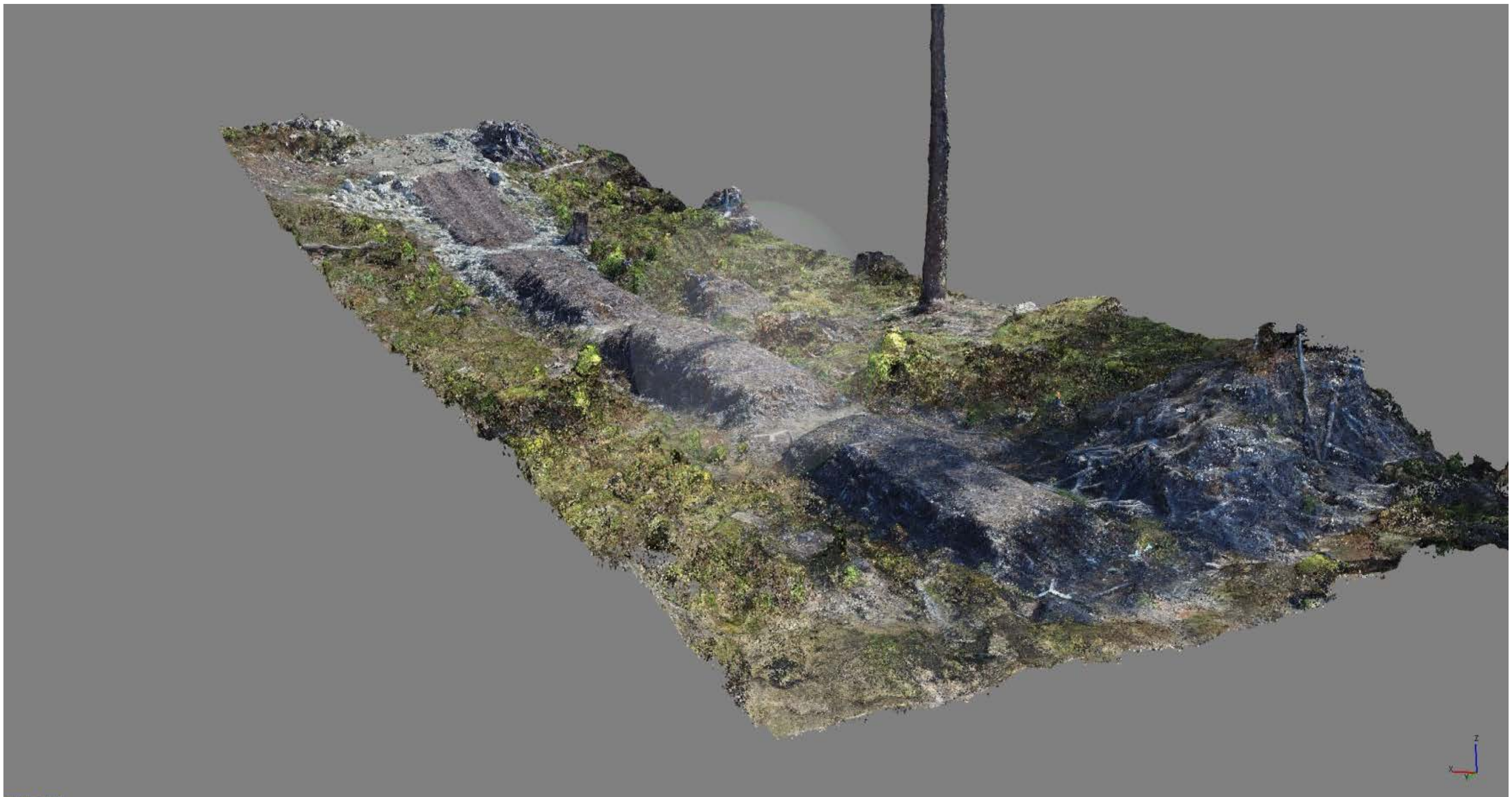

Assessment of Logging Debris Disposal Piles on Spur Roads in B.C.: Second Year Report

Technical Report no. 23 - March 2017

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ABSTRACT

This report describes the results of an assessment of bark and woody debris disposal piles using an Unmanned Aerial Vehicle (UAV). The practice of disposing of logging debris along spur roads is new and needs to be examined with respect to being a sound environmental practice. Water management and quality, biodiversity, and tree seedling survival are all discussed.

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1. INTRODUCTION

Debris management at logging sites and handling facilities is of increasing concern due to the volume of accumulated material and the constrained options for disposal. In March 2014, B.C. Timber Sales (BCTS) provided a timber sale on Maurelle Island that produced a large quantity of detached bark which originated from a 132-ha harvest area. Harvesting was during March 2014, and the predominant source of bark was from 41 150 m^3 of Douglas-fir which accounted for approximately half the harvested volume (88 050 m^3 total harvest volume). The bark accumulated at both a log storage area and on a transport barge during loading and unloading. The bark was disposed of along two dead-end spur roads (Figure 1). One of the spur roads has a small S6 stream (non-fish bearing) crossing through it. The disposal of logging debris (bark) along spur roads had not been considered or tried before by the Strait of Georgia Business Area of BCTS. The bark for Douglas-fir accounts for 30% by volume, which is the highest overall volume of bark for all softwood species (on average bark accounts for 10 to 15%).

FPInnovations visited the site to assess any environmental concerns regarding the debris disposal practice and to set up long-term monitoring options. FPInnovations used an Unmanned Aerial Vehicle (UAV) or drone at the site during September 2016. The image-capturing ability of the UAV along with accurate GPS data allowed for the generation of image-based point clouds, and orthomosaics, which in turn allowed for three dimensional (3D) modeling and surface terrain mapping used to determine ground surface flow patterns. The UAV provides a unique opportunity to measure and monitor pile volumes, area, dimensions, and decomposition over time. Surface flow maps provide another tool to enhance water management; cross-drains and waterbars can be strategically positioned where positive surface flow is away from streams and waterbodies. Leachate can be produced when woody debris is in contact with water (precipitation, surface water, or groundwater). Sediment can be suspended in surface flows during the erosion of exposed soils. Aquatic organisms (including the survival of fish) can be susceptible to the direct effects of leachate compounds and the various indirect effects such as pH, dissolved oxygen content, biochemical oxygen demand, and chemical oxygen demand. Erosion and the resultant sedimentation can also have a negative effect for aquatic environments.

Figure 1. Disposal piles at the end of spur 2. Note the distinct gap between piles.

Tree seedlings planted within one of the debris piles were tallied and visually assessed for growth and vigour. Planting debris piles with tree species which survive can provide additional biodiversity to the site, resulting in an improved environmental performance compared to an abandoned resource road.

2. BACKGROUND

FPInnovations has previously reported on the disposal technique and discussed the harvest operations for the bark piles along the two spur roads at the Maurelle Island sites. The primary question regarding the bark disposal was to explore and understand if it was a sound environmental practice. Gillies (2016) suggested that the disposal of bark along resource roads needs to be further investigated to determine whether it is a sound environmental practice; he further identified both monitoring opportunities and knowledge gaps. A common concern with the study and management of woody debris, especially large quantities as seen at dryland sort yards, is that of leachate originating from the source woody material. Leachate and sediment management techniques can be implemented to prevent either from reaching streams or aquatic environments. Cross-ditches were constructed on either side of an in-block stream, which crossed spur 1, to intercept and direct surface flows originating from the debris piles onto the forest floor, preventing direct connectivity to the stream and aquatic habitat. The cross-ditch also doubled to prevent sediment delivery to the stream or aquatic environment. Where the resource road approached the ocean, careful debris management and loading operations for the log transport barge kept bark from entering the ocean. Leachate from bark is a common potential impact source to ocean waters and marine environments (G3 Consulting Ltd., 2003).

A list of knowledge gaps presented in Gillies (2016) is provided below as a reference to the on-going research initiatives and to provide some insight as to the discussion within this paper:

- Should watercourses have a minimum buffer width from disposal material?
- Are there concerns with leachate?
- Will bark decompose over time?
- Will trees planted in bark survive and/or show favorable growth?
- Are there alternative disposal methods or options?
- Are the debris piles providing habitat and promoting biodiversity?
- What is an appropriate pile size (length, width, and height) or target volume per lineal metre?
- Are breaks in the piles providing a necessary performance measure?
- Can bark sloughing during harvest operations be predicted and planned for?
- Is there a maximum hauling distance at which the cost of disposal becomes prohibitive?
- Are there cost-effective alternatives for the use of bark?

3. SITE ATTRIBUTES & DATA COLLECTION

Bark had been delivered along the running surface of two spur roads. Each spur road had four piles placed along its length. Unique to spur 1 was a rock pit at the end which also received bark disposal to fill in the excavation. The debris pile at the rock pit (considered a fifth pile along spur 1) was the only debris pile planted with tree seedlings (Douglas-fir and western red cedar). A non-fish bearing stream crossed spur 1. Both spur roads were along upland sites (at least 300 m away from the ocean).

The UAV was flown at a height of 40 m above both spur roads to collect data related to the debris piles. Lower elevation flights also were flown to collect oblique aerial photographs to help create the orthomosaics, and the digital surface models of the debris piles (Figure 2 and Figure 3). To accurately position these 3D models, a mapping grade GPS with an external antennae collected X, Y, and Z coordinates at marked locations around the piles. Following differential correction, the relative accuracy for the horizontal measurement of the GPS data was within 10 cm. The estimated normalized height of the debris was calculated, over the horizontal plane of the pile, by subtracting the estimated vertical elevation of the road surface from the corresponding elevation above this point on the digital surface model of the debris pile. The summation of the normalized heights times a unit area associated with each measurement location provided an estimate of the total volume of debris in each pile.

Manual measurements of the length, width and a sample height of each pile also were collected, and the measurement locations were marked in the field. These manual measurements were used to calibrate and validate the 3D model by providing a reference for both pile heights and dimensions. The spatial data collected will allow future monitoring to be correlated to the same X, Y, or Z coordinates. The distance between the stream crossing spur 1 and the water management cross-ditch was measured.

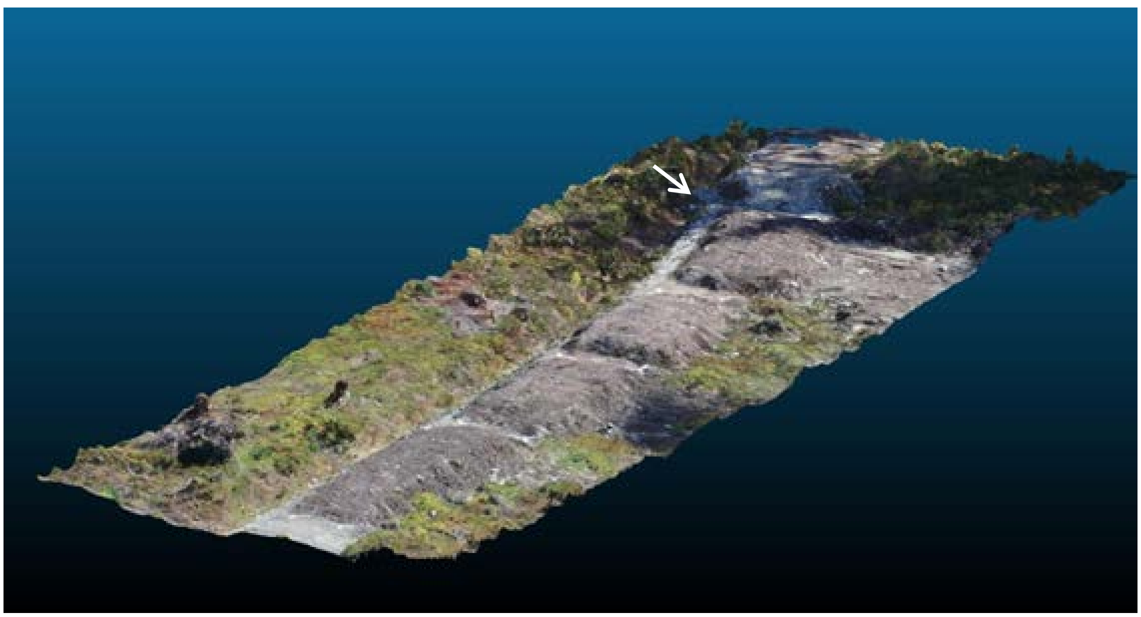

Figure 2. 3D model showing four debris piles along spur 1. A cross-ditch (see arrow) was constructed through the road to intercept and direct any surface flow from reaching an in-block stream (further along the road out of view).

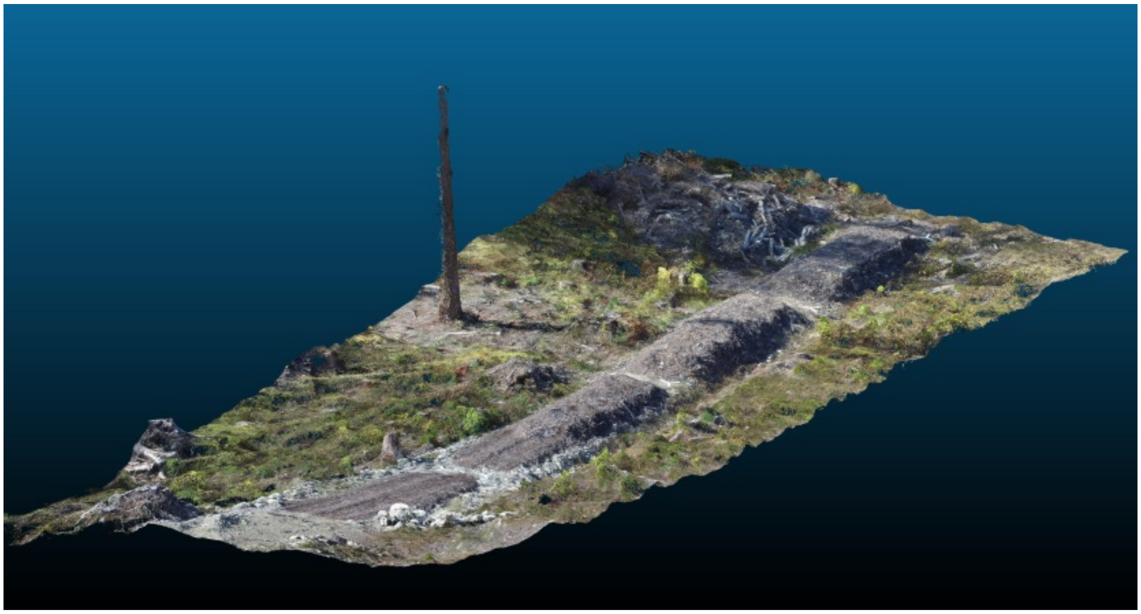

Figure 3. 3D model showing four debris piles along spur 2. Note the thin depth of debris within the first pile (far left), and half of the second pile, as well as the tall height and rounded top of the third and fourth piles. Also, the 3D model does not show live limbs on the tree because the data collection captured only the lower portion of the tree.

4. ENVIRONMENTAL MANAGEMENT

The harvest areas located on Maurelle Island are managed for many environmental and social considerations including wildlife, water, soil, viewscapes and tourism. Of common concern to the study and management of woody debris storage is that of leachate originating from the source material. A dedicated leachate section is provided with respect to water management to introduce the reader to the subject and the practical management options implemented at the study site.

The bark within the piles was of various sizes and dimensions, with some pieces measuring up to 30 cm long. The composition of the debris piles would be considered coarse with many large pieces mixed amongst the piles. Large coarse pieces have a smaller surface area compared to the same volume of smaller, fine pieces, and these results in less opportunity for water-induced leaching to occur. The volume of woody debris placed along the two spur roads is considered minor with respect to the debris management challenges faced by processing facilities and dryland sorts (Figure 8).

Leachate

A primary concern with wood residue piles is with respect to water soluble leachates. Spencer (2017) provides a brief description of leachates and runoff constituents, and the common classes of leachate compounds of concern which originate from the interaction of water passing amongst woody debris as phenolics (phenols), resin acids, tropolones, tannins and lignin. Douglas-fir bark has naturally occurring, concentrated, tannins (Samis et al., 1999).

One management option for addressing leachate from the woody debris piles is to let the suspended toxicants and leachate disperse over a natural forest floor and infiltrate into the soil. This process is termed “natural attenuation”.

The infiltration allows for various natural biological activities to adsorb and assimilate the leachates present and helps to contain the leachate in situ. The ability of a soil to reduce leachate constituents (attenuation capacity), is related to the soil porosity and its water-retention capacity (Samis et al., 1999). The actual attenuation mechanisms for soil include adsorption, ion exchange, precipitation, filtration, and biological degradation (NCASI, 1983). All attenuation mechanisms can perform amongst the natural forest floor to various degrees of capacity.

The following descriptions of attenuation mechanisms are from Samis et al. (1999):

Adsorption

> *Adsorption is a fixation process in which dissolved organic and inorganic constituents are attached to the soil surfaces by Van der Waals forces. The adsorption force of mineral soils is very limited while organic matter, such as peat, is capable of strongly adsorbing dissolved organics in leachate. Adsorption is probably the main attenuation mechanism for immobilization of constituents of wood-residue leachate*.

Ion exchange

> *Ion exchange operates on the principle of electrical attraction between opposite charges. In this process, an ion with a strong electrical charge in the leachate is preferentially attached to a soil particle with the opposite charge. This process causes release from the soil particle of an ion of the same charge as the leachate ion. Cation exchange takes place when the leachate ion is positively charged, whereas anion exchange occurs when the leachate ion is negatively charged*.

Precipitation

> *Precipitation involves the formation of an insoluble substance when the concentration of that substance exceeds its solubility limit or as a result of chemical reactions between different substances. Comparatively water-soluble constituents, such as tannins, are less likely to be precipitated than water-insoluble constituents, such as terpenes. However, tannins and tropolones can be precipitated as metal-chelated complexes when cations from the soil are dissolved by the acidic leachate*.

Filtration

> *Filtration is the physical retention of suspended and settleable solids (including precipitated, chelated and “biological growth” materials) in the leachate by soil. Filtration efficiency of a given volume of soil depends on the pore size of the soil and the hydraulic gradient of the leachate. Compaction and settlement of the soil reduces filtration efficiency.*

Biological degradation

> *Within each type of soil, there is a limited number of "sites" available to interact with and immobilize wood-residue leachate constituents on the basis of adsorption, ion exchange, precipitation and filtration. Immobilization is mainly a one-time phenomenon. Immobilization capacity is at its maximum when the soil is fresh and can quickly become saturated. Further immobilization of constituents in a leachate-saturated soil cannot occur unless the soil has been refreshed. Soil refreshment is accomplished by biological decomposition of the organic constituents immobilized in the soil. Natural biological activity occurs mainly in the soil layer above the water table*.

Management options

Cross-ditches and associated ditch blocks were built 35 m on either side of the stream crossing through spur 1. The cross-ditches were constructed to capture and redirect road surface and ditch flows, including those containing liquid leachate and suspended sediments away from the stream and onto the forest floor. Cross-ditches and waterbars are commonly used for water management along resource roads.

The placement of bark debris along spur roads can have a positive environmental effect. Spur roads are considered permanent access structures that, under current B.C. forestry regulations, can account for a maximum of 7% of the harvest area. Debris piles placed along abandoned spur roads can provide some biological diversity to the compacted running surface of the road. Natural ingress of trees and shrubs colonizing the piles over time may promote a level of biodiversity which would not otherwise be present over a compact road surface. Planting tree seedlings within the piles at the same time when the cutblock is planted would be cost effective and easily accomplished (easy planting spots as compared to the cutblock). Disposing of the bark along the spur roads, near to where it originated, will have a smaller carbon footprint than transporting the material off of the island on a transport barge to be disposed of elsewhere. Keeping the debris from being delivered to a dryland sort will help alleviate the concerns with debris management for dryland sorts where vast volumes are generated with constrained options for disposal. Allowing the bark to decompose along the spur roads may promote biological activity or habitat forming micro-sites. An alternative to storage in piles, burning the woody debris may not be feasible for certain areas or times of the year if air quality impacts are a concern.

Identifying the path taken by surface flows leaving a debris pile will assist with the positioning and alignment of cross-ditches or other flow deflection techniques (e.g., off take ditches, berms, waterbars, etc.) UAV-derived 3D surface modeling is illustrated in Figure 4 and can be a valuable tool to depict the path and direction of surface flows. The subtle differences of the ground elevation and downhill direction may not be visually obvious in the field. A complex and (or) simplified surface flow map can be utilized to enhance water management decisions.

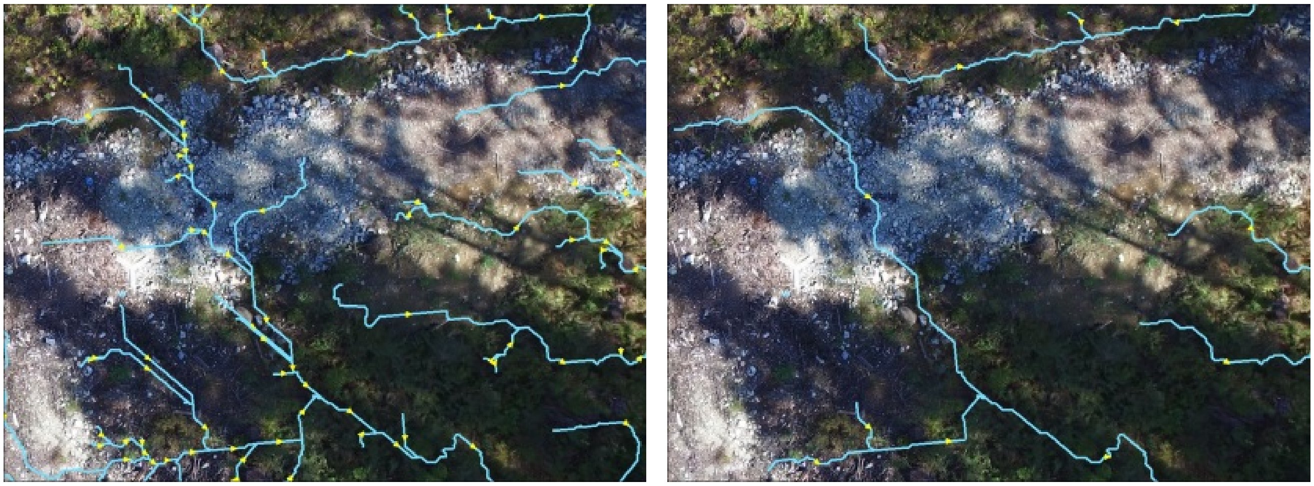

Figure 4. Mapped surface flow through a cross-ditch constructed through spur 1. The surface flow map can be complex (left) or simplified (right).

5. DATA ANALYSIS & SITE ASSESSMENT

The volume and surface area for each pile along the two spur roads is given in Table 1. The total volume of debris (based on bulk density which includes voids) from both spur roads was estimated to be 838 m^3. This is in close agreement with the total volume of 835 m^3 estimated manually by Gillies (2016). Although the total volumes from the manual and the orthographic modeling methods are similar, the individual pile volumes were different. The accuracy of manual measurements was improved when the debris pile had a square or rectangular shape with a consistent thickness. The orthographic modeling method did not have this constraint and can produce accurate volumes and surface area calculations for irregularly shaped piles. Although the piles along the spur roads were rectangular in shape, other sites could contain piles that are round or crescent-shaped.

It is believed that the orthographic modeling method provided more accurate estimates of volume for all piles. Further, the algorithm used for calculating the volume between the digital debris surface model and the digital road surface model is able to capture small surface changes and irregular shapes. The manual measurements underestimated the volume from all piles on spur 2, especially the thinner (pile 1 at 0.5 m) and thicker (pile 4 at 1.9 m) piles. The volume calculations for both the manual and UAV methods along spur 1 were similar in part due to the piles being flat and evenly spread. The manual method was accurate for piles with a consistent depth, and square or rectangular shape (Figure 5).

Table 1. Volume and surface area of debris piles as calculated by orthographic modeling, and the percent difference between the manual volume calculations previously reported by Gillies (2016)

	Pile 1	Pile 2	Pile 3	Pile 4
Spur 1				
Orthographic Volume (m^3)	162	92	100	74
Manual Volume (m^3)	165	85	90	85
Percent Difference (%)	+2	-8	-10	+15
Surface Area (m^2)	216	154	145	135
Spur Volume (orthographic) (m^3)	428			
Spur 2				
Orthographic Volume (m^3)	34	107	131	138
Manual Volume (m^3)	20	100	90	85
Percent Difference (%)	-41	-7	-31	-38
Surface Area (m^2)	151	159	143	141
Spur Volume (orthographic) (m^3)	410			
Total Volume (orthographic) of all piles (m^3)	838			

[a] The rock pit at the end of spur 1 was not assessed by the UAV method.

Figure 5. Debris pile on spur 1 illustrates the typical height of 1.2 m, width of 5 m, and shape of the debris piles.

The normalized heights of the debris pile digital surface model are illustrated in Figure 6. The modeled volumes are considered accurate, in part because of the ability of the model to take into account small variations in pile dimension (especially height). The manual method measured a single width, length and an average height. Utilizing the UAV to assess a pile's shape and volume provides an opportunity to help predict anticipated volumes of bark and debris generated during harvesting operations in a given site and stand, as well as to assess the breakdown and activity of the stored piles. The breakdown of the piles over time can be assessed precisely using the X, Y, and Z coordinates established during the initial UAV flight. Understanding changes in pile shape or density may prove to be important for the management of debris along spur roads. Where volume is shown to reduce over time due to reduced pore space, microbial activity, or overall consolidation, there may be a better understanding of a targeted thickness to promote biodiversity including crop tree establishment.

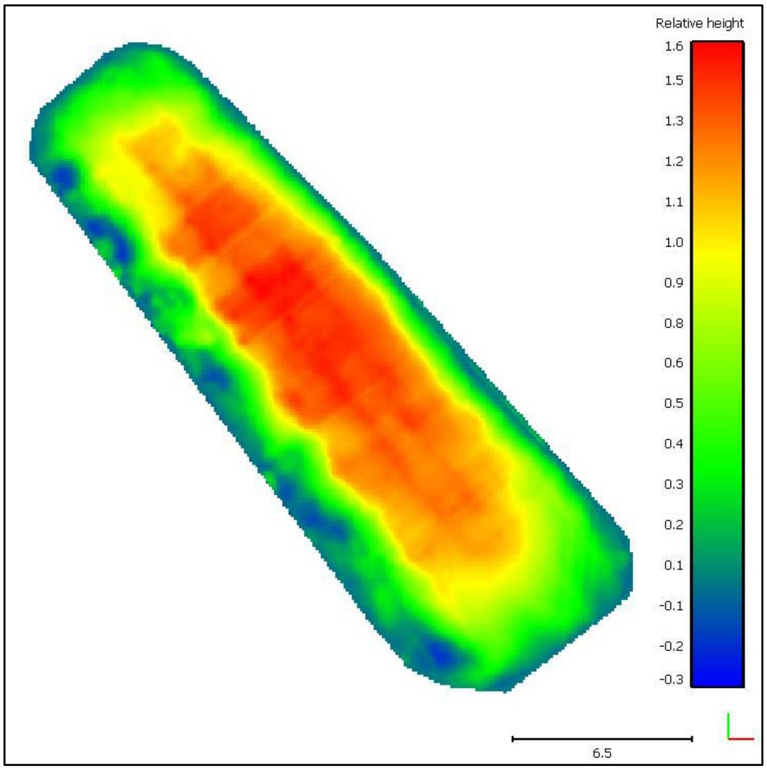

Figure 6. Modeling of debris pile 1, spur 1 showing a coloured view of normalized height of the debris pile surface.

Tree seedling survival was assessed at the end of spur 1 where the debris-infilled rock pit was planted, which was the only debris pile planted. Twelve western red cedar and seven Douglas-fir seedlings were counted within this area. Although the planted seedling sample size is small, there was an obvious difference between the western red cedar seedlings and the Douglas-fir; six (half) of the cedar seedlings were either showing signs of chlorosis (loss of greenness through chlorophyll deficiency) or had died (Figure 7). The seven Douglas-fir seedlings did not show similar signs of chlorosis.

Figure 7. Western red cedar (left) and Douglas-fir seedlings planted within the same debris pile. Note the obvious signs of chlorosis and unhealthy foliage for the western red cedar.

The cedar seedlings may not have done well in the full sunlight condition of the site, considering cedar is known to thrive (high tolerance) in low light. Western red cedars' tolerance to water deficit is medium, and likely requires protection from open area climate for warm and water-deficient sites; western red cedar has been extensively discussed by Klinka and Brisco (2009). The coastal islands of B.C. can be dry and hot during the growing season. Douglas-fir can withstand greater amounts of full sunlight, but also shows a medium tolerance to water deficit. There was visually more moisture present in the debris piles as compared with the surrounding soil. The bark debris as a growing medium may have a greater initial impact on cedar seedling growth compared to Douglas-fir due to the specific nutrient regime of the substrate.

Continued assessment of the planted seedlings will allow for some guidance with respect to the feasibility of seedling survival. A similar bark disposal method is being planned for an upcoming timber sale on Maurelle Island, and this may provide additional sites to be planted. This would increase the seedling sample size, and opportunity to plant other tree species for assessment. Additional bark and woody debris piles would also provide additional sites to model pile volumes and monitor over time with respect to the breakdown and functionality of the debris matrix.

The cross-ditches constructed to protect the S6 stream and the aquatic environment appeared to be working well. The cross-ditches were constructed through the road 4.5 m away from the closest debris piles and 35 m from the stream. The cross-ditches were functional (maintaining shape, not blocked and stable) and had evidence of flows passing through them (dry during field visit). Directing surface flows onto the forest floor as a method of leachate management (natural attenuation) is cost-effective and conducive for forest environments where the forest floor consists of organic matter, which has the ability to intensely adsorb dissolved organics in leachate. There are other options for the management of leachate, such as engineered wetlands with plant communities to absorb the leachate (phytoremediation), but not all are conducive to be constructed within a forest environment.

Preventing sediment from entering into a stream or the associated aquatic environment is also a standard forest management goal. Cross-ditches, waterbars, off-take ditches, and sediment ponds are all common BMPs which are effective at containing and preventing sediment delivery to water bodies.

Intercepting sediment-laden surface flows and directing them onto the forest floor promotes suspended sediment to fall out of suspension. Key to erosion and sediment control is preventing sediment laden water from having direct connectivity to a water resource. There was no evidence of sediment reaching the S6 stream.

The volume of bark debris along the two spur roads is relatively minor compared to a dryland sort where debris accumulation brings challenges for disposal and leachate management. A typical coastal dryland sort (Figure 8) would have roughly 1 Million m^3 of wood pass through it with 5–10% of that volume being managed as accumulated woody debris (depending on tree species and age). The 837 m^3 of debris placed in eight piles over the two spur roads are not likely to produce any significant amount of leachate. The presence of leachate was not visually observed during the site visit. Wood residue leachate is commonly described by being dark in colour, has a petroleum-like odor, and can produce an iridescent (rainbow-like) sheen; most of the phenolic compounds from wood waste are aromatic and produce a distinct odour (Samis et al., 1999). No odour or dark liquid (with or without an iridescent sheen) was noted at any of the sites.

Future examinations for leachate could include the collection of water samples to be analyzed at a laboratory coupled with visual and aromatic observations.

Figure 8. Woody debris / bark accumulated at a dryland sort.

6. CONCLUSIONS AND RECOMMENDATIONS

The disposal of bark and woody debris along resource roads was further investigated at the request of BCTS to help determine whether it is a sound environmental practice. In order for this technique of debris disposal to be embraced as a BMP, it needs to create acceptable levels of environmental impacts and be deemed preferable to other options. If the disposal method is shown to provide an environmental or biological benefit, there could be opportunities to learn, document and exploit these over time.

Disposing bark and woody debris along permanent access structures which are not going to be used again may provide environmental benefits. Disposing of bark and woody debris on-site may lessen the carbon footprint by not having to transport the material to a dryland sort. Debris management at dryland sorts and handling facilities is of increasing concern due to the vast volume of accumulated material and the constrained options for disposal. The volume of bark debris disposed of along the spur roads on Maurelle Island is minor compared to the debris accumulated at a typical coastal dryland sort.

The use of UAV to collect surface area data is faster, more convenient, and relatively inexpensive compared with an intensive survey. The digital surface modeling allows for pile volume to be accurately estimated by taking into account the variations in pile width and depth. Manual measurements of pile volumes collected at spur 2 in 2016 estimated smaller volumes than did the digital surface modeling, and likely under estimated the true volumes.

Water management for both leachate and sediment is recommended near streams to protect water and aquatic environments, including fish. The use of cross-ditches and (or) waterbars to direct water originating from debris piles onto the forest floor, and allowing any liquid leachate to disperse and infiltrate into the soil is recommended.

This is one BMP that is well suited for use along resource roads where cross-ditches and waterbars are easily constructed. Sediment management also would be accomplished by the use of the same cross-ditch and waterbars. Where streams are present, water management techniques could be compared and/or further improved upon based on water chemistry analysis, where warranted.

If there is opportunity to study additional bark disposal sites on Maurelle Island, the sites could be planted to assess seedling survival further. Long-term monitoring is planned for the initial sites and any additional sites which can be included.

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