, Dry 4, 6, and Z are marked as Yes. This is done to allow better measurements of carbon sources by the province. If such measurements are not a requirement or are not deemed necessary, this change would not be needed.

Section 1.2.4 Monetary Billings

- Apply a stumpage assessment for downed waste wood that is much higher than for standing waste with the intent to incent the carbon perspective that it is better to leave those trees that are going to be left behind as standing, rather than have them felled to waste. This will have to be carefully monitored to ensure that residual stands have future economic potential, and that the practice of leaving waste trees standing does not lead to high-grading.

  Example wording:

  1.2.4.1 Coast
  Felled avoidable waste volumes of Grade J or better are billed at 2 times the average stumpage rates determined in Appendix 3 of this manual. *(note 1)*
  Standing avoidable waste volumes of Grade J or better are billed at 0.5 times the average stumpage rates determined in Appendix 3 of this manual. *(note 2)*
  1.2.4.2 Interior:
  Felled avoidable waste volumes of Grades 1 or 2 are billed at 2 times the average stumpage rates determined in Appendix 3 of this manual. *(note 1)*
  Standing avoidable waste volumes of Grades 1 or 2 are billed at 0.5 times the average stumpage rates determined in Appendix 3 of this manual. *(note 2)*
  Note 1: Higher stumpage to penalize poor utilization/ incent better utilization, and to prevent operators from "falling to waste".
  Note 2: Lower stumpage to incent operators to not "fall to waste". Minimum stumpage of $0.25/m³ would still apply.

Scaling Manual

No enabling changes recommended at this time.

Silviculture Surveys Procedures Manual

No enabling changes recommended at this time.

2.3.3. Changes to the Corporate portion of the regulatory framework

Even without government executive direction, or without changes to the legal framework, licensees and BC Timber Sales could undertake some carbon management actions.

Forest Stewardship Plans

Modify or create new results and strategies that consider carbon:

- Existing results or strategies related to soils or timber could be modified - or new ones introduced - so that they consider carbon, even if there is no carbon Objective. The primary consideration is that these results or strategies would have to be effective without unduly reducing the supply of timber as required in FPPR.
- Results or strategies for other objectives can be reviewed for their potential impact on carbon, and could be modified in ways that help carbon management while still staying consistent with the existing legal framework.

Beneficial Management Practices or Standard Operating Procedures

Develop and implement Beneficial Management Practices (BMPs) or Standard Operating Procedures (SOPs) for carbon. These can include:

- Corporate direction to limit roads widths and soil exposure.

- Inclusion of carbon management and benefits in operational activity documents and meetings (pre-works, site inspections, contracts, etc.).
- Inclusion of educational materials regarding carbon.
- Activities to limit ground disturbance, such as:
  - using branch mats if machines require access to an area, or
  - considering winter logging/ winter thinning where conditions allow.
- Encourage recovery of cuttings where facilities exist.
- Avoiding creation of fire hazard by limiting concentration of, or accessibility to, forest fuels. For example:
  - planning for fuel hazard creation and abatement prior to starting falling,
  - separation of dirty logging debris from clean sub-merchantable logs (also allows future fibre recovery – see FPInnovations' BMPs for Integrated Harvest Operations in BC, Spencer and Roeser 2017),
  - scattering woody material where it will not result in significant elevated fuels,
  - safely leaving obvious poor stems standing in the cutblock rather than bringing them to the roadside (where they will have to be piled), or
  - managing access to harvest areas to limit human caused fire starts.
- Encourage partial cutting.
- Assessing potential danger trees rather than automatically falling all of them.
- Identifying appropriate carbon retention stems (if this is incorporated as a Strategy/Results in FSP), including how to determine live crown percentages.

Site Plans

Modifications or additions could be made to Site Plans:

- Include modified description of retained stems within Site Plan, as long as not in conflict with FSP.
- Include additional retention beyond WTRA defaults, identified as non-legal temporary retention area – it can also form the basis for visual or other resource feature retention (e.g. goshawk).
- Reduce road density, but keep in mind that this might mean longer yarding distances.
- Plan roads for rehabilitation and replanting and design them to be fail safe.
- Estimate carbon benefits of site level activities (i.e., carbon savings that are incremental to the legal obligations and the status quo) and include this in site plan documentation.

Cruising and waste assessment training

Require/ train cruisers and/or waste assessors to quantify sub-merchantable component of:

- initial stand conditions, and
- post-harvest conditions.

Record carbon benefits

Keep internal records to quantify carbon benefits and consider adding this to annual or public reporting. Do this as part of preparing

- Site plans
- Road systems and plans
- Cutting authority submissions
- Long-term development and silviculture planning

3. Conclusions

The forest sector has an important role to play in helping British Columbia achieve its legislated emissions targets. This report presents on-the-ground actions at the site level that will produce carbon benefits with the aim of helping BC meet its targets and combat climate change in the long-term.

While there are many actions that may produce carbon benefits, this report focuses on those that are deemed, based on existing literature or estimation, to have the largest carbon benefit. The site level actions include continuous cover forestry; partial cutting (e.g. commercial thinning, shelterwood); rotational age at harvest; decreased road density; road rehabilitation and planting; acceptance of stems with modified form and vigor; increasing the amount and changing the composition of tree retention; and employing treatments to avoid unnecessary burning of harvest residues.

Providing information on the benefits or extent of application of the above actions at the level of the biogeoclimatic zone or natural resource district will be very complex and multifaceted, and is beyond the scope of this project. Assuming executive direction is provided to manage for carbon, it will be important to identify and quantify the benefits at the scale of natural resource districts and BEC zones of ecologically appropriate variations of the actions noted in this report.

A suite of corporate, policy and legal actions are presented that could encourage the adoption of the site level actions. At the corporate level, individual licencees could make changes to their internal record keeping and training policies, or adopt carbon management into their planning. A “carbon directive” from government could empower changes to the policy and legal systems, including the inclusion of carbon as an additional forest value under the *Forest and Range Practices Act*, and as an objective set by government in the *Forest Planning and Practices Regulation*.

Further work to synthesize or model the carbon effects of various site level activities would help to inform the most appropriate one-the-ground and policy actions. The carbon info sheets being prepared through the Forest Carbon Initiative should prove helpful in this regard, and development of carbon measurement guidelines would ensure consistency in reporting.

The suggested actions in this report, supported by legal, policy, and corporate changes, have the potential for significant carbon benefits. While we have made some preliminary estimations of these benefits, and indications are that they may be in the order of millions of tonnes of CO_2e (see Appendix C), we must caution that these estimates **are unverified**. Therefore, we strongly suggest that verification – including carbon modelling - of the strategies and actions identified in this report be undertaken, and these verifications include consideration of regional and ecological variations across the province.

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Appendix A: Example Site Plans

The example site plan reviewed and revised to include/ incorporate carbon management strategies and actions is a BC Timber Sales block in the Coast Mountains Natural Resource District, within the Kalum Timber Supply Area.

The site plan for TEsw049 has been revised to demonstrate three silviculture systems:

- Clearcut with carbon Objective Set by Government
- Continuous Cover (Single-tree Selection) with carbon Objective Set by Government
- Group Selection with carbon Objective Set by Government

Block TEsw049 (Timber Sale Licence A90581) was chosen because it is an example of a northwest BC block with high levels of felled waste, and is an example where carbon management actions can reduce that waste, thereby retaining carbon.

The statistics for the block are:

From cruise:	
Gross volume (m^3/ha)	39,156
Net volume (m^3/ha)	24,503
Species distribution	70% Hemlock, 25% Balsam, 5% Spruce
Number of stems per hectare	294.5
Average tree height (m)	32.6 (28.4 m merchantable height)
Average tree size (m^3)	2.4 (gross), 1.5 (net)
Scaled volume (m^3)	16,125 (7,072 m^3 sawlog)
Waste scale volume (m^3):	13,343 (6,084 m^3 sawlog)

The site plan revisions include wording changes in red that are specific to management of carbon at the site, or operational, level, as suggested within the Final Report for "Forest Carbon Stewardship at the Site Level". Comments in blue are also provided to give some context to the changes made for carbon management. Highlighted items show where measureable/ quantifiable descriptions of carbon benefits can be included within a site plan.

Note that in digital versions of this report, the actual revised site plans are provided under separate cover.

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BC Timber Sales' site plan for TEsw049: revised to demonstrate Clearcut with carbon Objective Set by Government

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BC Timber Sales' site plan for TEsw049: revised to demonstrate Continuous Cover (Single-tree Selection) with carbon Objective Set by Government

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BC Timber Sales' site plan for TEsw049: revised to demonstrate Group Selection with carbon Objective Set by Government

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Appendix B: Actions considered for their potential in carbon management

The following actions were considered for their potential in implementing carbon management. While they all have potential, only some were selected for further development in Section 2.

Site level actions considered and specifically recommended for implementation:

Utilize continuous cover forestry (e.g. partial cutting systems like single tree selection), prescribing spacing wide enough to promote regeneration of crop trees in layers 3 and 4.

Operational activity: site and tactical planning, silviculture system selection, logging
Implementation requirements: corporate will and government policy change
Pursue at this time? Yes, due to carbon benefit and convergence with other values (wildlife, visuals, mid-term timber supply).

Promote commercial thinning and shelterwoods where ecologically appropriate

Operational activity: tactical planning, silviculture system selection, scheduling, permitting, and operational development of cutblocks
Implementation requirements: government policy change, likely supported by legal change
Pursue at this time? Yes, due to carbon benefit and convergence with other values (wildlife, visuals, mid-term timber supply). This action also aligns with the "Utilize partial cutting" action above.

Avoid short rotation (pre-culmination) clearcut harvesting

Operational activity: tactical planning, scheduling, permitting, and operational development of cutblocks
Implementation requirements: government policy change, likely supported by legal change; identification of preferred carbon rotation age(s) based on disturbance regime or biogeoclimatic ecological classification zones.
Pursue at this time? Yes, due to carbon benefit.

Decrease road density, i.e. shorten roads, narrow road widths, or preferentially build snow roads where possible.

Operational activity: site planning, road layout and design
Implementation requirements: corporate will; government policy change will be helpful
Pursue at this time? Yes, due to carbon benefit and relative ease of implementation within the regulatory regime.

Require rehabilitation and planting of roads where possible

Operational activity: site planning, layout, road construction, post-harvest
Implementation requirements: government policy and legal change
Pursue at this time? Yes, due to carbon benefit and relative ease of implementation within the regulatory regime; this action also aligns with the "Decrease road density" action above.

Accept modified form or vigour stems in layers 1 or 2.

Operational activity: Site planning, retention and leave tree characteristics, reforestation and silviculture surveys
Implementation requirements: government policy change, possibly legal change
Pursue at this time? Yes, convergence with other values (wildlife, visuals, mid-term timber supply), and relative ease of implementation within the regulatory regime.

Increase retention beyond wildlife tree retention area (WTRA) defaults or create temporary retention features.

Operational activity: Site planning, retention and leave tree characteristics
Implementation requirements: corporate will (= small benefit) or legal change (= moderate benefit)
Pursue at this time? Yes, due to relative ease of implementation within the regulatory regime. This action also aligns with the "Accept modified" action above.

Employ treatments to avoid burning, including lop and scatter, grinding and chipping of residuals or decking to leave

- E.g. Separate stump/branch piles from waste log decks
- E.g. Ensure piles are "clean, tight, and high" = efficient burning;
- E.g. Waste Logs spread out and decked = opportunity to recover/ utilize
- E.g. Restrict human access to sites = reduced ignition hazard

Operational activity: logging, post-harvest
Implementation requirements: corporate will and government policy change
Pursue at this time? Yes, due to relative ease of implementation within the regulatory regime, and consistency with current government directions.

Accept trees in retention areas that are not necessarily representative of the rest of the stand
Operational activity: Site planning, retention and leave tree characteristics, layout
Implementation requirements: government policy change
Pursue at this time? Yes, due to relative ease of implementation within the regulatory regime. This action also aligns with the "Accept modified" action above.

Site level actions considered but not specifically recommended for implementation at this time

Harvest and utilize all available volume to reflect modern wood product streams
Operational activity: logging, post-harvest
Implementation requirements: corporate will and government policy change; dependent on existence or development of fibre consumption facilities
Pursue at this time? No, as this is dependent on facilities or processes that may not exist. Improved utilization needs to be incented first.

Recover spacing, thinning cuttings where facilities exist
Operational activity: logging, post-harvest
Implementation requirements: corporate will and government policy change; dependent on existence or development of fibre consumption facilities
Pursue at this time? No, as this is dependent on facilities or processes that may not exist. Improved utilization needs to be incented first. Note that where facilities exist, the BC Fibre Recovery Strategy may apply.

Use site preparation to increase Site Index in appropriate areas
Operational activity: stand tending
Implementation requirements: corporate will
Pursue at this time? Not necessary from a regulatory standpoint: no regulatory barriers. Note that actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Use Class A/ select seed to provide better growth
Operational activity: reforestation
Implementation requirements: Corporate will. Might benefit from government policy change.

Pursue at this time? Not necessary from a regulatory standpoint: no regulatory barriers. Note that actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Target fertilizer to those stands that would see a net carbon benefit

Operational activity: site planning, stand tending

Implementation requirements: Corporate will. Might benefit from government policy change supported by legal change

Pursue at this time? Not necessary from a regulatory standpoint – actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Prescribe/ plant best carbon sequestration species – weigh against best sawlog species

- E.g. Retain deciduous trees with coniferous and deciduous reforestation

Operational activity: site and tactical planning, reforestation

Implementation requirements: government policy, likely supported by legal change

Pursue at this time? No, as the carbon benefit of specific species and utilization levels should be made clearer. Note that other actions will likely result in the regulatory changes necessary to provide a framework for future implementation.

Communication

- Educate staff and contractors on importance of avoiding long-butts and breakage in terms of carbon implications (e.g. fallers, buckers, feller-buncher operators, yarding crews, yarding machine operators, processor operators, chasers, buckers, loader operators, prescribing foresters, layout crews, cruisers, waste surveyors)

Operational activity: all field phases, emphasis on logging and road construction

Implementation requirements: corporate will

Pursue at this time? Not necessary from a regulatory standpoint – actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Avoid GBS on sensitive soils (unless on snow or on brushmats)

Operational activity: site and tactical planning, silviculture system selection, logging

Implementation requirements: Corporate will. Might benefit from government policy change supported by legal change

Pursue at this time? Not necessary from a regulatory standpoint – actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Prescribe winter logging

Operational activity: site and tactical planning, silviculture system selection

Implementation requirements: Corporate will. Might benefit from government policy change supported by legal change

Pursue at this time? Not necessary from a regulatory standpoint – actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Avoid planting when natural regeneration will work

Operational activity: site planning, reforestation

Implementation requirements: corporate will and government policy change, likely supported by legal change

Pursue at this time? No, as the carbon benefit is expected to be small, and the carbon benefit of specific species should be made clearer. Note that other actions will likely result in the regulatory changes necessary to provide a framework for future implementation.

Limit planting to small voids or fill-planting when natural regeneration is an option

Operational activity: site planning, reforestation

Implementation requirements: corporate will and government policy change, likely supported by legal change

Pursue at this time? No, as the carbon benefit is expected to be small, and it is not clear on a site series basis when or where avoiding the carbon cost of growing and planting seedlings will outweigh the benefit of prompt reforestation.

Prompt planting to remove the need for a brushing treatment

Operational activity: site planning, reforestation

Implementation requirements: corporate will

Pursue at this time? No, as the carbon benefit is expected to be small, and it is not clear on a site series basis when or where avoiding the carbon cost of growing and planting seedlings will outweigh the benefit of prompt reforestation.

Make site-specific, informed decisions regarding timing and need for brushing

- Avoid brushing where possible and appropriate
- Brush at optimal time to allow carbon fixing into long-term species (e.g., establishment brushing)

Operational activity: site planning, reforestation, stand-tending

Implementation requirements: corporate will and government policy change, likely supported by legal change

Pursue at this time? No, as the carbon benefit is expected to be small, and it is not clear on a site series basis when or where avoiding the carbon cost of growing and planting seedlings will outweigh the benefit of prompt reforestation.

Reduce soil exposure

- Ensure branch mats used if machines accessing the area

Operational activity: site planning, logging, stand-tending

Implementation requirements: corporate will

Pursue at this time? Not necessary from a regulatory standpoint – actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Schedule winter/ summer logging with soil disturbance in mind (e.g. balancing winter/ summer logging seasons)

Operational activity: tactical planning, scheduling, permitting, and operational development of cutblocks

Implementation requirements: corporate will. Might benefit from government policy change supported by legal change

Pursue at this time? Not necessary from a regulatory standpoint – actions already identified for pursuit will likely support development of this action by demonstrating "corporate will". Could include within Beneficial Management Practices.

Brush at optimal time to allow carbon fixing into long-term species (e.g. establishment brushing)

Operational activity: site and tactical planning, stand tending

Implementation requirements: corporate will and government policy change, likely supported by legal change

Pursue at this time? No, as the carbon benefit is expected to be small, and it is not clear on a site series basis when or where the benefit carbon cost of growing and planting seedlings will outweigh the benefit of prompt reforestation

Accept modified form or vigour stems in layers 3 or 4

Operational activity: Site planning, retention and leave tree characteristics, reforestation and silviculture surveys

Implementation requirements: government policy change, possibly legal change

Pursue at this time? No. One scenario examined actually resulted in a net carbon loss over the long term, but that was with "off-spec" species (i.e. neither preferred nor acceptable); more work would be needed to confirm if this is the case for "on-spec" species.

Site level activities to support carbon actions that were considered but not specifically recommended

Incent product development to economically stimulate utilization, improve stand valuations for appraisals, and change what is considered to be merchantable material, through

- *Developing/ promoting long-term storage products (e.g. mass timber products' substitution value over Concrete or Steel)*
- *Developing new long-term products used from fibre normally used for short term products (e.g. MDF instead of pulp)*
- *Developing products from sub-merchantable fibre*

Operational activity: Tactical and development planning; Research and Development; appraisal system, waste manual, cut control

Incent recovery of thinnings and/or logging residues to biomass facilities through building on/ application of program(s) similar to FESBC; i.e. to cover incremental costs allowing residue that would otherwise be piled to instead be chipped & delivered

Operational activity: Site planning; logging; post-harvest

Improve/ modify data collection methodologies and ensure adequate training to allow assessment of

- *Carbon left on site, or*
- *Carbon growing in competitor species vs crop species*

Specific examples:

- Conduct silviculture surveys to reflect Stocking Standards' definition of form and vigour (if changed)
- Accurately measure carbon on site at outset and completion of operations

This action is necessary if the province is going to want increased accuracy with respect to carbon reporting, and could apply to cruising, waste assessments, and silviculture surveys.

Scaling may also be involved, to reflect local variations in product streams (e.g. fibre vs pulp vs saw-log).

Audits and tests of the survey types would also be required.

Operational activity: Site planning, logging, post-harvest, reforestation

Changes to the Legal portion of the regulatory system considered but not specifically recommended for implementation at this time:

- Introduce a tax measure for biomass facilities that are not pulp mills such that a portion (e.g. up to 50%) of the cost of wood waste received from the field is eligible for a tax credit. Further detail is needed, and this would have to be looked at from the perspective of future expectations of a softwood lumber agreement.
- In the FPPR, look at locking free growing date (section 44(1)(b)) to a firm number (e.g. instead of "not more than 20 years", change FG to "not less than 20 years") = licensee not as incented to get to FG status ASAP, and therefore may be willing to implement decisions that reflect other objectives like carbon. This would require industry discussions, and the benefit of this needs to be confirmed.
- Modification of FSP Stocking Standards: In the future could consider prescription of alternative species for increased carbon sequestration:
  - Species that can provide long-term VS short-term sequestration (e.g. solid wood products VS paper products)
  - Species that sequester carbon from the atmosphere most quickly (may not be the same species as above)

Changes to the Policy portion of the regulatory system considered but not specifically recommended for implementation at this time:

- Interior (and Coastal) Appraisal Manuals:
  - Section 1.2.2 Stumpage Appraisal Parameters: include the valuation of carbon as a stumpage appraisal parameter. This could change the Average Market Value of a stand.
- As primary funders of FESBC, the Premier, with the Ministers of FLNRORD and Environment, could provide a letter to the FESBC Board of Directors suggesting that within its mandate, FESBC consider
  - Accepting projects to cover the incremental costs of winter logging and winter inventory, thereby reducing ground and soil disturbance from summer and/or wet logging operations
  - Accepting projects to cover the incremental costs of licensee abatement of fire hazard by means other than burning
  - Accepting projects to cover the incremental costs of licensee or biomass facility operators gathering and delivering sub-merchantable fibre, thereby avoiding slash- or pile burning
  - Working with FP Innovation on processes or pilots to incent recovery of thinnings to biomass
- As a major contributor to FP Innovations, the Premier, with the Ministers of FLNRORD and Environment, could provide a letter to the FP Innovations Board of Directors suggesting that they consider the following suggested directions:
  - Develop/ promote long-term storage products (e.g. mass timber products' substitution value over Concrete or Steel), with a particular focus on under-utilized tree species or grades (e.g. hemlock in the BC northwest coast, subalpine fir in the BC northwest interior)
  - Develop new long-term products used from fibre normally used for short term products (e.g. fibre used for structural materials as opposed to paper-like products)
  - Develop products from sub-merchantable fibre
- Tenure documents. Once an Executive Direction regarding carbon comes out:
  - New Cutting Authority documents could
    - Require narrow roads
    - Limit road density
    - Add carbon as a product, including utilization requirements;
    - Providing rights to carbon could be incorporated into more tenures

Appendix C: Carbon Benefits of Action Items

A summary of the approximate Green House Gas (GHG) benefits for the site level operational actions described in Section 2.1 is provided in the following table. As noted in Daigle and Dymond (2010), analysis of forest carbon emissions and uptake "are multi-faceted and complex". As a result, the summary in the following table is not to be construed as providing definitive information on the carbon benefit of the actions described above. While it is recommended that additional research, modelling, and cradle-to-grave analyses be carried out to determine a more accurate GHG benefit, this table provides a general idea for the purposes of comparing the amount and timing of the GHG benefit of each action. An explanation of how each GHG benefit was calculated is also provided in this Appendix.

Table: Approximate Green House Gas Benefit of Operational Actions

Action		Cumulative GHG Benefit of Action	
No.	**Description**	**2030 (tCO_2e per 1000 ha harvested)**	**2050 (tCO_2e per 1000 ha harvested)**
1	Utilize continuous cover forestry	268,000	756,000
2	Promote partial cutting (e.g. commercial thinning, shelterwood)	32,000	92,000
3	Avoid short rotation clearcut harvesting	86,000	243,000
4	Decrease road density	44,000	124,000
5	Require rehabilitation and planting of roads *	< 2,000	38,000
6	Accept modified form or vigour stems in layers 1 and 2	258,000	729,000
7	Increase retention beyond WTRA defaults	(Included in 6)	(Included in 6)
8	Accept trees in retention areas that are not necessarily representative of the rest of the stand	(Included in 6)	(Included in 6)
9	Employ treatments to avoid burning	(Included in 6)	(Included in 6)

* Item (5) is included for two reasons:

(a). Their cumulative impact is significant, so while it has little impact in 2030 and limited impact by 2050, by 2110 the estimated benefits (provincially) will accumulate to a much higher number. So, since these major (but later) benefits require time, the earlier they are implemented, the better.

(b). This action, as well as Action 4, is relatively easy to implement and can be incorporated into planning when implementing the other actions noted here.

There are some limitations on the estimates in the above table:

- As noted above, the actual numeric value of the benefits will need to be refined, particularly in terms of leakage, geographic and ecosystem distribution, and possibly through variations of different management systems. For example, the total carbon benefit will vary dependent on the ecosystem in which they are applied; partial cuts with different levels of removal will result in different understory growth rates and resultant carbon benefit; and also, the temporal distribution of carbon benefits from a partial cut with one entry will be different than from one with multiple entries.
- Additionally, benefits should ideally be considered from a cradle-to-grave perspective: the impact of these actions on other resource values have only been discussed in general terms. Describing specific impacts or benefits is dependent on the area in which the actions are applied, due to the requirements of higher level plans or land use orders, or ecological, wildlife or physical constraints. Each natural resource district will see different consequences from application of these actions. For example, within a natural resource district that has a high proportion of constrained areas (e.g. scenic areas) the application of partial cutting may result in

an upward pressure on allowable annual cuts. These actions may also result in cost considerations: since per hectare timber recovery (i.e. volume removed from the block and sent to a processing facility) from partial cutting will normally[3] be less than that from clearcut systems, logging and road-building costs may well increase, at least in areas – like old growth forests - without established road systems.

- Due to factors like those noted in the previous paragraphs, providing information on the benefits or extent of application of the above actions at the level of the biogeoclimatic zone or natural resource district will be very complex and multifaceted. While discussion of sub-regional actions and impacts was an original intent of this project, the level of complexity exceeds the time, financial, and modelling resources necessary. However, this does not preclude the value of doing this work at the natural resource district scale, and if a decision is made to make carbon a clear focus of forest management, it will then make sense to identify and quantify the benefits of the ecologically appropriate variations of the actions above, at the scale of natural resource districts.

Nonetheless, it is clear that the above actions have the potential for a significant carbon benefit if the estimates are verified as being accurate. For example, if these actions could be applied to 10% of the annual estimated harvest area of 180,000 ha/ year, the carbon benefits (if verified) could be over 10 million tonnes CO_2e by 2030, and over 30 million tonnes CO_2e by 2050. Therefore, it is recommended that verification of the estimates would be worthwhile.

Details on the Action items are provided on the next pages, and are organized as follows:

Carbon Management Action
Benefit Description and details about benefit Numerical estimate associated with benefit
Estimation of combined carbon benefit (tonnes CO_2e per 1000 hectares): 2030: *(note that while estimates are shown with precision, their accuracy still needs to be verified)* 2050:
Verification challenges

Basis for some of the numbers referred to in the Action Item are as follows:

Amount	Unit	Source
0.427	tonne/m^3 of wood	Average of BC species from FP Innovations – actual # will vary regionally
0.5	amount of carbon in wood	Multiple (e.g. forestlearning.edu.au)
3.67	Conversion: tonne of carbon to tonne of CO_2 equivalent	Multiple (e.g. forestlearning.edu.au)
180,000	hectares of logging per year	*from: 180,000 Nelson 2011 ABCFP article; 195,000 BC Gov't (MSRM) "BC's Forests - a geographical perspective" (est 2005); Forest Practices Board*
5,000	km of resource roads built per year	*Conservative estimate, based on review of FPB 2015 access mngt report: 240,000 km of resource (on-block) roads built by 2005 (est: 6 -25000 km/yr); 9 - 12,000 km/yr based on 16-20 ha developed per km (SCI, 1998); 3150 km/yr Nelson 2011*
8,900,000	ha 2nd growth (41-80 yrs old)	*from: 2011 BC Gov't (MSRM) "BC's Forests - a geographical perspective"*
2.3	tonnes CO_2e/ha/100 years	*from Hall 2011 re differential CO_2e savings of not burning (=0.023/ha harvested/yr)*
0.3	m3/stem (log)	*Conservative estimate of net tree volume. Compared to cruise information for several blocks in the Nadina, average net volumes/stem was 0.6 m3/ stem*

[3] In some cases, (e.g. in portions of northwest BC) where partial cutting may be able to avoid the creation of so much downed waste that recovered volume is equivalent to that from clearcutting.

Action 1: Utilize continuous cover forestry:

Benefits, based on group selection harvesting compared to a baseline of clearcutting:

Continued fixing of carbon in retained stems

- Based on example growth on group selection harvest in second growth Coastal Western Hemlock BEC zone compared to clearcut (growth and yield modelled in SORTIE). GROUP SELECTION: Volume removal approximately 33% of the harvest area scheduled for every 30 years, starting at year one in the model, and then again at year 30, 60 and 90. Resulting in the final removal of the second growth stands at year 60 of the model run, and the harvesting of the first cohort (originally harvested in year 1) at year 90 (age 90 is the approximate culmination age for many species on average sites in BC). CLEARCUT: The same stand can be logged using a clearcut system in year one, then common silvicultural treatments can be applied for that Biogeoclimatic Zone, and the stand subsequently clearcut again at year 90.
- Example growth on group selection versus clearcut (SORTIE run) = 102 m3/ha (over 90 years) = 1.13 m3/ha/yr (straight-line); Annual carbon benefit per hectare = 1.13*0.427*0.5*3.67 = 0.885 tonneCO_2e/ha/yr

Designation of stems as Carbon Retention Trees (CRTs)

- Based on retaining 100 carbon retention stems per hectare compared to falling the stems in a clearcut. This number may be more appropriate in some regions of the province and is used to give an indication of the potential of this action.
- 100 sph at an avg of 0.3 m3/stem; Annual carbon benefit per hectare = 100*0.3*.427*.5*3.67 = 23.5 tonneCO_2e/ha

Reduction of woody waste

- Since poorer wood is to be left in CRTs, then average quality of harvested stems would go up, so there should be a decrease in remaining woody waste. The amount of this decrease is not easy to estimate, so let's just assume it is accounted for in the CRT volume for now

Reduction of woody waste to be piled and burned

- Due to the more dispersed nature of the group selection harvesting, lop and scatter can be used to abate fire hazard and burning can be largely avoided. This has been seen in group selection blocks in the Skeena region. Unburned waste has been shown to provide a 2.3 tonne/ha/100 yr benefit per hectare harvested vs pile burning (Hall and Dymond, 2012). To be conservative, say some of the area will be burned and only 75% of this benefit is realized.
- Annual carbon benefit per hectare = 0.75*2.3/100 = 0.017 tCO_2e/ha

Unverified estimation of combined carbon benefit

2030: 268,499 tonnes CO_2e per 1000 hectares

2050: 756,679 tonnes CO_2e per 1000 hectares

Verification challenges

- Estimates do not consider temporal dynamics of clearcut vs group selection so 2030 and 2050 values are just “guesstimates” at this time. Modelling required.
- CRT retention of 100 sph is believed to be a conservative assumption, but is based on a limited sample set in one district; increased sampling required.
- Assumption that group selection would result in 75% less burning is based on a limited sample set.
- Need to consider geographic variations to clearly identify areas where harvest volumes could be maintained while implementing CRTs (e.g. areas within NW BC).
- Further research and/or modelling would address concerns about potential double counting between green tree retention and the reduction of emissions from burning.

Action 2: Promote partial cutting and shelterwood:

Benefits, based on partial cutting (e.g. commercial thinning) compared to a baseline of clearcutting

Continued fixing of carbon in retained stems

- An estimate carbon benefit of 0.81 to 1.3 tonne C/ha/yr has been associated with commercial thinning (Nabuurs et al 2000). Other sources indicate that the net carbon benefit of commercial thinning is dependent on many factors and is therefore unknown (Daigle and Dymond, 2010). While Nabuurs is used, additional verification is needed.
- Annual carbon benefit per hectare = 0.81 tonne C/ha/yr*3.67 = 2.97 tCO_2e/ha/yr

Reduction of woody waste to be piled and burned

- Commercial thinning allows the recovery of stems before mortality resulting in a reduction of waste to be piled and burned. Unburned waste has been shown to provide a 2.3 tonne/ha/100 yr benefit per hectare harvested vs pile burning (Hall and Dymond, 2012). To be conservative, it is still expected that some of the area will be burned and therefore only 75% of this benefit is realized.
- Annual carbon benefit per hectare = 0.75*2.3/100 = 0.017 tCO_2e/ha

Unverified estimation of combined carbon benefit

2030: 32,889 tonnes CO_2e per 1000 hectares

2050: 92,688 tonnes CO_2e per 1000 hectares

Verification challenges

- An assumption was made that partial cutting (especially CT) would result in 75% less burning: the actual reduction amount needs to be properly verified, including variations due to BEC.
- Further research and/or modelling would address concerns about potential double counting between green tree retention and the reduction of emissions from burning.
- Need to undertake field reviews and/or modelling to confirm carbon impacts of partial cutting (including CT)

Action 3: Avoid short rotation clearcut harvesting

Benefits, based on harvesting a stand at culmination compared to harvest of immature stand

Continued fixing of carbon during period of best growth

- Early harvest (e.g. prior to age 60) means the time when a stand could be putting on the highest annual increment of volume (and carbon) does not occur - instead the stand is dialed back to a "zero" state. Over the long-term, the loss is the incremental difference between the MAI at early harvest (e.g. MAI 60) versus at MAI at culmination (e.g. MAI 90); in the short-term (i.e. over 30 years), the carbon benefit is the difference between carbon fixed for the delayed harvest stand, i.e. from age 60 to 90 versus the carbon fixed for the new forest that was subject to early harvest, i.e. from age 0 to 30.
- Growth on immature (60-90 yr old) Balsam stand with medium productivity (Kalum TSA Technical Report, July 2010) estimated at an average 10 m3/yr annual increment = 7.8 tonneCO_2e/ha/yr

Reduction of woody waste to be piled and burned

- Delay means NO waste generated.
- Reduction = 0.023 tCO_2e/ha/yr as per Hall 2012

Unverified estimation of combined carbon benefit

2030: 86,253 tonnes CO_2e per 1000 hectares

2050: 243,077 tonnes CO_2e per 1000 hectares

Verification challenges

- Benefits over the long-term (multi-rotational) may result in a lower net carbon effect – modelling required.
- Short-term carbon impact would need to be weighed against mid-term timber supply considerations, i.e. may be a short-term reduction in total harvested volume due to age-class balances: policy reconciliation needed.
- 10 m3/ha/yr annual increment taken from on part of the province (NW BC Balsam) – need to use appropriate annual increment figures for each district
- Further research and/or modelling would address concerns about potential double counting between green tree retention and the reduction of emissions from burning.

Action 4: Decrease road density:

Benefits, based on decreasing the amount of new road built compared to the current average roads built per year

Reduction in forest floor converted to a deforested state

- Road construction requires full forest and overburden removal and subsequent release of carbon. Reducing that amount will provide a carbon benefit by maintaining some of existing carbon storage in the soil and reforesting to allow new sequestration.

Reduction of deforested land, thereby maintaining land for growing trees and fixing carbon

- Road construction requires full forest and overburden removal and subsequent release of carbon. Reducing that amount will provide a carbon benefit by maintaining some of existing carbon storage in the soil and reforesting to allow new sequestration.
- Incremental growth estimate interpolated from SMITH in POJAR report. Benefit will accrue non-linearly based on the modelling curve. 1% reduction of roads/year is estimated to be 50 ha/year. Benefit accrues by an additional 50 ha each year

Unverified estimation of combined carbon benefit

2030: 43,939 tonnes CO_2e per 1000 hectares harvested

2050: 124,379 tonnes CO_2e per 1000 hectares harvested

Verification challenges

- Estimates are based on broad assumptions and coarse interpretations; uncertainty exists around some basic numbers, e.g. actual amount of road built per year. Verification and validation of models and baseline numbers is critical.

Action 5: Require rehabilitation and planting of roads:

Benefits, based on the difference between a naturally regenerating road and one that is manually rehabilitated.

Reduction of deforested land, thereby maintaining land for growing trees and fixing carbon

- Road construction requires full forest and overburden removal and subsequent release of carbon, and once built, the road is unlikely to grow new vegetation for a significant period of time, and the amount of vegetation (= carbon sequestration) will be sparse. Rehabilitating roads to allow quick revegetation will allow new sequestration.
- Incremental growth based on Forest Carbon Initiative note 7. 1% reduction of roads/year = 50 ha/year. Benefit accrues by an additional 50 ha each year; Benefit will accrue non-linearly based on modelling curve.

Unverified estimation of combined carbon benefit

2030: 1,427 tonnes CO_2e per 1000 hectares harvested

2050: 37,947 tonnes CO_2e per 1000 hectares harvested

Verification challenges

- Estimates are based on broad assumptions and coarse interpretations; uncertainty exists around some basic numbers, e.g. actual amount of road built per year Verification and validation of models and baseline numbers is critical.

Action 6: Accept modified form or vigour stems in layers 1 and 2:

Benefits, based on a clearcut with designated Carbon Retention Stems compared to a clearcut without Carbon Retention Stems

Designation of stems as Carbon Retention Trees

- Allowing "poorer" quality stems to be designated as CRTs will prevent them from being felled to waste and immediately contributing to carbon release. Also will have wildlife habitat and biodiversity benefits, and may have contribute to a (likely small) reduction in wildfire hazard. Short-term carbon benefit.
- Retention of 100 sph at an average of 0.3 m3/stem = 100*0.3*.427*.5+3.67 = 23.5 tonne/ha/yr

Reduction of woody waste to be piled and burned

- Allowing "poorer" quality stems to be designated as future crop trees (e.g. as pulp or future fibre trees) will prevent them from being felled to waste in certain areas: less waste = less abatement required = less immediate carbon release. Leaving stems standing means future fibre recovery options will be maintained.
- Assuming that 50% of volume retained would otherwise have been burned, then 50% of 100 sph at an average of 0.3 m^3/stem = 100*0.3*.427*.5*.5 = 3.2 tonne/ha; Unburned waste provides a 2.3 tonne/ha/100 yr benefit (Hall 2012), 50% = 0.5*(2.3/100) = 0.0115 tonne/ha/yr

Unverified estimation of combined carbon benefit

2030: 258,696 tonnes CO_2e per 1000 hectares

2050: 729,053 tonnes CO_2e per 1000 hectares

Verification challenges

- Retention of 100 sph is based on a limited sample set in one district; increased sampling required to refine retention levels and their appropriate geographic and ecological distribution and.
- Confirmation (e.g. through sampling) of the actual amount of stems that would otherwise become waste is required.
- Further research and/or modelling would address concerns about potential double counting between retention within continuous cover forestry versus as part of additional retention areas.

Action 7: Increase retention beyond WTRA defaults

Benefits, based on a clearcut with modified retention requirements compared to a clearcut with "status quo" retention

Designation of stems that would otherwise be wasted within retention areas

- Similar to 6, but done through a different regulatory mechanism.
- Conservatively estimate that carbon benefit amount is included within 6 above.

Reduction of woody waste to be piled and burned

- Similar to 6, but done through a different regulatory mechanism.
- Conservatively estimate that carbon benefit amount is included within 6 above.

Unverified estimation of combined carbon benefit

2030: conservatively estimated to be included within Action 6 benefit until such time as independently modelled/ verified

2050: conservatively estimated to be included within Action 6 benefit until such time as independently modelled/ verified

Verification challenges

- As for action 6, and
- Need to verify whether this action is a subset of Action 6 or can be sampled and/or modelled as an independent action

Action 8: Accept trees in retention areas that are not necessarily representative of the rest of the stand

Benefits, based on a clearcut with modified retention standards compared to a clearcut with "status quo" standards

Inclusion of stems that would otherwise be wasted within retention areas

- Similar to 6 but done through a different regulatory mechanism, primarily to allow "poorer" quality stems contribute to wildlife, biodiversity and visual objectives.
- Conservatively estimate that carbon benefit amount is included within 6 above

Reduction of woody waste to be piled and burned

- Similar to 6, but done through a different regulatory mechanism, primarily to allow "poorer" quality stems contribute to wildlife, biodiversity and visual objectives. These stems may otherwise be felled to waste, therefore the additional benefit is a reduction in waste to be abated.
- Conservatively estimate that carbon benefit amount is included within 6 above

Unverified estimation of combined carbon benefit

2030: conservatively estimated to be included within Action 6 benefit until such time as independently modelled/ verified

2050: conservatively estimated to be included within Action 6 benefit until such time as independently modelled/ verified

Verification challenges

- As for action 6, and
- Need to verify whether this action is a subset of Action 6 or can be sampled and/or modelled as an independent action

Action 9: Employ treatments to avoid burning

Benefits, based on a clearcut with avoidance treatments employed compared to a clearcut without such treatment

Reduce hazard through access controls

- Controlling access will allow some areas to be deferred from burning, thereby providing a short-term benefit. Waste will still be there should a potential use for the woody material.
- Carbon benefit of not burning = 2.3 tCO_2e/ha/100yr = 0.023 tCO_2e/ha/yr

Reduce hazard through revised piling procedures such as piling only dirty fines and laying clean logs flat

- Piling can make a portion of woody residue more readily available for fibre recovery processors. Separating larger material from fines may reduce the amount of residue that needs to be abated.
- This is not easily quantifiable as the prescription would be site specific, related to total fuel loading. Suggest tests or trials be undertaken to try to quantify the potential benefit.

Abate hazard by removing material

- The best wildfire hazard abatement of woody residue is removal.
- Treatment actions are discussed and accounted for as part of 1,2,3,4 and 6 above.

Unverified estimation of combined carbon benefit

2030: 127 tonnes CO_2e per 1000 hectares

2050: 357 tonnes CO_2e per 1000 hectares

Verification challenges

- The benefit of reducing fire hazard and therefore avoiding a wildfire is real, but not verifiable

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Appendix D: Additional Carbon Budget Modelling Scenarios

Carbon budget modelling was in the initial scope of this project and modelling of some scenarios was initiated; however, due to time and budget constraints plus increased scenario complexity and output expectations, final modelling was not able to be completed. Initial model preparation for this project focused on group selection and single tree scenarios. As a further step to determining site level treatments that would produce carbon benefits, other potential modelling scenarios were also explored. The scenario descriptions are provided here for future consideration. In some cases, existing studies have explored the carbon outcomes of these scenarios, in other cases the scenarios are included as future opportunities for carbon modelling.

Commonly used models and tools in British Columbia, such as the Tree and Stand Simulator (TASS), Table Interpolation for Stand Yields (TIPSY), or Variable Density Yield Projection (VDYP), do not explicitly model spatial competition between trees. SORTIE represents the forest as individual trees and models the interactions and activities of these individuals in time and space (Bulkley Valley Research Center, 2009). In British Columbia SORTIE has been calibrated to the SBS Biogeoclimatic Zone, the Interior Cedar Hemlock (ICHmc2) Biogeoclimatic Zone, and the Coastal Western Hemlock (CWH ws1 and 2) Biogeoclimatic Zones (Coates, pers. comm.).

The Carbon Budget Model (CBM-CFS3) is an operational-scale carbon accounting tool that was developed by the Canadian Forest Sector. It simulates carbon stock dynamics in the forest and can be used at the stand and landscape level (Kurz et. al. 2009).

Scenario - Group selection

Variations:

The following two group selection treatments were considered for modelling:

a. Group selection starting with old growth in the Sub-Boreal Spruce (SBS) biogeoclimatic zone
b. Group selection starting with second growth in the Coastal Western Hemlock (CWH) biogeoclimatic zone

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of initial treatment and that further effects will be seen after each subsequent entry/treatment.

Scenario Description:

There is increased interest in alternate silvicultural systems in BC. Alternate systems, including group selection, potentially allow a certain amount of harvesting activities to occur in currently constrained areas. Group selection is a type of partial cutting system which, when compared to a baseline of clear-cut harvest with reserves, may offer carbon benefits at the site level by deferring harvest of a significant portion of the trees in the stand and, thereby maintaining carbon storage on the site. In addition, group selection systems are more dispersed across the site and are less accessible to the public so the need to mitigate fire hazard is potentially reduced.

The definition of group selection is:

> *'Group selection systems also promote uneven-aged stands with clumps of even-aged trees well distributed throughout the cutting unit. Unlike single tree selection, however, these even aged groups are large enough to accommodate some shade-tolerant seral species in addition to more tolerant climax species. Small gaps or openings are created on short intervals to develop into a*

mosaic of at least three or more age classes throughout the stand.' (BC Ministry of Forests Forest Practices Branch 2003)

Two common starting conditions in BC can be assumed. The first would be typical old growth stands, the second would be second growth stands that have achieved commercial operability. It is expected that group selection in old growth stands is less likely to result in volume benefits as existing old growth on the site would likely have lower growth rates and will persist longer into the future. Second growth group selection has greater potential volume and carbon benefits as more of the initial stand is being retained and that stand will be in the prime growing/sequestration ages.

Modelling Information/Status:

Where modelling does not exist for these scenarios, it is recommended that SORTIE be used to provide stand and volume tables for group selection scenarios, and carbon stores and fluxes be determined in CBM-CFS3.

Group selection systems on existing unharvested old growth stands and second growth stands that have reached commercial operability could be modelled. Openings created should be between 0.2 ha and 0.6 ha. Volume removal can be modelled based on removal of approximately 33% of the harvest area. Entries can be scheduled for every 30 years, starting at year one in the model, and then again at year 30, 60 and 90. The final removal of the original old growth or second growth stands would be at year 60 of the model run, and harvesting of the first cohort (originally harvested in year 1) would occur at year 90 (age 90 is the approximate culmination age for many species on average sites in BC).

Modelled scenarios are compared to a base case: in this case the same stand can be logged using a clearcut system in year one, then common silvicultural treatments can be applied for that Biogeoclimatic Zone, and the stand subsequently clearcut again at year 90 (assumed to be approximate culmination age). The base case should also be modelled in SORTIE to eliminate model bias (i.e. modelling the base case in TASS, TIPSY or VDYP may produce different results based solely on the model rather than the scenario modelled).

The following two variations of the scenario can be modelled:

1) **SBSmc site with old growth:**
   - This system modelled on a typical SBSmc site with old growth. Following removals, harvested units are regenerated to 1400 spruce (Sx) per ha (planted on a 2.9 m grid) and naturals generated by the model based on the existing stand.
   - For the base case, decay waste and breakage are assumed to be 25% of the net merchantable volume, 58% of this decay waste and breakage is assumed to be piled and burned (no residual utilization), the remainder is left scattered in the block (extrapolated from Blackburn (2017)).
   - The group selection scenario assumes approximately 33% of the area is harvested with each entry. While the volume harvested varies with each entry because of changing timber characteristics, the modelling assumed a common decay waste and breakage for each entry. Due to the more dispersed nature of the group selection harvesting, lop and scatter was assumed to be sufficient to abate fire hazard and there is no piling and burning. Note that group selection activities at several sites in the CWH ws1 have utilised lop and scatter, which provides support for modelling of this scenario.
2) **CWHws1 managed stand at age 60.**
   - System modelled on a typical CWHws1 managed stand at age 60 (assumed to be commercially operable). Following removals, harvested units regenerated to naturals (generated by the model). The base case regenerated to 7000 naturals per ha at age 3.

- For the base case, decay waste and breakage derived from personal experience with harvested stands in CWHws1 second growth stands in the Coast Mountain Natural Resource District. For average second growth stands in the CWHws1, decay and breakage is assumed to be 20% of the net merchantable volume; 70% of this decay waste and breakage is assumed to be piled and burned (on ground-based harvest systems with no residual utilization).
- The group selection scenario will harvest 33% of the area with each entry. While the volume harvested varies with each entry because of changing timber characteristics, the modelling will assume a common level of decay, waste and breakage for each entry. Due to the more dispersed nature of the group selection harvesting, lop and scatter is assumed to be sufficient to abate fire hazard and there is no piling and burning.

Scenario - Single Tree selection / continuous cover forestry

Variations

The following two single tree selection treatments were considered for modelling:

a. Single tree selection starting with multistory old growth
b. Single tree selection starting with second growth

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of initial treatment and that further effects will be seen after each subsequent entry/treatment.

Scenario Description:

There is increased interest in alternate silvicultural systems in BC. Alternate systems potentially allow a certain amount of harvesting activities to occur in currently constrained areas. Single tree selection systems may offer carbon benefits at the site level by various means including deferring harvest of a significant portion of the trees in the stand and potentially reduced burning of residuals. Two common starting conditions in BC can be assumed. The first would be multilayered old growth stands, the second would be second growth stands that have achieved commercial operability and are converted over time to the desired stand structure.

Modelling Information/Status:

Where modelling does not exist for these scenarios, the carbon effects of single tree selection and continuous cover forestry could be modelled using CBM-CFS3.

Scenario - Avoidance/delay in burning

Variations:

The following three treatments were considered to avoid or delay burning:

a. Lop and scatter
b. Grinding/chipping – with and without utilization
c. Decking to leave

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of initial treatment and will potentially diminish over time.

Scenario Description:

While not a treatment *per se*, avoidance/delay in burning is an operational action that potentially has a major impact on carbon in British Columbia and it is important to understand the level of impacts from avoidance/delay in burning. Typically harvesting results in residuals remaining after harvest. Leaving some residuals can be beneficial for a variety of reasons including soil carbon, soil nutrients and coarse woody debris/biodiversity (Stevens, 1997); however excessive residual material often presents an increased fire risk or limits site availability for regenerating forests. Often treatments must be undertaken to reduce fire or silvicultural risk to acceptable levels. Typically in BC excess residuals are piled and burned resulting in an immediate large output of carbon. Situations that decrease the amount of residuals that require piling and burning should reduce BC's carbon outputs.

In general, silvicultural systems with similar market forces (opportunities to utilize similar timber) will produce similar amounts of residuals; however, some harvesting methods will distribute this material differently throughout the harvested area. Processing in the woods allows residuals to be retained where they are generated: in some situations, this material may not be sufficient to require treatment by burning. Similarly, material can be redistributed in some forest types using 'lop and scatter' to avoid concentrations of slash that would otherwise require treatment. Silvicultural systems such as single tree selection with low intensity entries may also create insufficient residuals to require treatment (depending on various factors). In cases where residuals could be ground/chipped instead of burned some of this material may potentially be utilized. It is also possible in some situations that residuals could be decked and left.

Modelling Status:

A study of carbon budget modelling was carried out by Hall (2011) to determine greenhouse gas (GHG) impacts of burning harvest residues compared to a base case of GHG releases from natural decomposition of residues for the Strathcona Timber Supply Area. This study suggests that allowing residue to decompose instead of burning accrues two important benefits: the delayed release of carbon for years, decades or even centuries; and the avoidance of methane (CH_4) and nitrous oxide (N_2O) which both have a greater greenhouse effect than CO_2 (Hall, 2011). The study presents total annual and cumulative GHG releases for the study, and a synopsis of this study by Hall and Dymond (2012) indicates that pile burning resulted in a net 100-year cumulative impact of 2.3 tonnes CO_2e per ha harvested. While the study did not look specifically at the different treatments suggested in this scenario, it demonstrates that short- and long-term carbon benefits are seen if burning is avoided and harvest residues are left on site to decompose.

Scenario - Avoidance of ground disturbance

Variations

The following two treatments were considered to avoid ground disturbance:

a. Winter harvest
b. Low impact harvesting methods (low ground pressure equipment, cable harvesting)

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 5 years of initial treatment with an unknown duration.

Scenario Description:

Like avoidance/delay in burning, avoidance of ground disturbance is an operational action that potentially has an impact on carbon in British Columbia and therefore it is important to understand the level of impacts from avoidance of ground disturbance. While some aspects of ground disturbance may be beneficial (i.e. improving seed bed for certain species) excessive ground disturbance may result in

increased carbon outputs and potentially reduced forest productivity. Typically in the majority of the BC interior harvesting under appropriate winter conditions results in minimal ground disturbance. Various low impact harvesting methods also exist. In general cable harvesting with good deflection or harvesting with low ground pressure equipment under appropriate conditions results in significantly less ground disturbance than harvesting during non-winter conditions with standard equipment.

Modelling Information/Status:

Investigations to date leave it unclear as to whether growth & yield data has been prepared for this type of scenario or if it has been modelled. However, in a study to understand the effect of site preparation on soil carbon, Prescott et. al. (2017) suggests forest floor material that is buried has a 5 to 15% increase in the rate of decomposition in the short-term (3-year period) compared to material on the surface. This study could be used to adjust soil carbon fluxes within the CBM-CFS3 and assess the short-term impact on carbon from different levels of ground disturbance, such as those associated with winter harvest or low impact harvesting methods when compared to a base case. To fully understand the long-term impact of ground disturbance on forest soil carbon stocks, further study is needed.

Scenario - Retain advanced regeneration

Variations

The following two treatments were considered:

a. Retain preferred and acceptable conifers of good form and vigour (as per advanced regeneration standards)
b. Retain all advanced regeneration except those infected with forest pest but including suboptimal species and trees of poor form or vigour

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of initial treatment, with an unknown duration.

Scenario Description:

Retention of advanced regeneration is an important part of many silviculture systems. It may be on an ad-hoc basis as in typical clearcut harvesting in British Columbia or it may be part of a deliberate system to encourage and preserve advanced regeneration as in a shelterwood silvicultural system. Following disturbance such as logging it takes many years before newly established regenerating trees begin storing significant amounts of carbon. Retaining advanced regeneration potentially shortens the time between harvesting and when significant carbon begins to be stored in the regenerating forest. The successful retention of significant amounts of advanced regeneration implies that soil disturbance is minimized: activities that cause significant amounts of soil disturbance are likely to damage or destroy the advanced regeneration. The amount and size of the advanced regeneration will influence how much and how fast the carbon begins to be stored (and potentially the rate at which stored carbon from the original stand is released). A variation of this would be to retain advanced regeneration of poor form or vigour or of a sub-optimal species to determine if the carbon benefit outweigh the loss of the site to the suboptimal species.

The benefits of retaining good quality advanced regeneration are obvious, less obvious are the potential benefits of retaining poor quality advanced regeneration or advanced regeneration of suboptimal species. This analysis would also be applicable to shelterwood silvicultural systems.

Modelling Information/Status:

Where modelling does not exist for these scenarios, the carbon effects of retaining different densities and heights of preferred and acceptable conifers as well as the effects of retaining different densities

and heights of suboptimal advanced regeneration could be modelled using CBM-CFS3. Modeling these scenarios will hopefully give direction to the amount and timing of retaining advanced regeneration during harvesting.

The following provides criteria that could be used to conduct carbon modelling for this scenario.

Commonly used models and tools in British Columbia (TASS, TIPSY, VDYP) do not explicitly model spatial competition between trees in partial cut scenarios (including retention of larger advanced regeneration); therefore, we would recommend using SORTIE for this scenario and the base case.

The starting condition for this scenario and base case assumes unharvested old growth stands in the SBSmc and CWHws1 that are logged by clearcut. It also assumes 7% wildlife tree retention as a single patch in the center of the opening. The model assumes harvesting in the summer and assumes ground disturbance on 50% of the harvested area.

The base case would be the same stand logged using a clearcut system with no advanced regeneration retention and reforested using common silvicultural treatments for the Biogeoclimatic Zone modelled to at least 90 years (assumed to be approximate culmination age). The base case for the SBSmc assumes planting occurs at year 2 with 1400 stems per ha of spruce. The base case for the CWHws1 assumes reforestation with randomly distributed natural regeneration at year 3.

The following four advanced regeneration scenarios could be run and compared to the base case:

1. After the stands are harvested, retain 800 stems per ha of preferred species advanced regeneration less than 5 cm dbh in a random distribution across the block: spruce in the SBSmc and western hemlock, western red cedar, amabilis fir (balsam) and spruce in the CWHws1. Reforest the blocks to target numbers of preferred species: 1400 stems per ha of spruce planted at year 2 in a 2.9 m grid in the SBSmc and natural regeneration reforested in year 3 in a random distribution for the CWHws1. This overstates the amount of planting that would actually be required in the SBSmc as some of the planted trees would be adjacent to the advanced regeneration but SORTIE will kill these unnecessary trees via intra tree competition.
2. A second scenario is the same as the previous scenario except advanced regeneration is larger: between 5 and 15cm dbh.
3. The third scenario recreates the first scenario except the advanced regeneration is assumed to be a suboptimal species. In the SBSmc this would be acceptable but lower performing subalpine fir.
4. The fourth scenario recreates the second scenario except the advanced regeneration is assumed to be poor quality. For the CWHws1 this is assumed to be hemlock and amabilis fir of poor quality resulting in a pulp tree at rotation for all advanced regeneration.

Scenario - Thinning

Variations

The following two thinning treatments were considered:

a. Pre-commercial thinning
b. Commercial thinning

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of initial treatment and that further effects will be seen after each subsequent entry/treatment.

Scenario Description:

Thinning is a silvicultural treatment that can be thought of as having two major variants. Pre-commercial thinning is spacing where the residual volume is left on site because the costs of removing it

to be processed is greater than the value of the residuals. This will result in an output of stored carbon. In a commercial thin a component of the residuals is removed and processed into commercial products.

The use of various thinning treatments has the potential to affect the remaining carbon stores, the carbon sequestration rate, and the timing of final harvest of a stand. D'Amato et. al. (2011) found that a thinning method had an influence on the stand's carbon stores and carbon sequestration rate. Thinning methods that targeted subdominant trees resulted in larger remaining carbon stores compared to methods that targeted dominant or codominant tress. Thinning methods that targeted dominant/ codominant trees resulted in higher sequestration rates than thinning methods that targeted subdominant trees. Thinning is also commonly associated with decreasing the time to final harvest (by concentrating growth on fewer stems allowing an earlier harvest), but can also be used to defer final harvest on the site by allowing an entry to harvest a component of the volume while leaving the remainder of the stand to continue to grow.

The timing of various harvest entries is closely associated with the release of stored carbon; therefore, commercial thinning potentially adjusts the timing of carbon release. If commercial thinning results in the recovery of stems before mortality, it would reduce the woody waste that is piled and burned and provide a carbon benefit, although this would be subject to the frequency and intensity of operational entries.

Modelling/ Information Status:

Investigations to date leave it unclear as to whether growth & yield data has been prepared for this type of scenario or if it has been modelled. Where modelling does not exist for these scenarios, the carbon effects of thinning treatments could be modelled using CBM-CFS3.

Scenario - Effective increase in Site Index

Variations

The following three treatments were considered as a means to increase Site Index:

a. Site preparation resulting in a permanent increase in Site Index (i.e. mounding wet soils)
b. Fertilization
c. Class A seed

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of treatment.

Scenario Description:

Several silvicultural treatments potentially result in an increase in Site Index. An increase in Site Index should result in a greater amount of carbon fixed.

Modelling/ Information Status:

Investigations to date leave it unclear as to whether growth & yield data has been prepared for this type of scenario or if it has been modelled. Where modelling does not exist for these scenarios, the carbon effects of site preparation (that permanently increases potential site index), fertilization and using Class A seed could be modelled using CBM-CFS3.

Scenario - Deciduous management

Variations

The following two deciduous management treatments were considered:

a. Retain low, medium and high basal area of deciduous with conifer reforestation
b. Retain low, medium and high basal area of deciduous with deciduous reforestation

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will become noticeable within 10 years of treatment, but the duration of the effect is unknown.

Scenario Description:

Deciduous trees such as aspen, birch, alder, maple and cottonwood are often retained on conifer dominated areas following harvest. These retained trees can have beneficial effects on wildlife and biodiversity and may confer a carbon benefit. This benefit may occur because of increased retention of stored carbon via the retained stems or potentially through rapid growth of deciduous stems postharvest. Retaining or managing deciduous tree species also creates a risk related to the growth of conifers affected by the deciduous trees and to carbon outputs as deciduous trees in BC are typically used for products with a shorter lifespan than conifers.

Modelling/ Information Status:

Investigations to date leave it unclear as to whether growth & yield data has been prepared for this type of scenario or if it has been modelled. Where modelling does not exist for these scenarios, the carbon effects of retaining different basal areas of deciduous trees while managing for conifer regeneration as well as the impacts of switching from conifer reforestation to deciduous reforestation could be modelled using CBM-CFS3.

Scenario - Rotation length

Variation

Compare sites harvested at economic rotation to sites harvested at culmination age and extended rotation lengths.

Hypothesized timing of carbon effect(s):

It is hypothesized that the carbon effects will be noticeable in the short term and the long term, and that changes to rotation length will affect carbon storage and release.

Scenario Description:

While not a treatment *per se*, rotation length is a factor that potentially has a major impact on carbon in British Columbia and it is important to understand the level of impacts from changes to rotation length in relation to forest carbon. Following disturbance, it takes many years before significant carbon storage begins in a new forest. Forests less than 20 years old are often a source of carbon emissions as the amount of carbon released through decomposition of harvest/natural disturbance residuals is greater than the amount of carbon being sequestered by the young trees. Studies show that as stand age increases so do carbon stores (D'Amato et. al. 2011). Net carbon uptake reaches a peak in intermediate aged forests (30-120 years old) but continues in older forests (Pojar, 2019). Shortened rotations have a smaller portion of the rotation where net carbon uptake is at its peak.

The results of this scenario will likely be of best use when combined with other treatments, such as thinning or partial cutting.

Modelling/ Information Status:

Investigations to date leave it unclear as to whether growth & yield data has been prepared for this type of scenario or if it has been modelled. Where modelling does not exist for these scenarios, the carbon effects of various rotation ages (economic rotation, rotation at culmination age and extended rotation) could be modelled using CBM-CFS3.

Appendix E: Interim Progress Report

Note that for digital versions of this report, the Interim Progress Report is provided under separate cover.

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Natural Resource Solutions:

Practical - Professional - Innovative