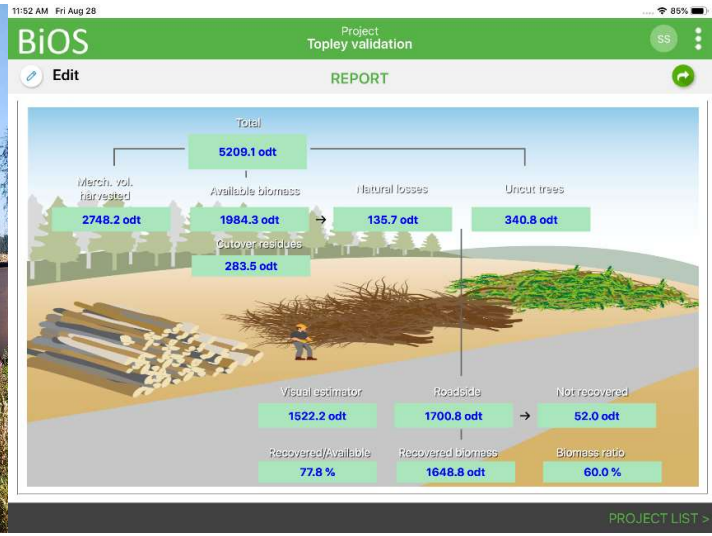


BIOS APP VALIDATION SUMMARY

October 26th, 2020

Stu Spencer, Senior Researcher, Forest Feedstocks

Sylvain Volpe, Senior Researcher, Forest Feedstocks

FPInnovations

FPINNOVATIONS

AGENDA

- Background
- What is BiOS and why is it needed?
- How will BiOS be utilized?
- BiOS App walkthrough
- Validation results
- Next steps
- Pile measurements

FPINNOVATIONS

BACKGROUND

- The BiOS mobile application project is a key part of a larger initiative within the Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD) aiming to develop a Forest Residual Biomass Geographic Information System for the development of the British Columbia forest bioeconomy (Forest BioGIS).
- Development began in 2017 and has included many updates throughout the development process. See Appendix I at the end of the presentation for a comprehensive list of upgrades.

BiOS App – What is it and why is it needed?

What is it?

- BiOS is an App designed to calculate available biomass volume and secondary harvest costs after completion of the primary harvest within a single cutblock.
- It is designed to show GHG benefits of biomass recovery and measure viable options (pathways) for disposal of residue piles.
- BiOS is currently in the beta stage of development.

BiOS App – What is it and why is it needed?

Why is it needed?

- Harvest of merchantable roundwood generates logging residues to the amount of ~10 million oven-dry tonnes (odt) per year (assuming .15 odt/m^3)
- It is estimated that in 2015, 2.5M odt of forest fibre was piled and burned in BC. Need to mitigate particulate matter and GHG emissions from existing slash burning operations.
- BC has committed to reducing greenhouse gas emissions to 80% below 2007 levels by 2050.

BiOS App – What is it and why is it needed?

Why is it needed?

- Improve TSA-level estimates by providing a tool to foresters to better assess the amount of logging residues and to measure the supply chain cost and carbon footprint.
- Provide data to industry which will help to improve biomass utilization and support the bio-economy.

How will FLNRORD use BiOS?

Forest BioGIS update

BiOS app data will allow updating each individual grouping of pixels on the ArcGIS Online map

An open maps viewer published by FLNRORD through an easily accessible web portal will allow biomass ventures to quickly assess the biomass potential surrounding a particular community, along with the supply cost and carbon footprint

Link to access Portal:
https://governmentofbc.maps.arcgis.com/home/index.html

B.C.'s Map Hub

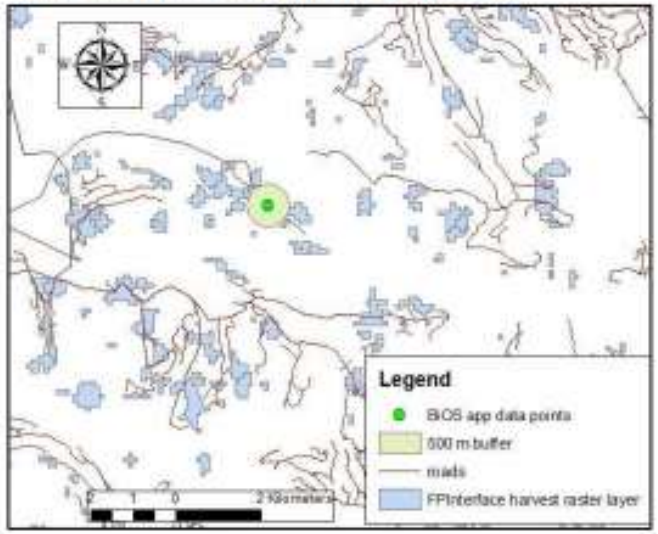
Layer name: BiomassUtilizationData :
https://governmentofbc.maps.arcgis.com/home/item.html?id=2664220793f14ffea0aa166945a86c58#overview

How will FLNRORD BiOS?

Forest BioGIS update

BiOS app data will allow updating each individual grouping of pixels on the ArcGIS Online map

- A specific ArcGIS Online (AGOL) server application will be required to update the attributes of the base layer
  - VRI
  - FPInterface original biomass estimates at the harvest raster level (pixels)
  - BiOS app data
- This AGOL programming should be completed by the owner/administrator of the site

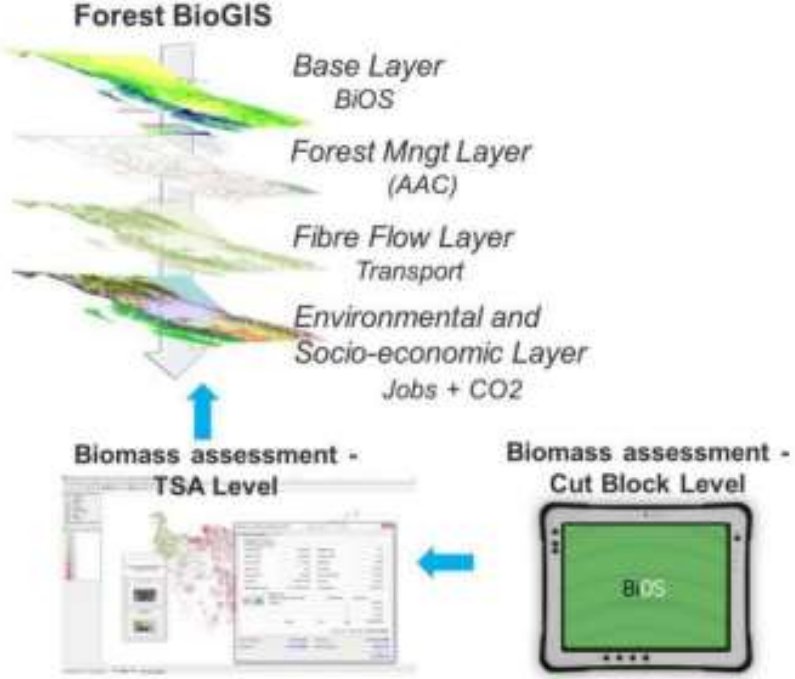


How will FLNRORD use BiOS?

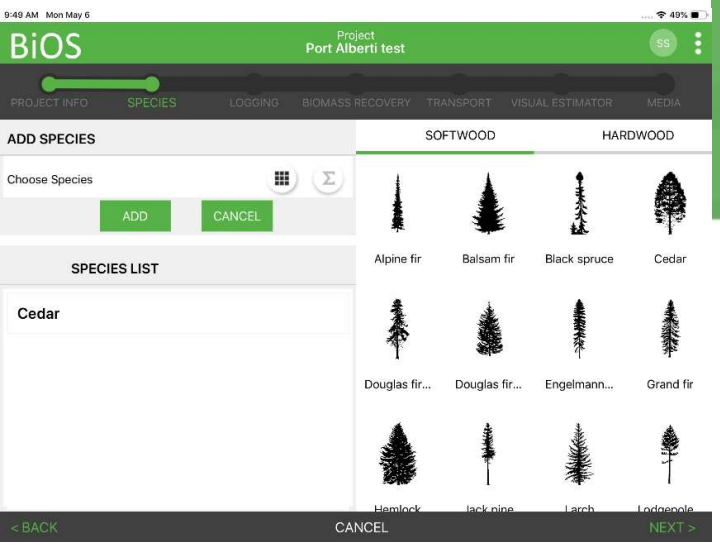
Forest BioGIS update

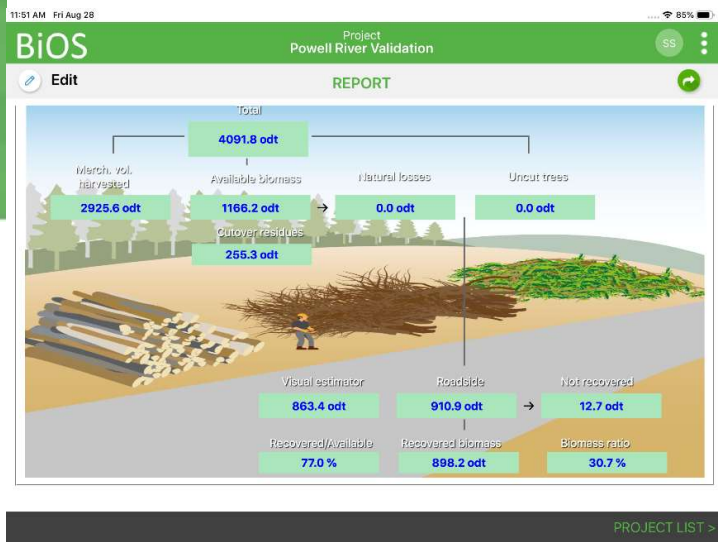
BiOS app data will allow updating each individual grouping of pixels on the ArcGIS Online map

FPI has a role to play with the administrator of the AGOL site to create this open maps viewer



BIOS WALKTHROUGH

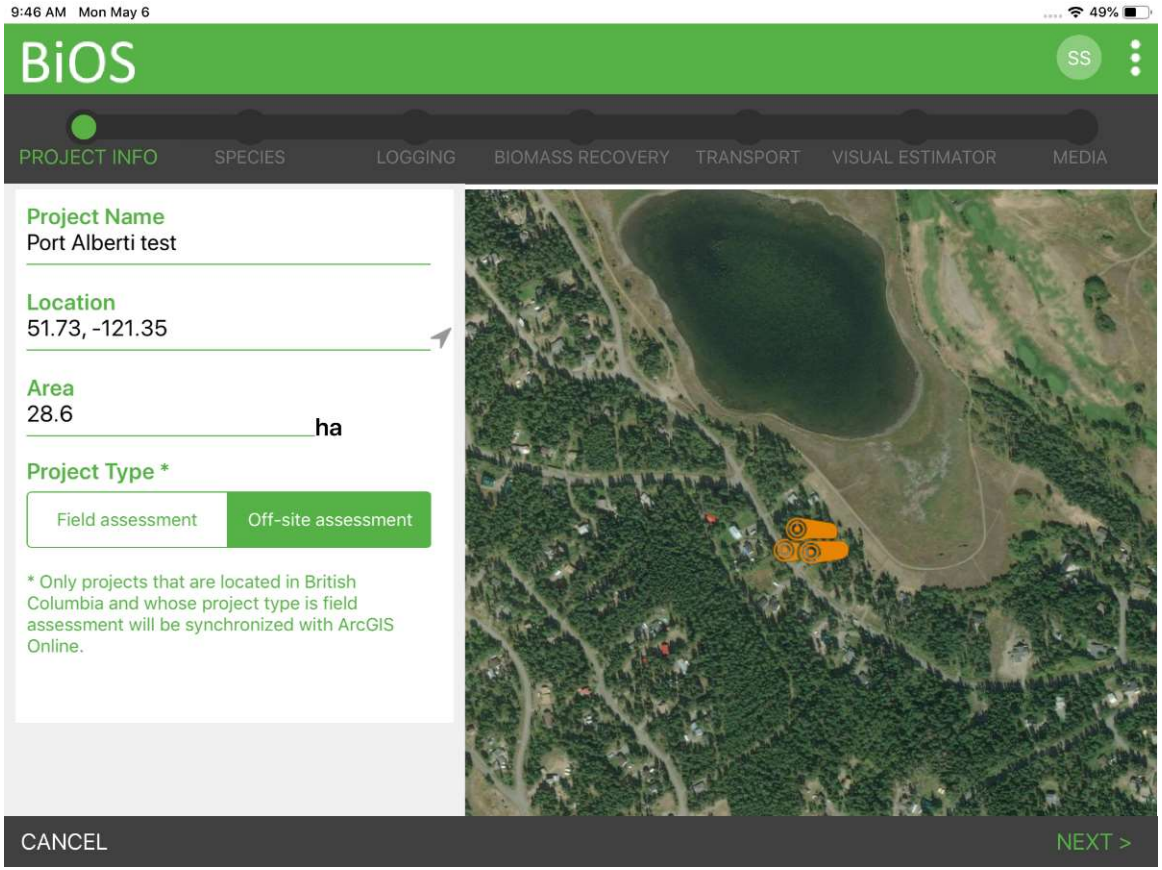




BiOS App Walkthrough

Project Info Page

Step 1 – A project name is entered. BiOS will determine the coordinates automatically if the assessment is completed in the field or coordinates can be entered manually (new feature).
Step 2 – Enter the area for the cutblock
Step 3 – Pick option ‘Field assessment’ or ‘Off-site assessment’.

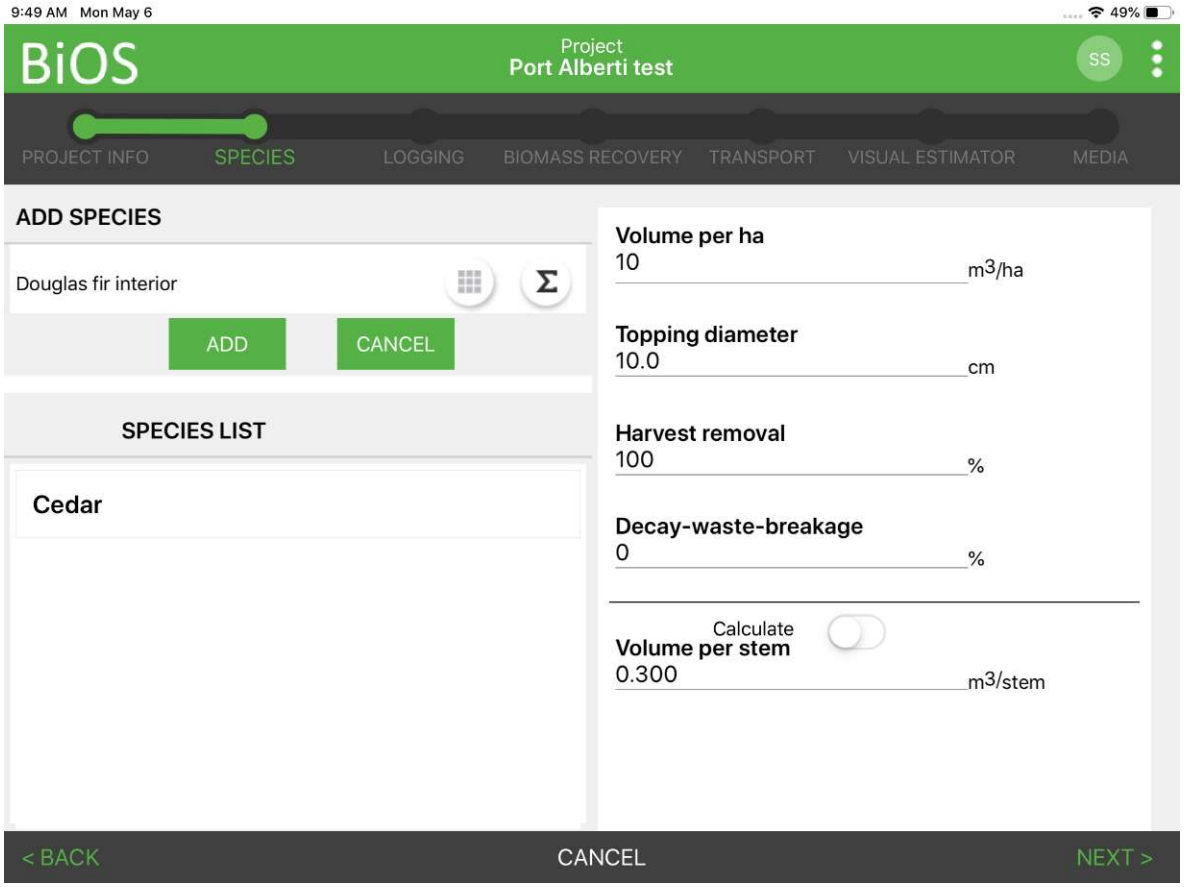


BiOS App Walkthrough

Species Page

Step 1 – Add a species from the species list.
Step 2 – Enter from cruise data:

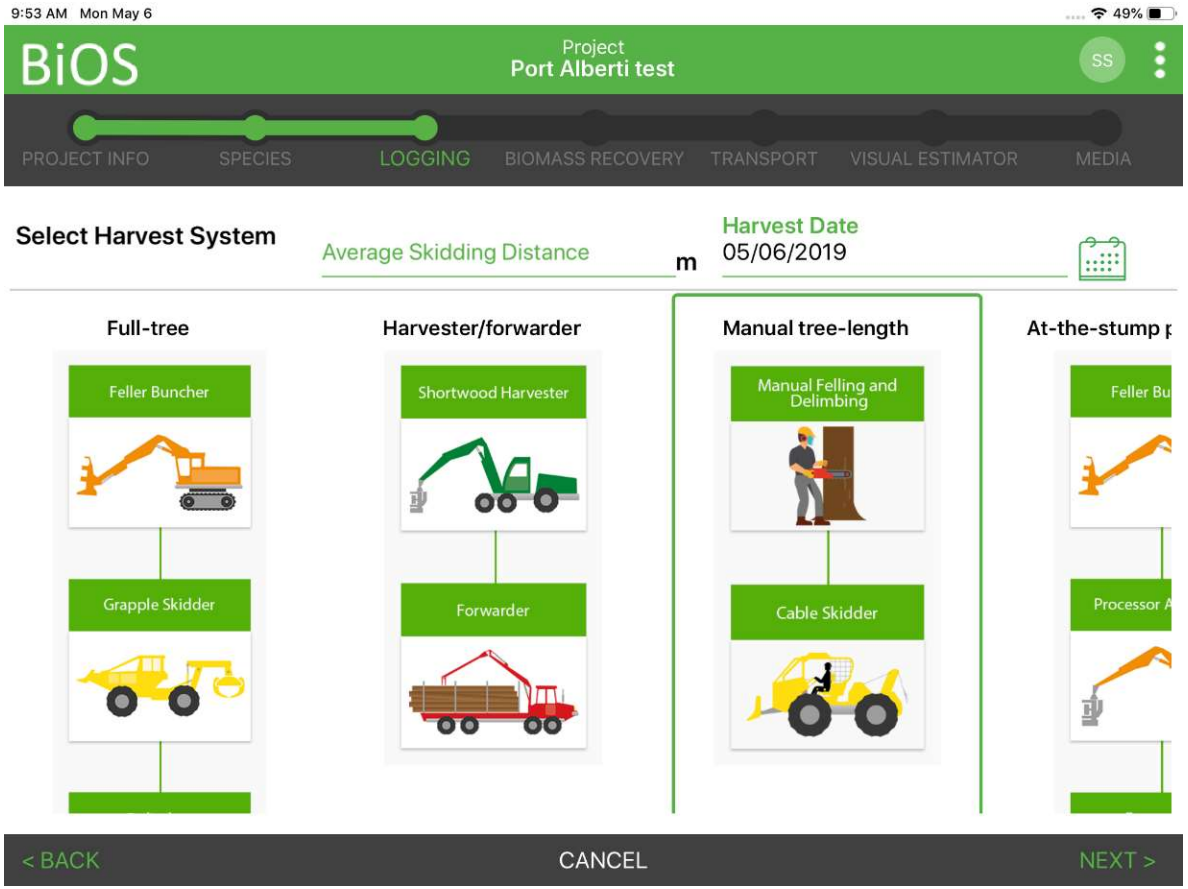
- Volume per ha
- Topping diameter
- Harvest removal %
- Decay-waste-breakage %
- Volume per stem



BiOS App Walkthrough

Logging Page

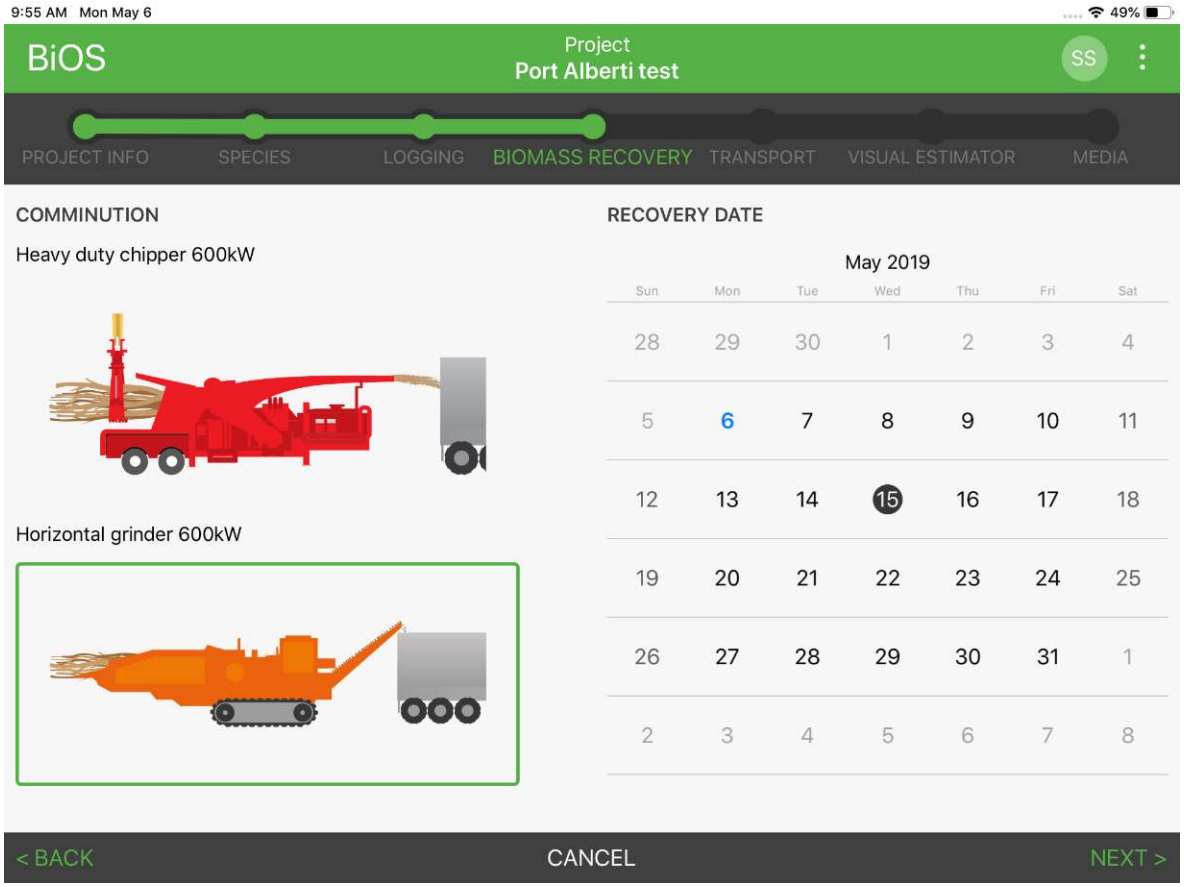
Step 1 – Choose the primary harvest method (7 methods to choose from but only conventional ground based at this time).
Step 2 – Choose an average ‘skidding distance’.
Step 3 – Enter the harvest date.



BiOS App Walkthrough

Biomass Recovery Page

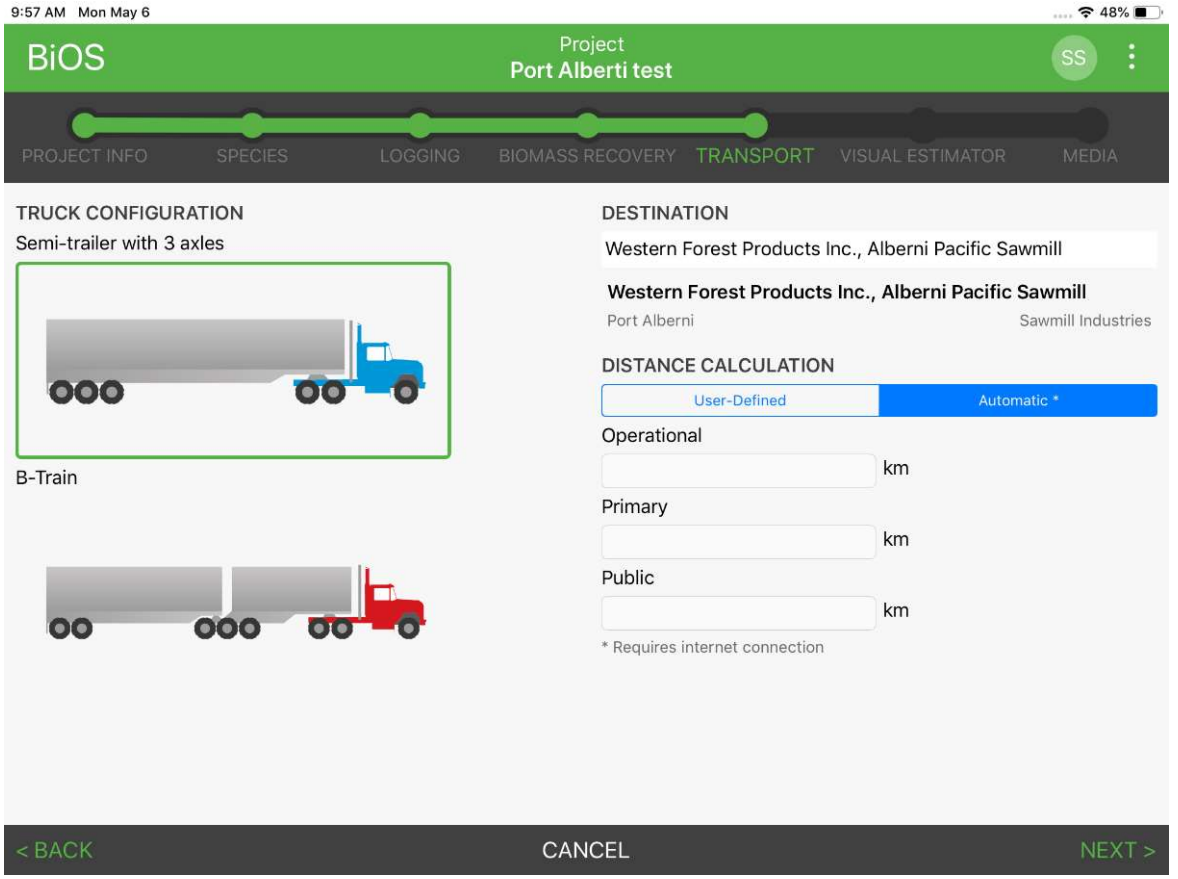
Step 1 – Choose a secondary harvest method. (Chipping and grinding currently, unprocessed collection in development).
Step 2 – Enter a secondary harvest date.



BiOS App Walkthrough

Transport Page

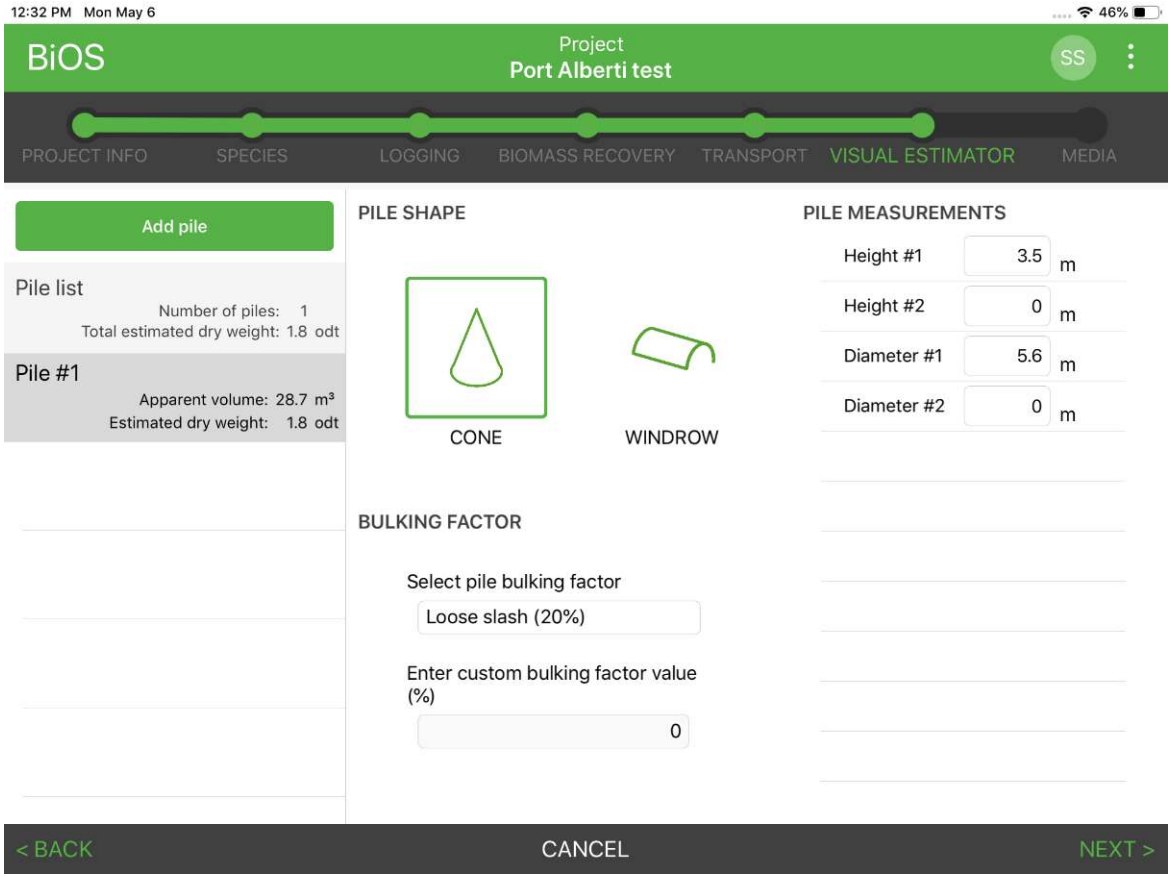
Step 1 – Choose a truck configuration (new bin truck option coming soon).
Step 2 – Enter a destination. If delivery point is not available in list, enter distance into cycle time calculator manually.



BiOS App Walkthrough

Visual Estimator Page

Step 1 – Add a pile.
Step 2 – Pick a pile shape, a bulking factor and enter the pile dimensions. (a function where the GPS footprint can be downloaded is in development).



BIOS OUTPUTS

BiOS App Walkthrough

BiOS App Reporting

The report page provides a summary of biomass recovery information

Biomass recovery

Area	28.6 ha
Recovered biomass	30.4 odt
Average moisture content	45.0 %
Biomass yield	1.1 odt/ha
Biomass (odt)/Merchantable (m^3)	0.084 odt/m^3
Low heating value	10.0 MJ/kg
Fuel consumption	9.4 L/odt
GHG emissions (CO2eq)	0.8 tonnes

BiOS App Walkthrough

BiOS App Reporting

Biomass transportation and costing

Biomass transport

Distance to Western Forest Products Inc., Alberni Pacific Sawmill by road category	**630.2 km**
Operational (resource road)	63.0 km
Primary (resource road)	63.0 km
Public (paved)	504.1 km
Fuel Consumption	53.0 L/odt
GHG emissions (CO2eq)	4.4 tonnes

Biomass supply cost

Recovery (stump to roadside)	37.17 $/odt
Transport (roadside to mill)	7.54 $/odt
Total	44.71 $/odt

BiOS App Walkthrough

BiOS App Reporting

Carbon reporting by species

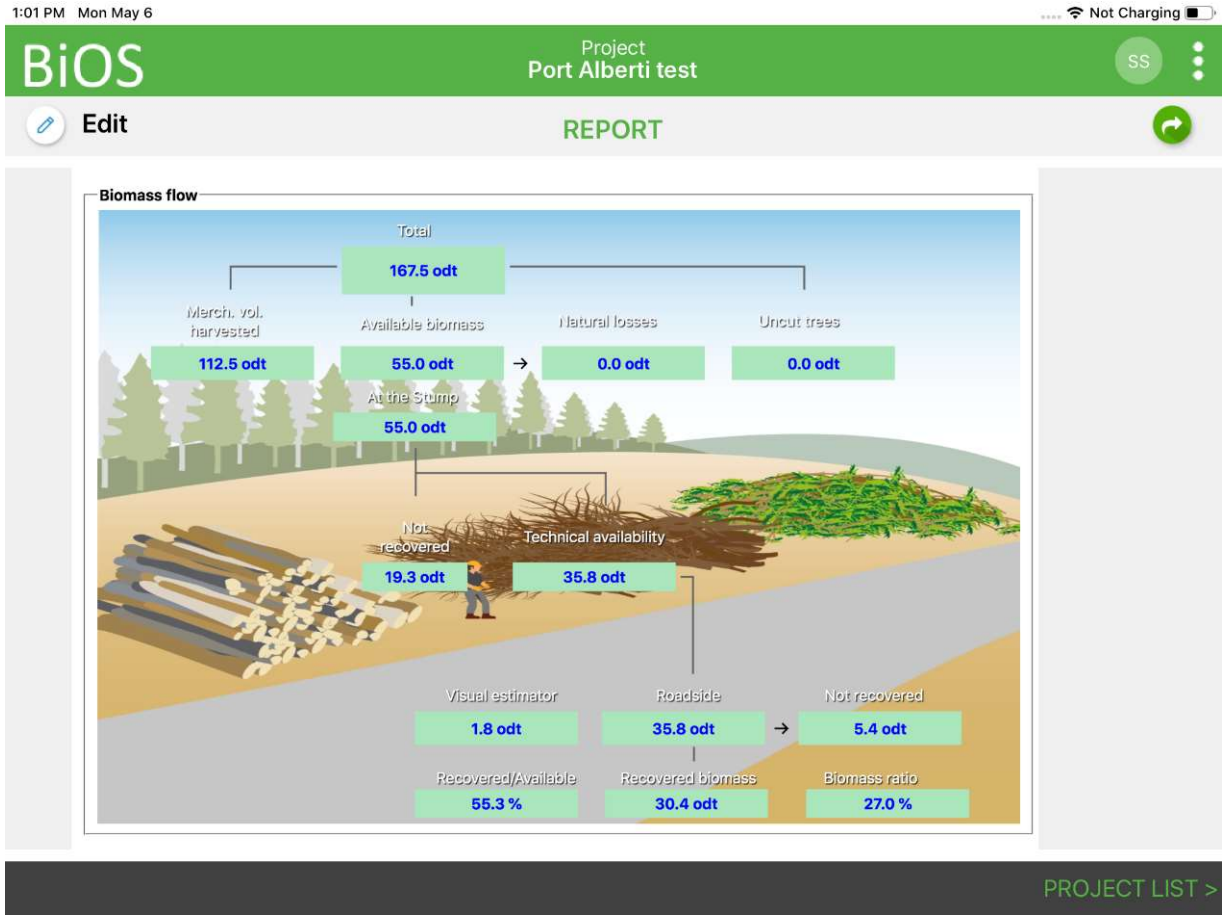
Species breakdown

Species	Carbon delivered (tonnes)	Avoided GHG (tonnes CO2eq)	odt	odt/m³	odt/ha
White spruce	188.3	613.7	376.5	0.1740	33.03
Black cottonwood	0.0	0.0	0.0	0.0000	0.00
Trembling aspen	0.0	0.0	0.0	0.0000	0.00
White birch	0.0	0.0	0.0	0.0000	0.00
	188.3	613.7	376.5	0.1740	33.03
Carbon ratio (delivered:emitted)	34:1				

BiOS App Walkthrough

BiOS App Reporting

The biomass flow page shows a breakdown of how fibre from the cutblock is categorized



BiOS App Walkthrough

BiOS App Reporting

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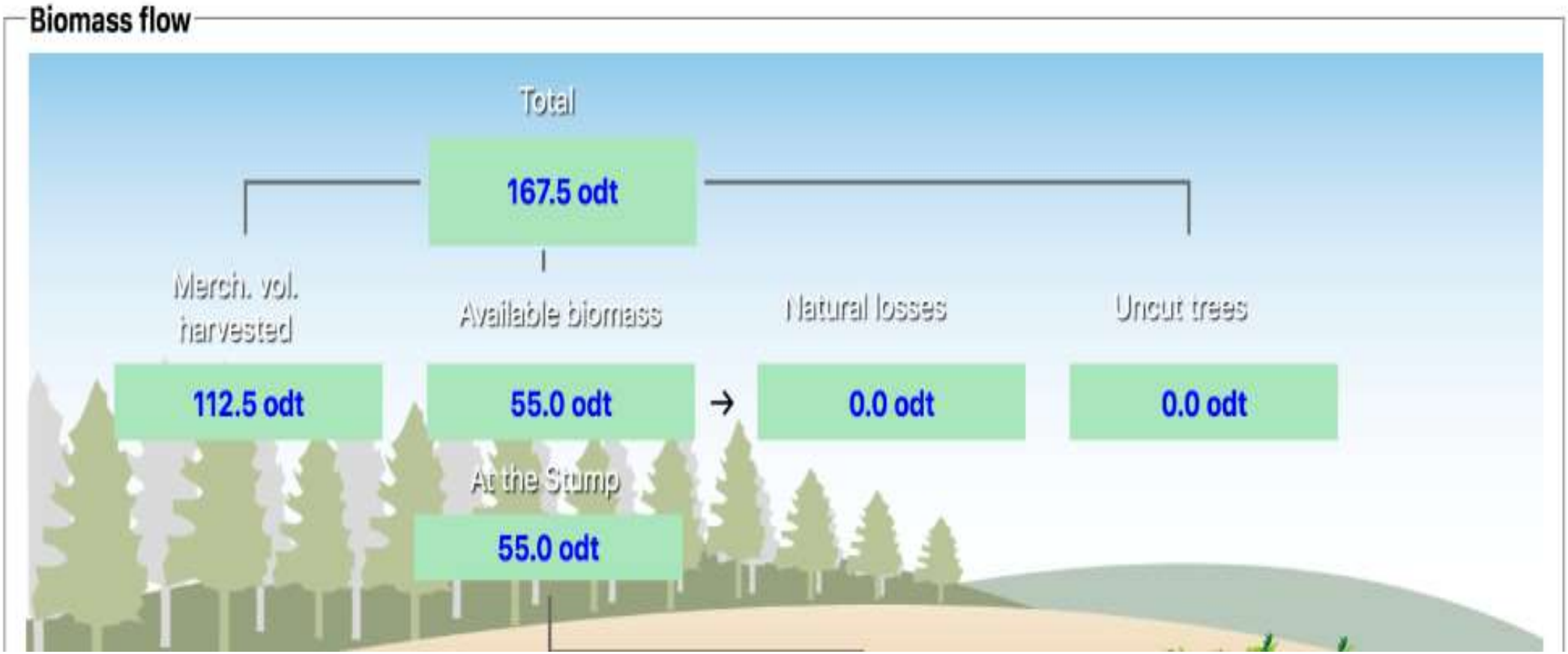

BiOS App Walkthrough

BiOS App Reporting

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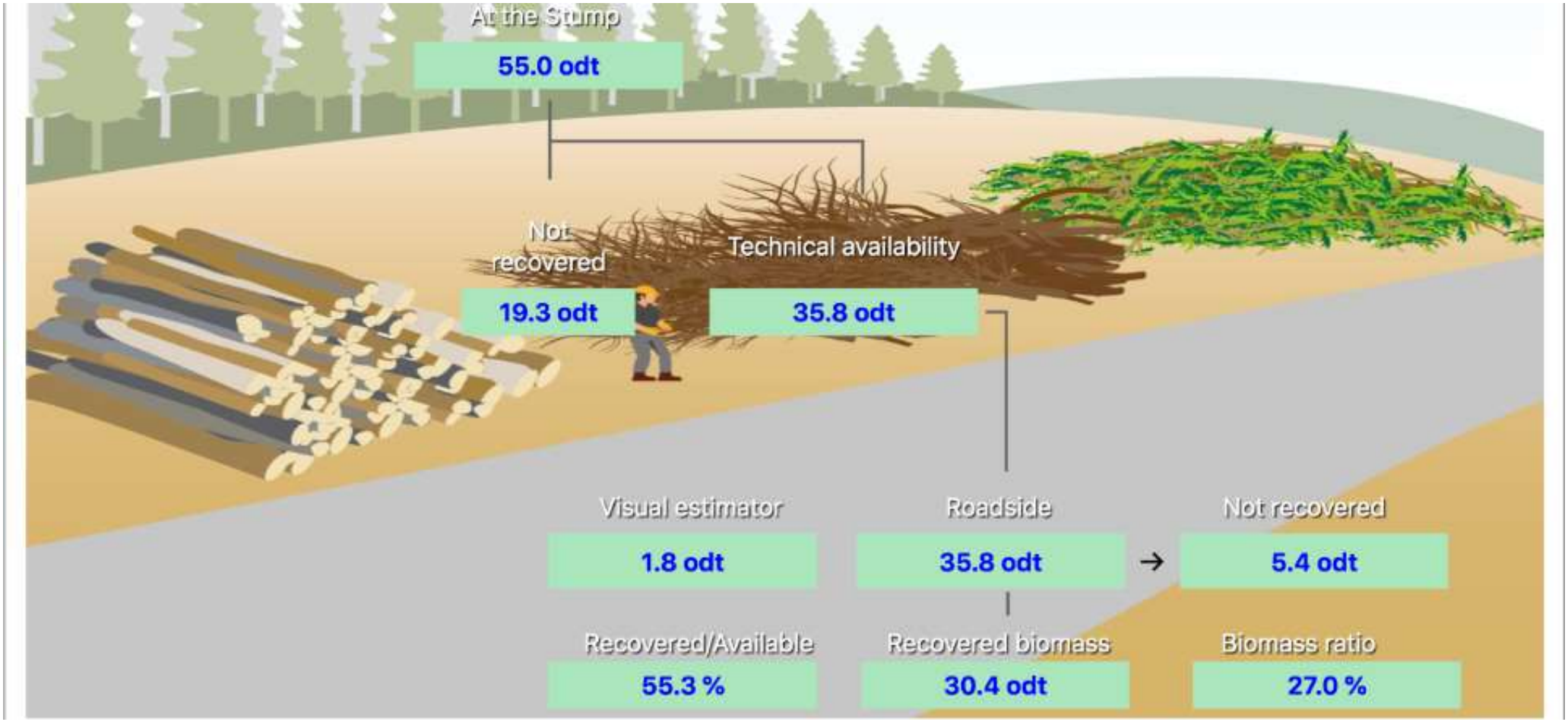


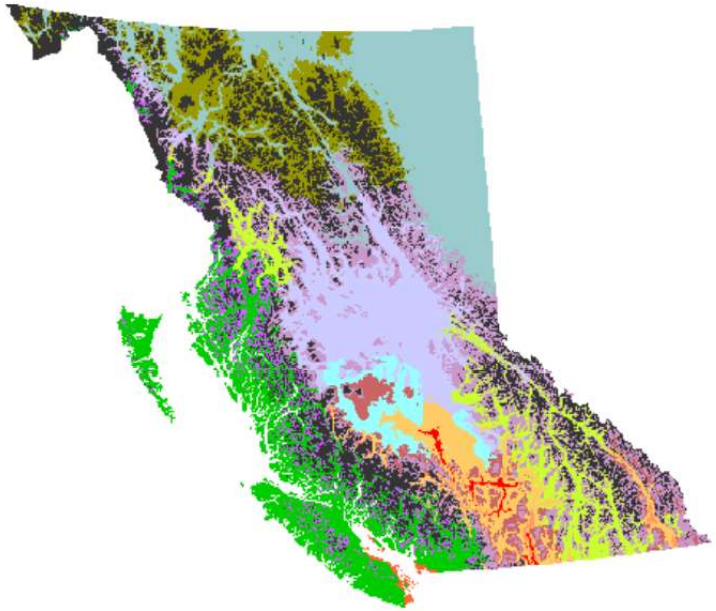
VALIDATIONS

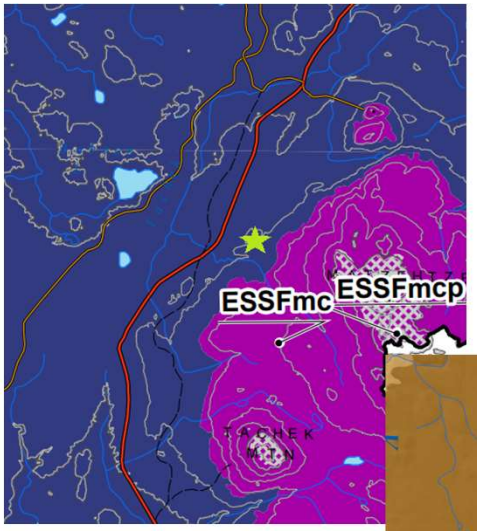
FPINNOVATIONS

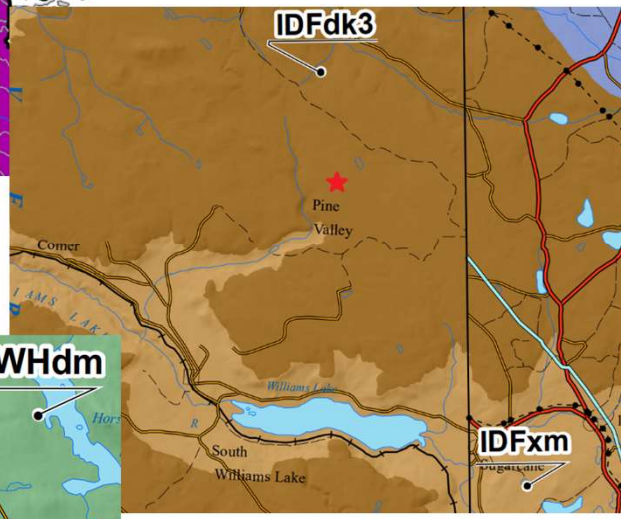
BIOS VALIDATIONS 2018-2020

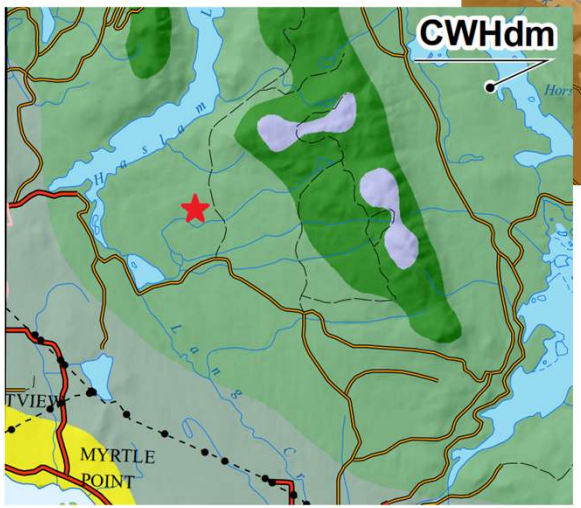
The BiOS App needs to be validated to make sure that the results expressed by the App reflect reality in a number of situations

Field trials in various biogeoclimatic zones under different conditions need to be validated





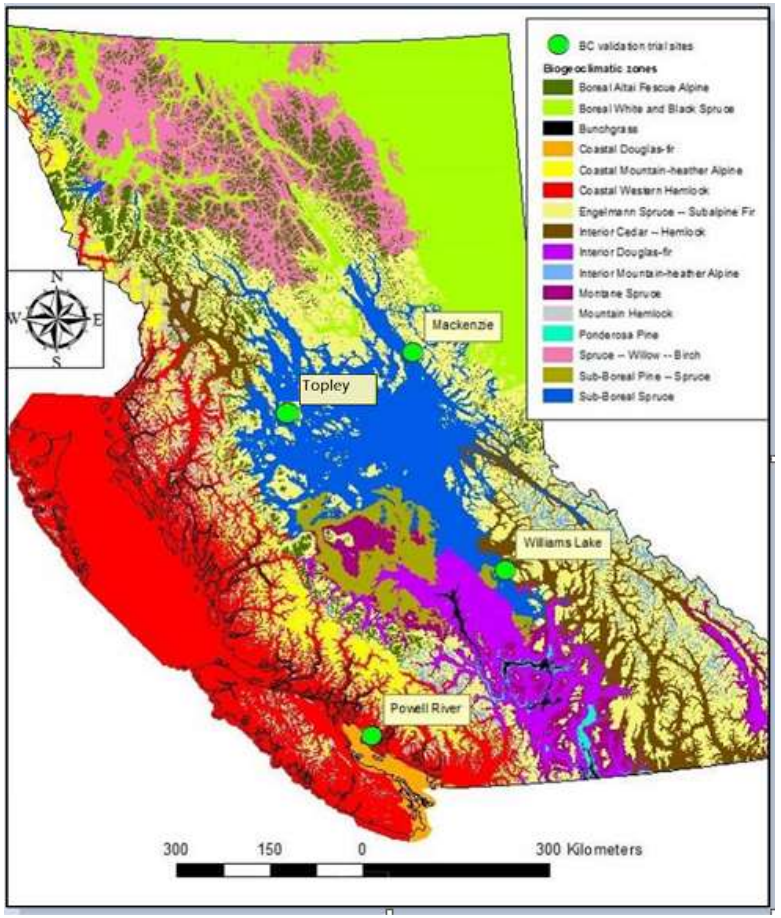




VALIDATION LOCATIONS

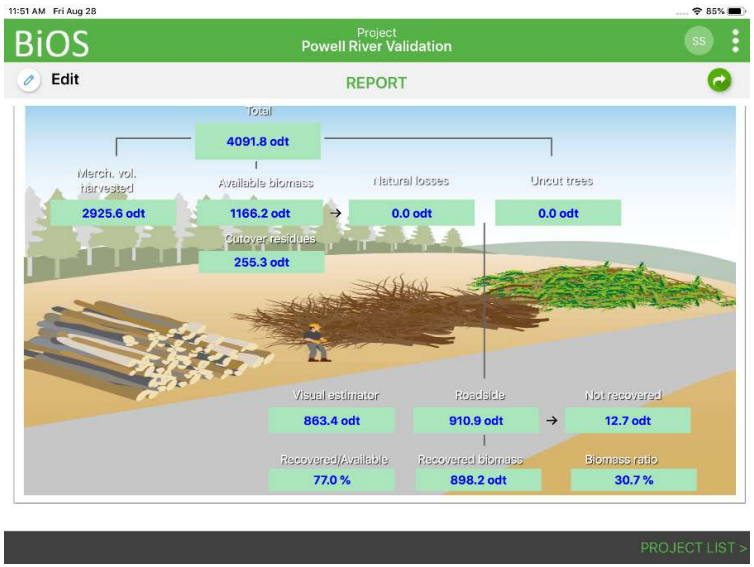
FOUR TO DATE:

- Mackenzie – February 2019
- Powell River – February 2020
- Topley (Burns Lake) – July 2020
- Williams Lake – August 2020



OBJECTIVES

- Determine efficacy of the BiOS App equations by comparing measured field results with BiOS outcomes (Primary)
- Compare pile measurement techniques (Secondary)
- Determine density in residue piles using different pile measurement tchniques (Secondary)



SITE DESCRIPTION AND SPECIES

Location	Biogeoclimatic zone	Subzone variant	Species
Mackenzie	Sub-Boreal Spruce (SBS)	mk2 - moist cool	Hybrid spruce (60%), trembling aspen, black cottonwood, birch
Powell River	Coastal Western Hemlock (CWH)	dm - dry maritime	Coastal Douglas-fir (77%), western hemlock, western red cedar
Topley	Sub-Boreal Spruce (SBS)	mc2 - moist cold	Lodgepole pine (84%), hybrid spruce, subalpine fir, trembling aspen, black cottonwood
Williams Lake	Interior Douglas-Fir (IDF)	dk3 - dry cool	Interior Douglas-fir (66%), hybrid spruce, lodgepole pine, trembling aspen

HARVEST SYSTEMS

Location	Primary Harvest Method	Secondary Harvest Method	Secondary Transportation	End User	Distance to End User
Mackenzie	feller buncher, skidder, roadside processing	Horizontal grinder	53ft walking floor trailers	Conifex Power - Mackenzie, BC	18.5 km
Powell River	feller buncher, in woods processing, hoe chuck to roadside	Horizontal grinder	tri drive with dual bin, 48ft chain drive trailer, 52ft chain drive trailer	Catalyst Pulp - Powell River, BC	53 km
Topley	feller buncher, skidder, roadside processing	Horizontal grinder	tri drive with 53ft walking floor, tandem drive with 53ft walking floor, 52ft chain drive trailer	Pinnacle Pellet - Burns Lake, BC	99 km
Williams Lake	feller buncher, skidder, roadside processing	Horizontal grinder	53ft walking floor trailers	Atlantic Power - Williams Lake, BC	17.6 km

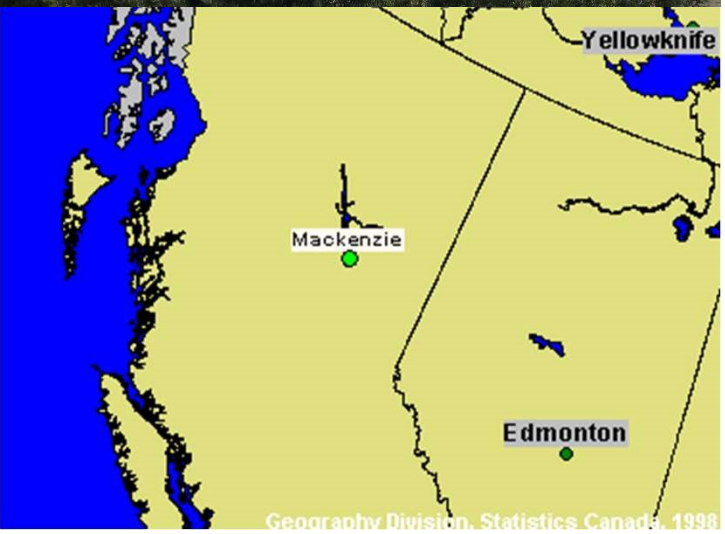
FIELD MEASUREMENTS

Measurements needed for BiOS validation

- *Standing residual volume* – If no volume was left standing within the cutblock, measurements were not made. If 100% of a species was left standing, cruise data was used.
- *Dispersed volume* – Line transect surveys were performed to quantify volume in the dispersed cutblock area. A description of the line transect methodology can be found in the validation reports.
- *Volume remaining in footprint after secondary harvest* – After each pile was harvested a line transect survey was performed within the footprint. A description of the line transect methodology can be found in the validation reports.
- *Topping diameter* – Companies rarely cut to the merchantable topping diameter of 10cm. Therefore the 'actual' topping diameter needs to be measured for entry in BiOS.
- *Secondary harvest volume* – Load slips are collected and tabulated. Moisture content is assessed at the delivery point or samples are collected at the time of harvest. Point of origin (pile number) is recorded for each load.

Measurements needed for pile measurement

- To be explained later in the presentation after the BiOS validations breakdowns.



RESULTS COMPARISON - MACKENZIE

Challenges:

- Late start for validation field work created challenges with snow cover.
- Proximity to Mackenzie airport led to a late cutblock location change (UAV's cannot fly within a certain distance to airports and built up areas).
- A portion of the aspen and cottonwood trees were cut and left in the dispersed area and beside the road. During the trial, some were ground up and others left, making it challenging to quantify volumes for the different fibre categories.

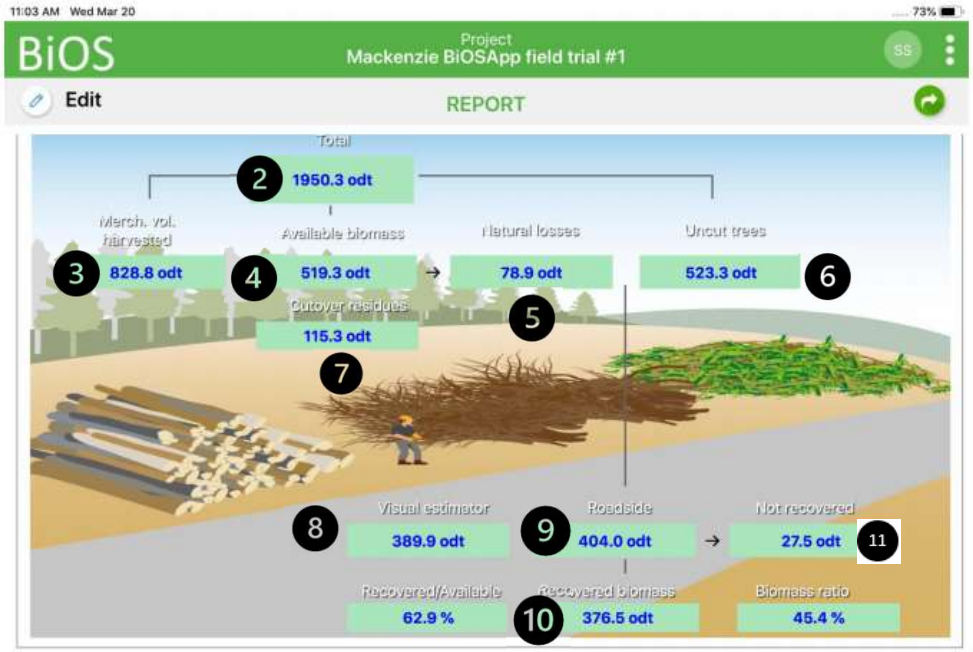
Unique Features:

- First validation – it was all unique in terms of BiOS validation.
- Looking back, was the only validation completed in the snow.

RESULTS COMPARISON - MACKENZIE

Line	Field	BiOS Values	Actual Results	Difference between BiOS and Actual
1	Topping Diameter (cm)	14.7	10.0 (cruise)	n/a
2	Total Fibre (odt)	1950.0	2052.7	-5%
3	Merchantable Volume Harvested (odt)	828.8	780.9	6%
4	Available Biomass (odt)	519.3	518.5	0%
5	Natural Losses (odt)	78.9	78.9	not assessed
6	Uncut Trees (odt)	523.3	674.4	-29%
7	Cutover Residues (odt)	115.3	115.3	not assessed
8	Visual Estimator (odt)	389.9	403.2	-3%
9	Roadside (odt)	404.0	403.2	0%
10	Recovered Biomass (odt)	376.5	377.0	0%
11	Not recovered (odt)	27.5	26.3	4%

Line 9 = Line 10 + Line 11
Line 4 = Line 5 + Line 6 + Line 7 + Line 8
Line 2 = Line 3 + Line 4



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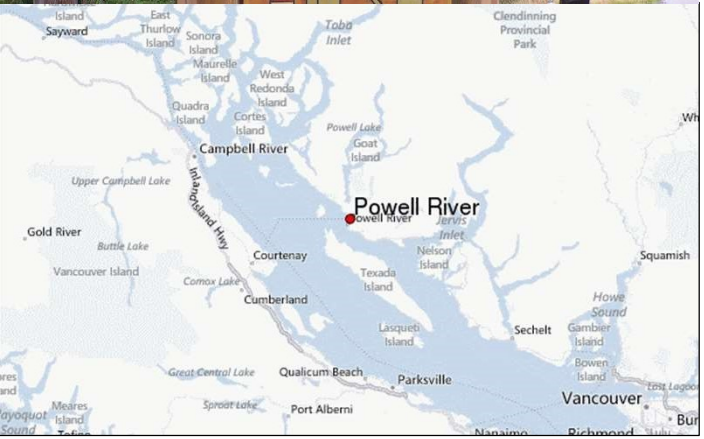
- Line 11 – Volume left within the pile footprint after secondary harvest. Estimation within 4% is very acceptable.
- Line 9 – Recovered biomass estimates were very close (<1% difference) to the actual results! At the time, we were very excited about this but needed to temper our enthusiasm with the understanding that this was one data point. Therefore, more validations.

- Line 8 - The visual estimator's prediction was 3% different from the actual volume in the piles at roadside. This is considered an acceptable variance.
- Line 7 – Cutover residues were not measured due to snow cover at the time of validation.
- Line 6 – There was significant difference between the BiOS estimate for standing trees and the actual measurement. This was due to the difficulty in measuring the standing trees and those cut and left under the snow, at the time of validation (>3ft snow).
- Line 5 – Natural losses not measured (measuring leaves and needles that have fallen off branches is virtually impossible).
- Line 4 – Available biomass estimate (addition of Lines 5,6,7 and 9) was <1% different from the measured result and is very acceptable in terms of accuracy.
- Line 3 – Merchantable volume prediction was within 6%. This is within acceptable standards.
- Line 2 – Total fibre was within 5%. This is within acceptable standards.

RESULTS COMPARISON – POWELL RIVER



Challenges:

- No permanent scale available to measure load weights, so portable scales were used. Portable scales less precise.
- Community forests are not required to timber cruise which meant that we had to cruise the adjacent stands to provide input data.

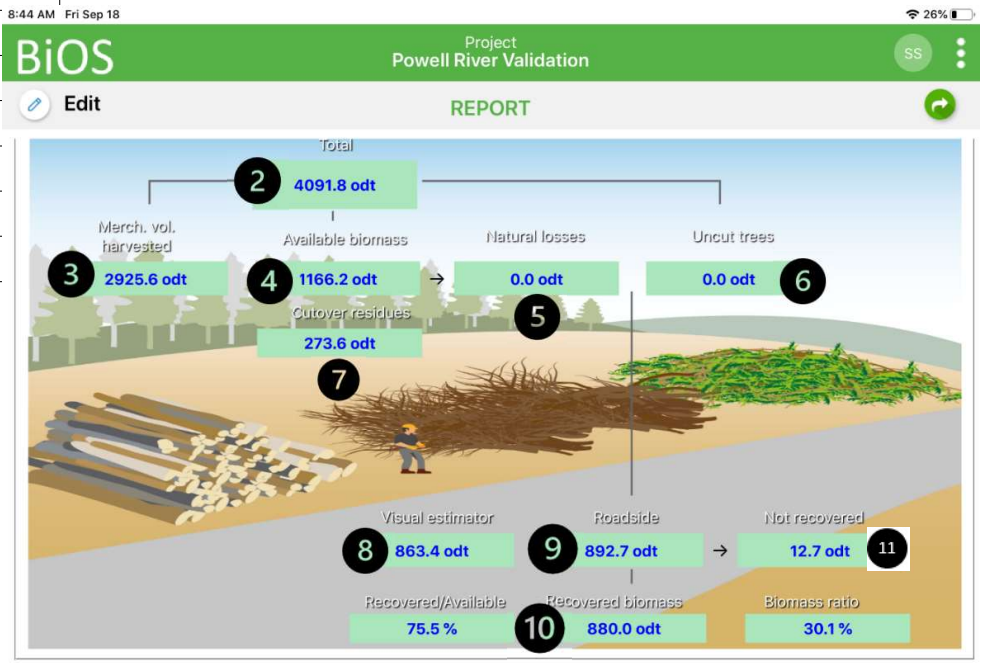
Unique Features:

- First coastal validation.
- Stems were processed in the dispersed area and residue was piled at the stump, then later moved to roadside and re-piled into larger piles.

RESULTS COMPARISON – POWELL RIVER

Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
1	Topping diameter (cm)	16.0	16.0	n/a
2	Total fibre (odt)[a]	4091.8	4164.6	-1.7%
3	Merchantable volume harvested (odt)	2925.6	2928.9	-0.1%
4	Available biomass (odt)	1166.2	1235.7	-5.6%
5	Natural losses (odt)	0	0	n/a
6	Uncut trees (odt)	0	0	n/a
7	Cutover residues (odt)	273.6	242.9	12.6%
8	Visual estimator (odt)	863.4	992.8	-13.0%
9	Roadside (odt)	892.7	992.8	-10.1%
10	Recovered biomass (odt)	880.0	985.4	-10.7%
11	Not recovered (odt)	12.7	7.4	71.6%

Line 9 = Line 10 + Line 11
Line 4 = Line 5 + Line 6 + Line 7 + Line 8
Line 2 = Line 3 + Line 4



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11	Not recovered (odt)	12.7	7.4	71.6%

- Line 11 – 72% difference looks huge! But simply means secondary harvester collected more volume from the pile than the default value forecasted. Can be adjusted for a specific harvester if consistently found to be inaccurate.
- Line 9 – 10.7% difference between BiOS and measured results. More volume was collected than forecasted. Sources of error are possible from the portable scales, or possibly from the firewood that was collected before researchers arrived (firewood was estimated by load).

- Line 8 - The visual estimator's prediction was 13% different from the actual volume in the piles at roadside. This is likely a function of the bulking factor choices available by BiOS (e.g. default 50% was chosen for these piles but could have been 43% in actuality). Users can refine bulking factor for their specific situations over time to improve accuracy.
- Line 7 – The cutover residue value was 12.6% higher than the measured result. However, the recovered volume was higher than predicted, so it is possible that more volume was brought to roadside, especially with the double piling that occurred on this site.
- Line 5 and Line 6 – Residues were very fresh (1 month) so no natural loses. All trees were cut.
- Line 4 – Available biomass was 5.6% (addition of Lines 5,6,7 and 9) and should be considered acceptable in terms of accuracy.
- Line 3 – Merchantable volume prediction was within 0.1%. This is likely because measured topping diameter accuracy was high.
- Line 2 – Total fibre was within 1.7%. This is very acceptable!

RESULTS COMPARISON – TOPLEY

Challenges:

- Spring / early summer in 2020 was very wet! This meant that woodland operations were very delayed.
- Covid-19…enough said.

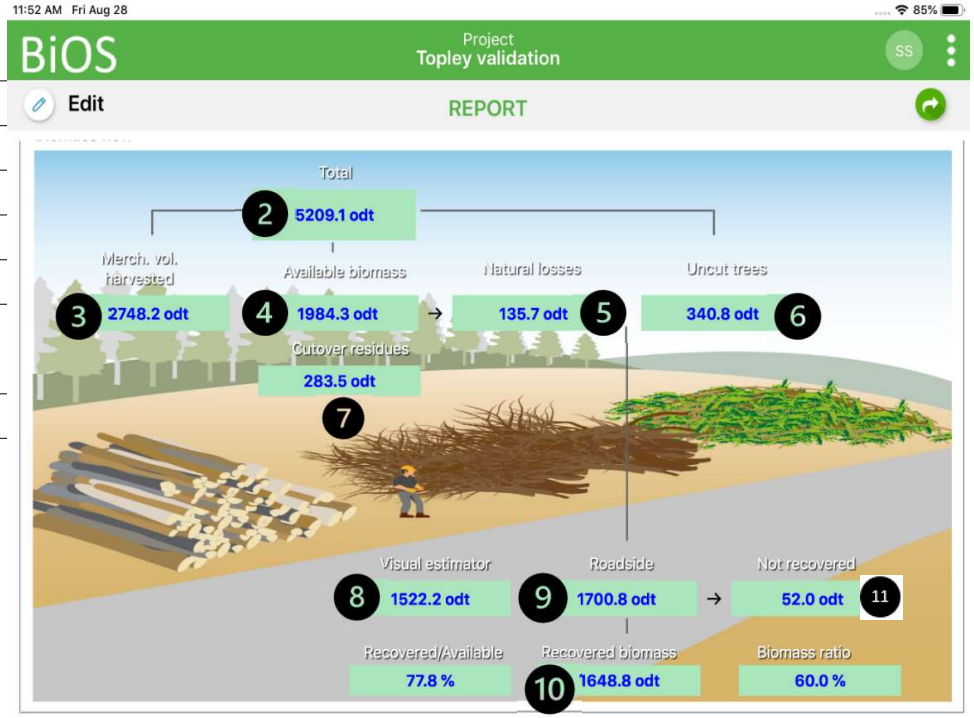
Unique Features:

- First validation cutblock with significant amounts of mountain pine beetle killed residue.

RESULTS COMPARISON – TOPLEY

Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
1	Topping diameter (cm)	(Pl 12.6, Sx 12.5, Bl 13.0)	(Pl 12.6, Sx 12.5, Bl 13.0)	n/a
2	Total fibre (odt)[a]	5209.1	5802.0	-10.2%
3	Merchantable volume harvested (odt)	2748.2	3292.7	-16.5%
4	Available biomass (odt)	1984.3	2032.8	-2.4%
5	Natural losses (odt)	135.7	135.7	n/a
6	Uncut trees (odt)	340.8	340.8	n/a
7	Cutover residues (odt)	283.5	292.4	-3.0%
8	Visual estimator (odt)	1522.2	1740.4	-12.5%
9	Roadside (odt)	1700.8	1740.4	-2.3%
10	Recovered biomass (odt)	1648.8	1707.1	-3.4%
11	Not recovered (odt)	52.0	33.3	56.2%

Line 9 = Line 10 + Line 11
Line 4 = Line 5 + Line 6 + Line 7 + Line 8
Line 2 = Line 3 + Line 4



Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
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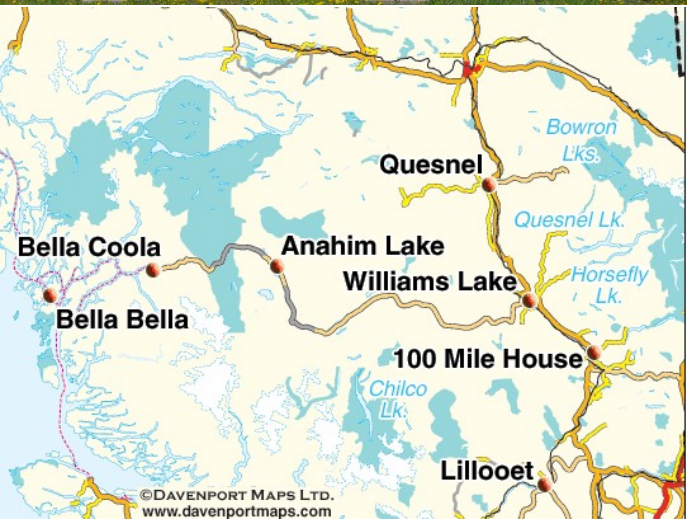
11	Not recovered (odt)	52.0	33.3	56.2%

- Line 11 – 56% looks like a large difference, but simply means secondary harvester collected more volume from the pile than the default value forecasted. Can be adjusted for a specific harvester if consistently found to be inaccurate.
- Line 9 – A 2.3% difference between BiOS and measured results is very acceptable in terms of accuracy.

RESULTS COMPARISON – TOPLEY

- Line 8 - The visual estimator's prediction was 12.5% different from the actual volume in the piles at roadside. This is likely a function of the bulking factor choices available by BiOS or simply the difference between perfect geometric shapes in BiOS and actual shapes found at roadside. Users can refine bulking factor for their specific situations over time to improve accuracy.
- Line 7 – The cutover residue value was 3.0% higher than the measured result but is well within acceptable accuracy parameters.
- Line 6 – All coniferous trees were cut, and all aspen trees were left standing. Timber cruise results were used to determine deciduous standing volume.
- Line 5 – Natural losses not measured (measuring leaves and needles that have fallen off branches is virtually impossible).
- Line 4 – Available biomass estimate (addition of Lines 5,6,7 and 9) was 2.4% different from the measured result and is very acceptable in terms of accuracy.
- Line 3 – Merchantable volume prediction was 16.5% different from the measured result. This is a result of the variance in the total fibre prediction (line 2).
- Line 2 – Total fibre prediction was within 10.2%. It is unclear what caused this discrepancy because all other fibre category, other than merchantable volume were correctly predicted.

RESULTS COMPARISON – WILLIAMS LAKE



Challenges:

- The cutblock was immediately adjacent to the Williams Lake airport which prevented the use of the UAV for pile measurement.
- Very wet spring created delays because of poor road conditions.

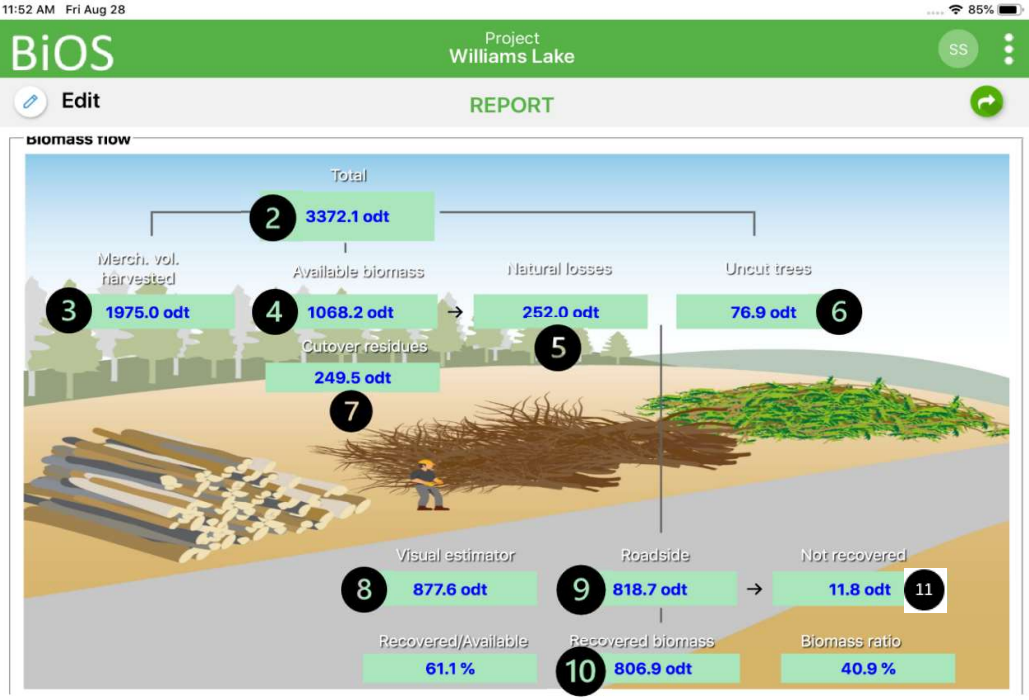
Unique Features:

- First validation in which the stand had been part of a massive wildfire (2017) prior to primary harvest. This changed the volumes in the dispersed areas of the cutblock.
- First validation cutblock in the interior Douglas-fir stand type.

RESULTS COMPARISON -WILLIAMS LAKE

Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
1	Topping diameter (cm)	12.1	12.1	n/a
2	Total fibre (odt)[a]	3372.1	3261.6	3.4%
3	Merchantable volume harvested (odt)	1975.0	2027.8	-2.6%
4	Available biomass (odt)	1068.2	904.9	18.0%
5	Natural losses (odt)	252.0	252.0	n/a
6	Uncut trees (odt)	76.9	76.9	n/a
7	Cutover residues (odt)	249.5	114.4	118.1%
8	Visual estimator (odt)	877.6	790.5	11.0%
9	Roadside (odt)	818.7	790.5	3.6%
10	Recovered biomass (odt)	806.9	778.7	3.6%
11	Not recovered (odt)	11.8	11.8	0.0%

Line 9 = Line 10 + Line 11
Line 4 = Line 5 + Line 6 + Line 7 + Line 8
Line 2 = Line 3 + Line 4



RESULTS COMPARISON – WILLIAMS LAKE

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10	Recovered biomass (odt)	806.9	778.7	3.6%
11	Not recovered (odt)	11.8	11.8	0.0%

- Line 11 – No difference between the BiOS estimate and actual results!
- Line 9 – There was a 3.6% difference between BiOS and measured results. This is acceptable in terms of accuracy.

- Line 8 - The visual estimator's prediction was 11% different from the actual volume in the piles at roadside. This is likely a function of the bulking factor choices available by BiOS or simply the difference between perfect geometric shapes in BiOS and actual shapes found at roadside. Users can refine bulking factor for their specific situations over time to improve accuracy.
- Line 7 – The cutover residue estimated value was 118.1% higher than the measured result! This is a direct result of the wildfire that burned most of the volume on the ground in the dispersed area.
- Line 6 – All coniferous trees were cut, and all aspen trees were left standing. Timber cruise results were used to determine deciduous standing volume.
- Line 5 – Natural losses not measured (measuring leaves and needles that have fallen off branches is virtually impossible).
- Line 4 –Available biomass estimate (addition of Lines 5,6,7 and 9) was 18.0% more than the measured result. This was due to the missing volume burned in the fire (ie if you add the missing 135 odt of cutover residue volume, the available biomass volumes are very close).
- Line 3 – Merchantable volume prediction was within 2.6%. This is well within acceptable standards.
- Line 2 – Total fibre estimate was within 3.4%. This is well within acceptable standards.

RESULTS COMPARISON – OVERALL ASSESSMENT

So what did all that mean?

First and foremost, the BiOS App is working well!

- For all three interior validations, the roadside biomass assessments were within 4% of the measured results. This is very good!
- The coastal validation roadside biomass assessment was within 10%. This is also ok, but a second validation in the CWH would help to identify whether the difference was caused by the allometric equations or the practices in the validation (portable scales and adjacent stand cruising).
- Although each of the trials had unique challenges (snow, re-piling, beetle wood, burned area), the BiOS assessments all came close for the roadside measurements. This speaks to the robustness of the model. However, future developments may need to include user data entry suggestions to allow for these unique challenges. For example, a fire salvage cutblock may automatically reduce the volume attributed to the 'cutover residues' category.
- In all of my work with the App so far IOS version, no software bugs were found, the app was very easy to use and move around in. Future updates will continue to focus on improved user interface.

DEVELOPMENT ROADMAP – 2020/2021 UPGRADES

2020 Developments

- Added ability to enter coordinates of cutblock manually
- Added Bin Truck configuration
- Added function that allows pile footprint shapefiles to be downloaded into the project file
- Allow edit function for chippers and grinders in the primary data entry stage
- Added an ‘oriented pile’ choice to pile shapes in the visual estimator

Past developments from 2017 to 2019 can be found at the end of this presentation (slides 57 to 59).

NEXT STEPS

1. Validations in new biogeoclimatic zones
    - Engelmann Spruce – Subalpine Fir
    - Interior Cedar Hemlock
2. Additional validations in large and diverse zones
    - Coastal Western Hemlock
    - Interior Douglas-fir

The challenge with targeting specific zones is the need to follow the grinders. If they are not working in a specific zone, we can be restricted from trial work. Also, planning can be difficult as most secondary harvesters do not know where they will be until just before they move to a specific cutblock.

NEXT STEPS

1. Continued upgrades to user interface and functionality
    - Ability to download UAV volume assessments for visual estimator?
    - Updates of productivity and costs
    - Development of video series, training series and/or instruction manual for BiOS users. Guide to include management techniques for unique site conditions.

NEXT STEPS

1. Connection to ministry systems to start validating and testing relations to biomass availability studies (Forest BiOGIS) and validation of EFI estimates.

PILE MEASUREMENTS – APPARENT VOLUME AND DENSITY

PRE-HARVEST PILE MEASUREMENT TECHNIQUES APPARENT VOLUME

1. Stringbox measurement
   - Length, width measured with stringbox to build footprint
   - Height measured and shape factor assigned
2. GPS footprint measurement
   - GPS tracking feature used to measure footprint area
   - Height measured and shape factor assigned
3. UAV point cloud measurement
   - UAV flown over all piles in the cutblock
   - Software used to determine apparent volume in the pile
4. BiOS Visual estimator
   - Similar to stringbox method.
   - Length, width and height of the pile are entered into the app
   - Volume is calculated based on the two available shapes

PILE MEASUREMENT TECHNIQUES
PILE DENSITY

- To determine pile density, fibre volume (oven dry kilograms) is divided by apparent volume of the pile (geometric volume, m^3).
- The pile's apparent volume is measured using the techniques described in the previous slide.
- Fibre volume is measured from the loads delivered when harvesting the pile. A moisture content analysis is completed to determine the oven dry weight of each load.

PRE-HARVEST PILE MEASUREMENT MACKENZIE

- 4 methods used to measure apparent volume of piles
- Mackenzie had a mix of windrows, haystacks and oriented piles
- Overall variance can be found between the pile measurement methodologies
- This is a function of the pile shapes and the techniques
  - Stringbox and GPS methods had similar aggregate apparent volumes
  - The UAV method predictably had a lower apparent volume because all outside airspace is removed
  - The BiOS visual estimator had a higher apparent volume. Likely due to the need to use the haystack and windrow shapes for oriented piles
  - Full analysis can be found in the report

Apparent volume (m^3) and density ($odkg/m^3$) for four measurement methods – Mackenzie				
	Stringbox method	GPS footprint method	UAV point cloud method	BiOS Visual Estimator
Apparent Volume (m^3)	5018	5216	3657	6184
Density ($odkg/m^3$)	69.7	67.0	95.6	56.5

PRE-HARVEST PILE MEASUREMENT POWELL RIVER

- 4 methods used to measure apparent volume of piles
- All piles were haystack pile shape
- Overall variance can be found between the pile measurement methodologies
- This is a function of the pile shapes and the techniques
  - Stringbox method and visual estimator aggregate volume assume a circular footprint but piles were more oblong, reducing the aggregate apparent volume for these methods
- Full analysis can be found in the report

Apparent volumes (m^3) and density (odkg/m^3)of four residue measurement methods – Powell River				
	Stringbox method	GPS footprint method	UAV point cloud method	BiOS Visual Estimator
Apparent volume (m^3)	2264.4	2901.6	3064.1	1898.2
Density	146.8	120.3	114.7	175.6

PRE-HARVEST PILE MEASUREMENT TOPLEY

- 4 methods used to measure apparent volume of piles
- Pile type: 100% windrow
- Overall variance can be found between the pile measurement methodologies
- This is a function of the pile shapes and the techniques
  - Topley had long windrows, which made measuring width with a stringbox difficult
  - The UAV method predictably had a lower apparent volume because all outside airspace is removed
- Full analysis can be found in the report

Apparent volumes (m^3) and density (odkg/m^3) of residue pile measurement methods – Topley				
	Stringbox method	GPS footprint method	UAV point cloud method	BiOS Visual Estimator
Apparent volume (m^3)	17025.7	18449.1	16162.3	18819.1
Density (m^3)	96.3	89.6	113.1	87.1

PRE-HARVEST PILE MEASUREMENT WILLIAMS LAKE

- 3 methods used to measure apparent volume of piles
- UAV method could not be used due to airport proximity
- Williams Lake had small windrows
- Overall variance can be found between the pile measurement methodologies
- This is a function of the pile shapes and the techniques
  - Stringbox aggregate apparent volume was less than the other two methods. This was likely due to the inconsistent widths of the windrows
- Full analysis can be found in the report

Apparent volumes (m^3) and density (odkg/m^3) of three residue measurement methods – Williams Lake			
	Stringbox method	GPS footprint method	BiOS Visual Estimator
Apparent volume (m^3)	9233.8	10644.8	10206.5
Density (odkg/m3)	86.0	70.0	78.0

PRE-HARVEST PILE MEASUREMENT TECHNIQUES APPARENT VOLUME

Summary

- There are a number of factors which create variance in measuring apparent volume of piles.
  - Piles can be difficult to physically measure across the width of the pile (safety)
  - If the width varies significantly along the length of the pile, widths can be skewed
  - Pile shape equations assume consistent shapes (footprint or side of piles), this is rarely the case in real life
- The method of measurement should be included in pile measurement results to increase consistency (ie apples are compared to apples).

PILE DENSITY

Summary

- For pile density assessments there even more factors than apparent volume measurements which create variance in the bulking factor of piles.
  - Piles can be difficult to physically measure across the width of the pile (safety)
  - If the width varies significantly along the length of the pile, widths can be skewed
  - Pile shape equations assume consistent shapes (footprint or side of piles), this is rarely the case in real life
  - Species (some are denser than others)
  - Merchantability specifications (affect the size of pieces within the pile)
  - Consistency of piling method (e.g. neatness of oriented piling affects airspace)
- The method of measurement for apparent volume should be included in pile density results to improve consistency (ie apples are compared to apples).
- Pile density is exceedingly hard to predict and would require very large samples sizes to model effectively.

APPENDIX I – DEVELOPMENT ROADMAP

Start up

Original development plan approved August 8th, 2018

- Add user registration certification
  - Use App analytics to populate user database
- Add Project type requests
- BC project synchro only
- Parameter updates
  - Carbon content set at 50% to be consistent with other FLNRORD estimates
  - Calorific value set to low heating value
  - Default topping diameter (cm) set at 10 cm
- Roadside pile volume estimator

User experience

Workshop improvements

APPENDIX I – DEVELOPMENT ROADMAP

Start up

User experience

User Interface (UI) and User Experience (UX) design improvements

Workshop improvements

- User Interface (UI) design improvements
  - Improved navigation in project wizard with separate phases for biomass recovery and transport
  - Look and feel improvements (i.e.: font size harmonization, date & time formats)
  - Bug fixes (i.e.: saved values not registered, malfunctioning edit button, project list won't scroll)
- User Experience (UX) design improvements
  - Improved biomass flow calculations
  - Include transport distance into trucking cost ($/PMH) shown in detailed edit
  - Automatic transport distance didn't work is some instances
  - Updated default chipper/grinder productivities
  - User location didn't register without Wi-Fi
  - Improper Lat/Long coordinates sent to ArcGIS Online
  - Improved process time in project wizard

APPENDIX I – DEVELOPMENT ROADMAP

Start up

User experience

Workshop improvements

Asked by users following October 17 workshop in Mackenzie, BC

- Add option for Decay-waste-breakage % from merch volume. % taken from merch odt estimate shown in biomass flow
- Change Carbon to CO2eq
  - In the report, change "Carbon emitted" to "GHG emissions (CO2eq.)" using GHG emissions for Off-road Diesel Tier 4 engines of 2.743 kg CO2 eq/L from the IPCC 5th assessment report
- Add Avoided GHG (CO2eq) from utilization (recovery) instead of roadside piling/burning
  - Cambero et al. 2015 - Table 5 on page 67 shows 1,630 kg CO2eq/ODt for burning forest residues at roadside

FPInnovations

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