5.4.0 BIOMASS SUPPLY ESTIMATES FOR THE CONFEDERATED SALISH AND KOOTENAI TRIBES BASED ON HARVEST PLANNING AND MANAGEMENT GOALS

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Introduction and Background

A mix of economic, policy, and social forces are pushing us to increase the use of forest residues from managed timberlands. In this report the terms forest residue and slash are used interchangeably and refer to any woody material left at the site of a timber harvest or thinning operation. Typically these materials are burned in slash piles in the forest to reduce the available fuel for wildfires. Assessment of forest biomass residues is therefore increasingly important for determining the viability of bioenergy projects, understanding the fire-related characteristics of forest to help in wildfire prevention and decision making, and studying the effects of changing forest conditions on the carbon cycle and global climate change.

Nearly all biomass assessment strategies that quantify the amount of available forest residues rely on regional data from mills or other wood processing facilities, or from FIA (Forest Inventory Analysis program) plot data. FIA data characterizes forests in the U.S. using aerial and satellite imagery, as well as field measurements (one sample site per 6,000 acres)[1]. Information from either mills or FIA is generally used to determine how much timber is available within a county or state, and what the "average" stand characteristics (forest structure, mix of species, tree sizes, etc.) in that region are. Such regional stand characteristics are input to a software program that simulates forest growth. Then, the volume of forest residue available can be determined using:

- regional conversion factors for volume of slash per volume of delivered timber[2,3,4,5,6]
- allometric equations based on characteristics of the harvested trees[7]
- or allometric equations based on characteristics of the entire stand[8]

In rare cases biomass assessments use alternative strategies such as calculating the total volume of forest residue based on a percentage of the annual allowable cut[9], or taking actual measurements of the forest, and slash piles, pre- and post-harvest across a harvest site[10,11]. The predictive capability of these alternative strategies is generally not applicable outside the local region studied.

As described above, assessment of biomass supply chains often takes place on the regional scale, usually applying regional average conversion factors to estimate available biomass. These regional conversion factors are based on historical harvest practices and volumes, and they cannot be used to assess what is actually on the landscape if the landowner's harvest practices differ significantly from the regional norm. Assessing the available biomass when ecologically based forest management takes place (different from conventional industrial forestry) requires more detailed knowledge of the distribution and composition of forest resources. We are working with the Confederated Salish and Kootenai Tribes (CSKT) to assess the availability and costs of collecting slash from planned forest management activities. Our estimates are based on detailed landscape-level information of the forest composition and actual CSKT harvest strategies.

CSKT's Forest Management Plan[12] outlines 12 goals for the management of Tribal forests:

1. Strengthen Tribal sovereignty and self-sufficiency through good forest management.
2. Manage forest ecosystems to include natural processes and to balance cultural, spiritual, economic, social and environmental values.
3. Adopt a process which accommodates changes in Tribal values and resources.
4. Facilitate Tribal member involvement in forest stewardship.
5. Provide sustained yield of forest products and maintain or enhance forest health.
6. Develop options for managing land use conflicts.
7. Provide perpetual economic benefits of labor, profit, and products to local communities.
8. Manage forested ecosystems to protect and enhance biological diversity.
9. Provide a variety of natural areas that Tribal members can use for solitude, cultural activities, and recreation pursuits.
10. Work cooperatively with adjacent landowners and federal agencies to minimize cumulative impacts.
11. Protect human life, property and forest resources through fire suppression and fuels management.
12. Comply with Tribal and Federal laws.

To meet these goals, Tribal foresters use an ecosystem-centered approach to managing their forests that differs from more typical industrial forestry, which focuses most on economic benefits. CSKT foresters have developed two ecological descriptors to aid in prescribing management strategies: fire regimes and seral clusters.

A *fire regime* refers to the type of fire behavior that occurred on the landscape during pre-European times. They reveal basic information about how the ecosystem functioned before fire suppression. Five fire regimes have been defined by the Tribes based on fire frequency, fire intensity, and the pattern of vegetation that fires create.

Seral clusters are another ecological descriptor defined by the Tribes. A seral cluster describes the structure and composition of the forest – the size and age of trees, how close they are to each other, whether stands are single- or multi-layered, and whether species are shade tolerant or intolerant. A stands seral cluster also provides information about fire risk and severity, cover for big game, habitat for insects and birds, and risk of disease. Twelve seral clusters, A-L, are defined by the Forest Management Plan.

Silvicultural treatments on the reservation are ecologically determined by the seral cluster and fire regime at the harvest location.

When modeling the Tribal forest resources we used data from 296 Continuous Forest Inventory (CFI) plots from across the forested areas of the reservation (Figure 4.1.1). CFI is a forest sampling system that periodically re-measures specific forest stands or plots of individual trees to record how the forest changes over time. In each CFI plot the size, species, and structure of every tree on a 1/5 acre plot of land is recorded. Our CFI plot data is from 1999.

Table 4.1.1. An annual allowable cut of 18.1MMBF (million board feet) is set forth in the Forest Management Plan and this is the annual harvest volume we use in our analysis

Acronyms:	
AAC	Annual Allowable Cut
CFI	Continuous Forest Inventory
CSKT	The Confederated Salish & Kootenai Tribes
DBH	Diameter at breast height
FVS	The Forest Vegetation Simulator
GIS	Geographic Information System
MMBF	Million Board Feet

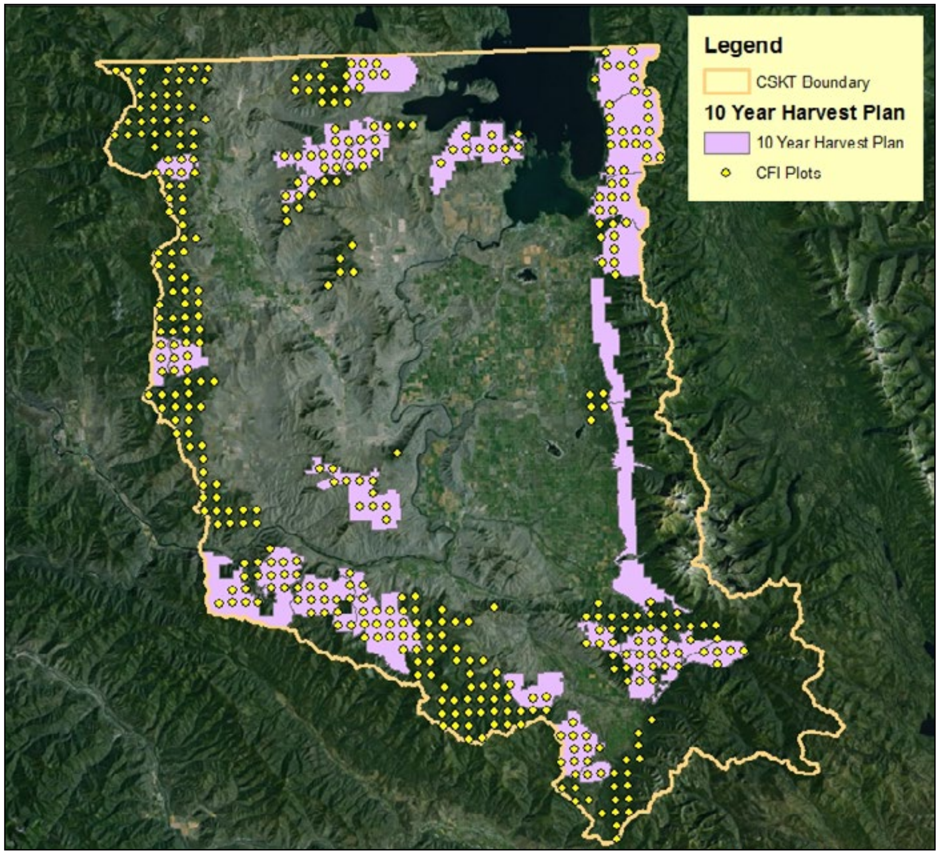

Figure 4.1.1. CFI plots on the reservation are shown with the planned harvest areas for the next 10 years

1 http://www.fia.fs.fed.us/
2 Morgan, T. An Assessment of Forest-based Woody Biomass Supply and Use in Montana. Report for Montana Department of Natural Resources and Conservation. Missoula (MT): 2009.
3 Fitzpatrick, J. et al. Developing a Business Case for Sustainable Biomass Generation: A Regional Model for Western Montana. Report for NorthWestern Energy (2010).
4 Howard, J. Ratios for Estimating Logging Residue in the Pacific Northwest. Research Paper PNW-288. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station (1981).
5 Richardson, J. J. et al. Uncertainty in biomass supply estimates: Lessons from a Yakama Nation case study. Biomass and Bioenergy 35, 3698–3707 (2011).
6 Skog, K. et al. Forest-Based Biomass Supply Curves for the United States. J. Sustain. For. 32, 14–27 (2013).
7 Perez-Garcia, J. et al. Washington Forest Biomass Supply Assessment. Report for Washington Department of Natural Resources. Seattle (WA): 2012.
8 Rørstad, P. K., Trømborg, E., Bergseng, E. & Solberg, B. Combining GIS and Forest Modelling in Estimating Regional Supply of Harvest Residues in Norway. Silva Fenn. 44, 435–451 (2010).
9 Cozzi, M., Di Napoli, F., Viccaro, M. & Romano, S. Use of Forest Residues for Building Forest Biomass Supply Chains: Technical and Economic Analysis of the Production Process. Forests 4, 1121–1140 (2013).
10 Alam, B., Pulkki, R. & Shahi, C. Woody biomass availability for bioenergy production using forest depletion spatial data in northwestern Ontario. Can. J. For. Res. 516, 506–516 (2012).
11 Bouriaud, O., Ştefan, G. & Flocea, M. Predictive models of forest logging residues in Romanian spruce and beech forests. Biomass and Bioenergy 54, 59–66 (2013).
12 Available at http://www.cskt.org/documents/forestry/fmp05.pdf

FVS Analysis

We worked with Tom Richards at Northwest Management, Inc. to simulate the growth and projected harvests from 296 CFI plots on the CSKT reservation using the Forest Vegetation Simulator (FVS). FVS is a set of forest growth simulation models provided by the US Forest Service[13] that can predict how the forest will change as a result of natural growth and proposed management activities. The tool is based on decades of forestry research and experience and it is widely used in the natural resource industry.

This project used the Expanded Inland Empire variant of FVS version 0979. Key input settings are described in the appendix. FVS Simulations were run on all 296 CFI plots provided by CSKT, representing each defined seral cluster. The prescriptions in Table 4.1.2, provided by Tribal foresters, define the harvest treatments for different seral clusters in FVS.

We defined merchantable wood as any harvested bole wood between a one foot stump height and a four inch diameter top from trees with DBH's over seven inches. Defect ratios are applied based on tree size as defined in Table 4.1.3. The simulations predict the amount of merchantable wood (board feet/acre) harvested from stands of each seral type, broken down by tree species, and we used that information to calculate slash volumes as described in the next section.

Table 4.1.3. Defect and breakage losses during harvest. The simulations predict the amount of merchantable wood (board feet/acre) harvested from stands of each seral type, broken down by tree species, and we used that information to calculate slash volumes as described in the next section.

DBH (inches)	Loss from defect & breakage (%)
5	5
10	5
15	7
20	7
25	10
30	11
35	12
40+	13

Table 4.1.2. Silvicultural Treatment Matrix, provided by Tribal foresters, define the harvest treatments for different seral clusters in FVS.

Seral Cluster	Fire Regime				
	Encroachment	Non-Lethal	Mixed Severity	Lethal	High Elevation
A_0, A_1	No Harvest	No Harvest	No Harvest	No Harvest	No Harvest
A_2	No Harvest	No Harvest	No Harvest	No Harvest	No Harvest
B & C	No Harvest	Pre-Commercial Thin – 300 TPA	Pre-Commercial Thin – 300 TPA	Pre-Commercial Thin – 300 TPA	No Harvest
D	No Harvest	Commercial Thin – 300 TPA	Commercial Thin – 300 TPA	Even-Aged Clearcut – 20% of area	No Harvest
E & I	No Harvest	Even-aged Clearcut – 20% of area	Even-Aged Clearcut – 20% of area	Even-Aged Clearcut – 20% of area	No Harvest
F	No Harvest	Uneven-aged Q of 1.1 – to 45 BA	Uneven-aged Q of 1.1 – to 60 BA	Even-Aged Seed Tree – 20% of area	No Harvest
G	No Harvest	Uneven-aged Q of 1.1 – to 45 BA	Even-Aged SW – 25% of area (30 BA), Uneven-aged – 50% of area (60 BA)	Even-Aged Seed Tree – 20% of area	Even-Aged Clearcut – 20% of area
H	No Harvest	No Harvest	No Harvest	Even-Aged Seed Tree – 20% of area	Even-Aged Clearcut – 20% of area
J	No Harvest	Thin from below to 70 BA	Uneven-aged Q of 1.1 – to 70 BA	Even-Aged Clearcut – 20% of area	Even-Aged Clearcut – 20% of area
K	No Harvest	Thin from below to 80 BA	Uneven-aged Q of 1.1 – to 80 BA	Even-Aged Clearcut – 20% of area	No Harvest
L	No Harvest	No Harvest	No Harvest	Even-Aged Clearcut – 20% of area	No Harvest

Slash Volume Estimation

FVS simulations predicted the volume of merchantable wood per acre that will be harvested and delivered to a mill for each seral cluster and year. Unfortunately FVS cannot directly predict the amount of slash that will be left on the landscape after a harvest. To estimate the amount of slash we worked with Todd Morgan, Erik Berg, and Eric Simmons from the Bureau of Business and Economic Research at the University of Montana. Todd and his team were able to use the Resources Planning Act (RPA) Timber Product Output (TPO) database[14] to estimate the volume of slash per board foot delivered for each tree species in our FVS output (Table 4.1.4.). The slash volume estimated here includes tops, limbs, and any defect or breakage left on the site (note that pulp wood is considered a merchantable product and is not included in slash, but if pulp market conditions are poor it could add to the total slash volume available).

The RPA TPO database is built using data collected from all wood-using mills in every state, along with on-the-ground studies of a cross-section of actual logging operations in each state to relate TPO from the mills to slash left behind. RPA TPO slash estimates used in this project were based on data from Western Montana.

Applying these slash estimates to the FVS output data results in an estimate of the total volume of slash generated per acre after harvesting stands of each seral cluster/fire regime combination. It should be noted that because the RPA TPO database only accounts for timber delivered to a mill, any slash generated from thinning of trees with a DBH less than seven inches is not included in our final predicted slash volume.

Table 4.1.4. Volume of slash remaining on the landscape per board foot of merchantable wood delivered to a mill.

Species	FIA Species Code	Slash (ft^3)/board foot delivered to mill
Western Red Cedar	242	0.0944
Ponderosa Pine	122	0.0868
Whitebark Pine	101	0.0739
Engelmann Spruce	093	0.0695
Aspen	746	0.0715
Douglas Fir	202	0.0667
True Firs (Grand & Subalpine)	017, 019	0.0841
Western Larch	073	0.0649
Lodgepole Pine	108	0.0700

GIS Analysis

To gain detailed landscape-level understanding of the managed forest resources on CSKT lands we used geographic information system (GIS) data covering Tribal lands. All GIS analysis was performed using ArcMap version 10.2.[15]

CSKT provided us with GIS layers for their scheduled forest management areas for the next 10 years (Figure 4.1.2), their logging road network, and the distribution of Tribally-defined seral clusters and fire regimes across the landscape. Each seral cluster/fire regime forest type will lead to a unique estimate of available slash after harvest. To determine the acreage of each seral cluster/fire regime designation required analysis of all the Tribal GIS data.

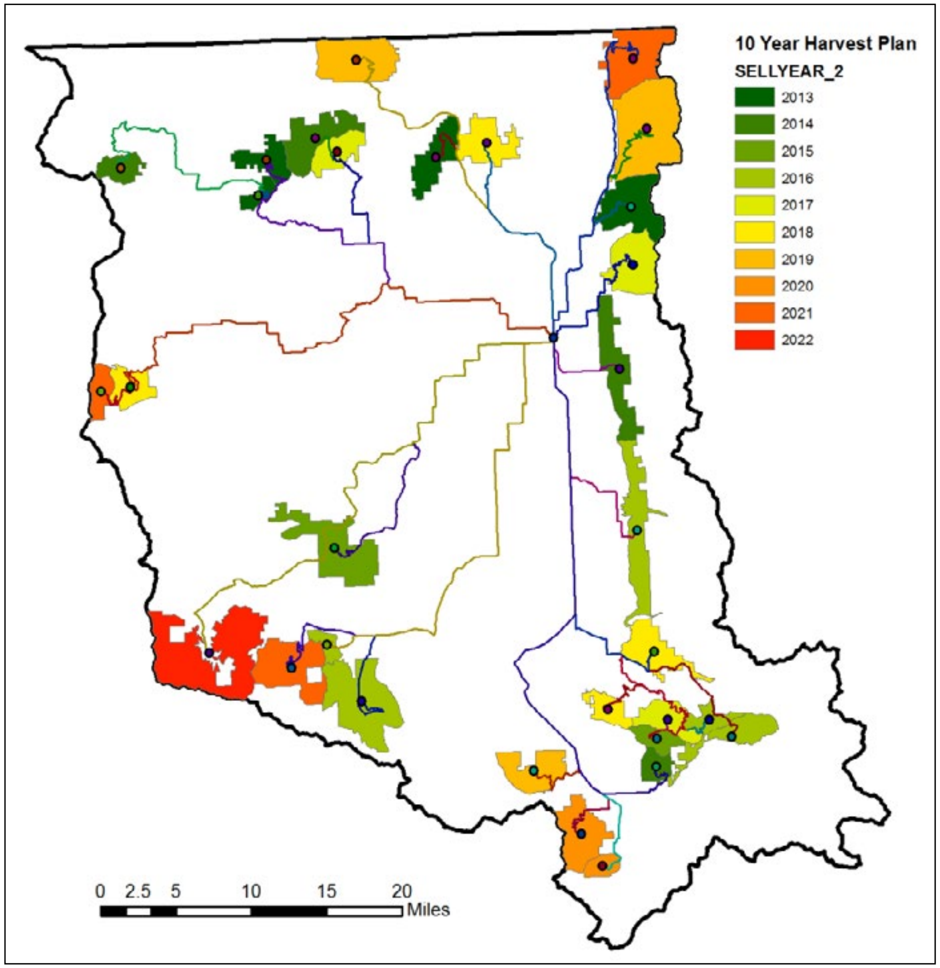

Figure 4.1.2. Forest management areas on the CSKT Reservation for the next 10 years. Roads connecting the centroid of each management area to a central facility in Pablo, MT

The Tribal road network layer (Figure 4.1.3) contains information on the quality and safe speed of each road. Based on this information and discussions with Tribal foresters we identified which roads are accessible by the articulated chip vans, which will be necessary to remove slash from the harvest areas (class 0-3 roads are assumed accessible).

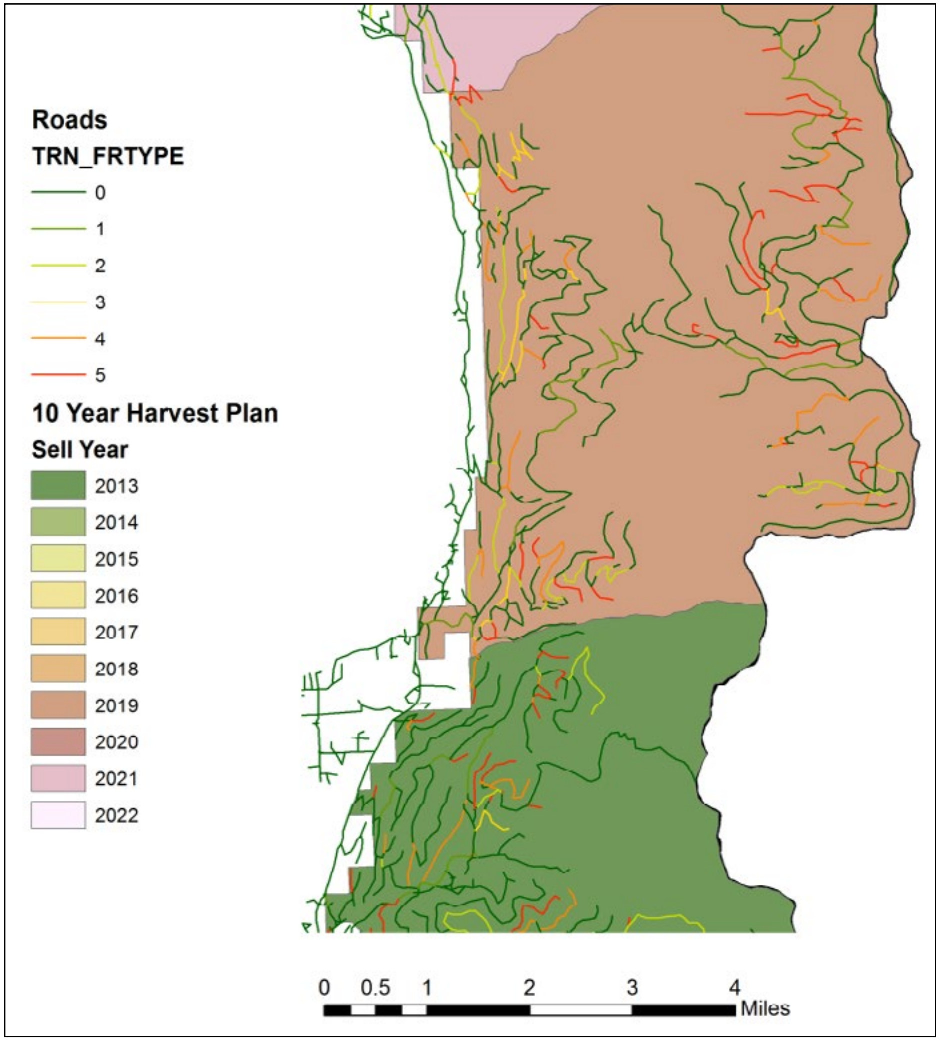

Figure 4.1.3. Sample harvest areas showing road class designations.

Around each chip van-accessible road we built a 400-foot buffer to define how far off the road harvesting operations will extend (Figure 4.1.4). 400 feet is an average harvest buffer distance provided by the Tribes based on their current harvest practices.

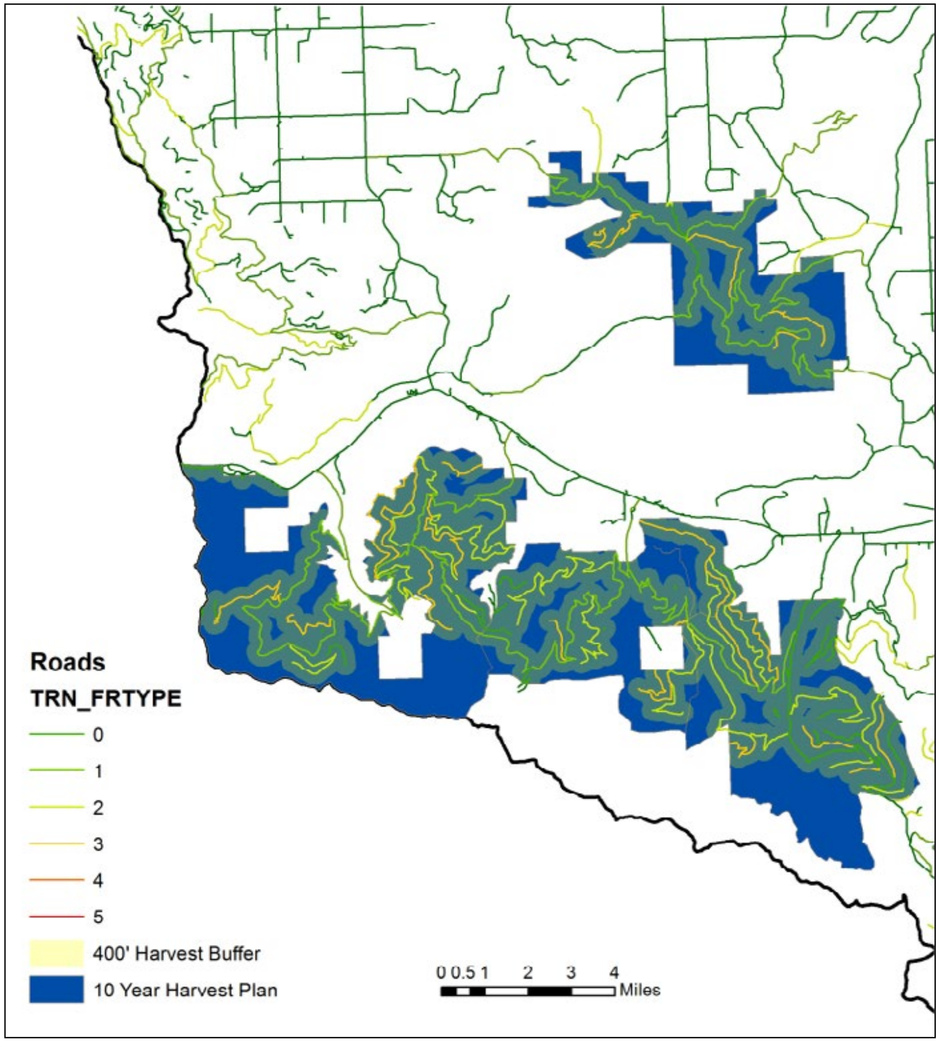

Figure 4.1.4. 400' harvest buffer applied around chip van-accessible roads within harvest areas. This defines the harvestable area where slash will be available to extract.

As described earlier, CSKT divides their forests into 13 structural classes, called seral clusters, describing tree size, stand density, species composition and layering. Five fire regimes area also defined based on the fire frequency, intensity, and pattern during the pre-European era. Computing the intersections of the seral cluster and fire regime GIS layers produced 50 new combined seral cluster/fire regime designators that can be mapped (Figure 4.1.5).

By combining the seral cluster/fire regime map with the 10 year harvest plan and harvest buffer zones we were able to extract the number of acres of each seral cluster/fire regime designation within each harvest area by year.

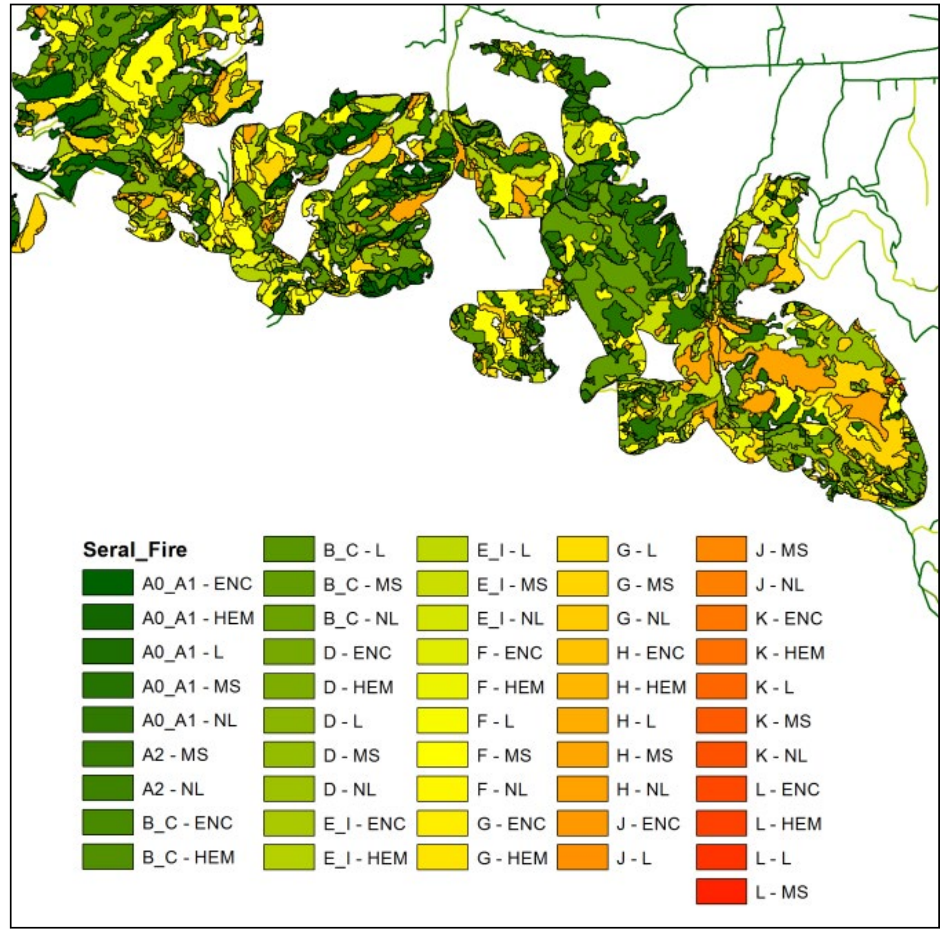

Figure 4.1.5. Seral cluster/fire regime designations describe all forested land on the reservation. Each designation has a different management strategy (resulting in different slash volumes), and mapping these within the harvest buffer zone gives the acreage and location of each seral/fire designation, allowing slash yield to be determined at specific locations.

Application of Slash Estimates to the CSKT Landscape and Transportation Analysis

In order to determine the predicted slash volume and board feet of timber harvested each year it was necessary to write a program that calculates the total acreage of each seral cluster/fire regime designation within a given harvest area and year, then apply the silviculturally specific slash and harvest estimates from FVS and the RPA TPO database.

For this initial analysis we have assumed that 65% of the total slash volume is recoverable for chipping and removal from the forest. This recovery factor was chosen because it is the value currently used by other NARA research groups, however we expect that the actual recoverable fraction may be much higher because harvest operations on CSKT lands often use whole-tree to landing harvesting techniques. A conversion factor of 0.015 BDT/ft3 was used to convert slash volumes from cubic feet to BDT[16].

In all but one year simulated, the total projected volume of harvestable timber exceeds the annual allowable cut of 18.1 MMBF. In order to remain within the AAC limit, the fraction of each harvest area where we allowed a computed harvest to occur was reduced until the number of board feet harvested equaled the AAC. The available fractions of all harvest areas for a given year were reduced by the same amount when making these adjustments.

To estimate the cost of delivering slash to a potential processing site in Pablo, MT we made the following assumptions, all based on input from Tribal foresters:

- Landings are located every quarter mile along logging roads
- Chip vans have a capacity of 30 BDT
- The cost to chip and load slash at a landing into a chip van is $8.90/BDT
- The cost to transport chips from the forest to Pablo is a flat rate of $3.50/mile
- The entire volume of slash from a given harvest area is evenly distributed over all landings in that harvest area (this results in an average of 40 BDT/landing)
- Chip vans pick up from only one landing before returning to Pablo, so they may not always be full

When calculating the cost of processing and transporting chips from a landing to Pablo the driving distance used was from the centroid of a harvest area to Pablo (see Figure 4.1.2).

13 The Forest Vegetation Simulator (FVS) and related documentation are available at http://www.fs.fed.us/fmsc/fvs/
14 http://www.fia.fs.fed.us/program-features/tpo/
15 ESRI (Environmental Systems Resource Institute). 2013. ArcMap 10.2. ESRI, Redlands, California.
16 U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p.

RESULTS

The results of our analysis on the availability of slash and cost to chip and deliver it to Pablo for the planned 10-year harvest schedule are shown in Table 4.1.5 (annual totals) and Table 4.1.7 (by harvest area).

Table 4.1.5. Total timber harvest and recoverable slash volumes

Year	Harvested Area (Acres)	Harvest (MMBF)	Recovered Slash (yd^3)	Recovered Slash (BDT)	Avg. Delivered Cost ($/BDT)
2013	11,049	18.1	31,966	12,946	16
2014	7,554	18.1	32,243	13,059	24
2015	10,431	18.1	31,992	12,957	21
2016	9,459	18.1	32,170	13,029	20
2017	8,822	18.1	32,283	13,075	17
2018	7,836	18.1	32,343	13,099	19
2019	9,482	18.1	32,266	13,068	20
2020	7,826	16.8	30,228	12,242	22
2021	9,541	18.1	32,364	13,108	20
2022	9,318	18.1	36,119	14,628	24

Our total annual slash volumes (predicted in Table 4.1.6) agree well with rough estimates of slash calculated using a general conversion factor for Montana of 1,096 BDT per 1 MMBF[17]:

Table 4.1.6.

Year	Slash predicted using our method (BDT)	Slash predicted using general Montana factor (BDT)
2013	12,946	12,894
2014	13,059	12,894
2015	12,957	12,894
2016	13,029	12,895
2017	13,075	12,894
2018	13,099	12,895
2019	13,068	12,894
2020	12,242	11,957
2021	13,108	12,895
2022	14,628	12,894

17 Morgan, T. An Assessment of Forest-based Woody Biomass Supply and Use in Montana. Report for Montana Department of Natural Resources and Conservation. Missoula (MT): 2009.

Table 4.1.7. Timber harvest and recoverable slash volumes by harvest area

Year	Harvest Area	Harvested Area (Acres)	Harvest (MMBF)	Recovered Slash (BDT)	Distance to Pablo (mi)	Landings (#)	Delivered Cost ($/BDT)
2013	Hellroaring	4,362	8.7	6,247	14	167	14
	Jette	3,267	4.9	3,534	20	118	14
	Rattle Snake	1,095	2.0	1,454	31	52	17
	Sullivan	2,325	2.4	1,711	35	70	19
2014	Deep Draw	2,776	7.6	5,480	30	134	19
	Dry Fork	942	0.7	532	52	23	25
	North Buffer Zone	2,806	8.8	6,348	7	86	11
	Stevens	1,030	1.0	700	42	73	40
2015	Ferry Basin	4,718	7.2	5,201	30	125	19
	Skunk	2,343	4.3	3,059	40	187	26
	Yellow Bay	3,371	6.6	4,697	29	94	17
2016	Central Buffer Zone	2,281	6.3	4,510	17	69	14
	Delaware	2,090	3.8	2,745	36	90	25
	Eva Paul	1,116	1.4	1,024	38	42	20
	Revais	3,518	6.0	4,330	40	91	21
	Sheep Springs	453	0.6	421	35	11	22
2017	Irvine	2,565	3.1	2,256	28	126	20
	Moss Peak	2,898	8.6	6,207	13	129	13
	Pistol Creek	3,360	6.4	4,612	38	187	20
2018	Lamoose	1,541	2.4	1,713	33	41	20
	South Buffer Zone	1,653	4.8	3,491	27	99	20
	Sunny Slope	3,007	7.3	5,281	17	154	16
	Welcome Springs	1,635	3.6	2,613	44	26	21
2019	Boulder	5,211	10.7	7,618	23	167	16
	Meadow	2,889	5.6	4,097	31	128	22
	Saddle Mountain	1,382	1.8	1,353	39	69	23
2020	Charity Peak	5,982	12.7	9,317	43	214	23
	Schley	1,844	4.0	2,925	42	63	22
2021	Dog Lake	1,487	2.2	1,547	49	31	23
	Magpie	4,683	10.0	7,330	42	99	21
	Yellow Bay	3,371	5.9	4,231	29	94	18
2022	Seepay-Vanderburg	9,318	18.1	14,628	44	237	24

FVS Settings

All simulations were run using FVS Version 0979 – Inland Empire Expanded variant. The starting year for each simulation is 1999 and the simulation end year is one year past treatment year. For example, for a treatment in 2014, the simulation would begin in 1999 and end in 2015.

Input Database – CSKT_Database

Total of 296 CFI Plots - 1/5th acre plots

- Seral Cluster "A" Plots – 140
- Seral Cluster "B" Plots - 23
- Seral Cluster "C" Plots - 46
- Seral Cluster "D" Plots - 7
- Seral Cluster "E" Plots - 29
- Seral Cluster "F" Plots - 57
- Seral Cluster "G" Plots - 27
- Seral Cluster "H" Plots - 16
- Seral Cluster "I" Plots - 1
- Seral Cluster "J" Plots - 37
- Seral Cluster "K" Plots - 8
- Seral Cluster "L" Plots – 5

Volume Settings

Defect – Cubic Foot – for all species:

- 5 inch trees = 0.05;
- 10 inch trees = 0.05;
- 15 inch trees = 0.07
- 20 inch trees = 0.07;
- 25 inch trees = 0.10;
- 30 inch trees = 0.11
- 35 inch trees = 0.12;
- 40 inch and larger trees = 0.13

Defect – Board Foot – for all species:

- 5 inch trees = 0.05;
- 10 inch trees = 0.05;
- 15 inch trees = 0.07
- 20 inch trees = 0.07;
- 25 inch trees = 0.10;
- 30 inch trees = 0.11
- 35 inch trees = 0.12;
- 40 inch and larger trees = 0.13

Board foot Volume Settings;

- ALL SPECIES (CODE = 0);
- MINIMUM DBH = 7.00;
- TOP DIAMETER = 4.00;
- STUMP HEIGHT = 1.00
- FORM CLASS = 80.00;
- METH OF VOL CALC = 6.

Prescription Settings

Prescriptions were applied based upon the Seral Cluster (forest type) and Fire-regime as described in Table 4.1.1. Below are the general settings for each of the prescriptions.

Clearcut (CC)

- Reserve 5 TPA > 21"
- Applied to Seral Clusters D, E, G, H, J, K, L

PCT

- Low thin – thin to 300 trees per acre
- Applied to Seral Clusters B, C, D

Seed tree

- Residual of 10 TPA
- Applied to Seral Clusters F, G, H

Un-even aged (UA)

- Q quotient of 1.1 for all un-even aged scenarios
- Thinned to residual BA of 45, 60, 70. Depends on Seral Cluster
- Applied to Seral Clusters F, G, J, K

Commercial Thin (Thin)

- Applied to Seral Cluster J, K
- Thin from below to specified BA (70, 80). Depends on Seral Cluster

Shelterwood (SW)

- Residual of 30 TPA
- Applied to Seral Clusters G