

**National to local: a pre & post assessment of the Fuel Characteristic
Classification System (FCCS) landscape variables for the Confederated Salish and
Kootenai Tribes**

Laurel Lynn James

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science

University of Washington

2012

Committee:

Thomas Hinckley, Committee Chair
Stephen West, Committee Member
Adrian Leighton, Committee Member
Daniel Schwartz, Committee Member

Program Authorized to Offer Degree:
College of the Environment
School of Environmental and Forest Sciences

University of Washington

Abstract

**National to local: a pre & post assessment of FCCS landscape variables for
Confederated Salish and Kootenai Tribes**

Laurel Lynn James

Chair of Supervisory Committee:

Dr. Thomas Hinckley

College of the Environment

School of Environmental and Forest Sciences

A modified Fuel Characteristic and Classification System (FCCS) fuelbed was created for the Confederated Salish & Kootenai Tribes (CSKT) of Montana. This crosswalk of data combined two principal sources of data: (1) locally the Bureau of Indian Affairs (BIA) Continuous Forest Inventory Data (CFI) and (2) nationally the US Forest Service (USFS) datasets associated with Landscape Fire and Resource Management Planning Tools Project (LANDFIRE). These two data sets were chosen for various reasons. Initially, these two data sources were used as the foundation for a geospatial assessment that was completed as part of the UW-IGERT (Cohort 2), “Bioresource based Energy for Sustainable Societies” program. That project

constituted the first step in the development of this thesis. LANDFIRE was a tool that the Forestry and Fire Management programs of the CSKT were familiar with, and, in addition, this tool provides a nationally consistent high resolution (30m) coverage that is compatible with other USFS fire and management tools. Therefore, LANDFIRE allowed for modifying the FCCS database to incorporate the local and site-specific data of CSKT. This benefit affords an opportunity for future adjustments that will produce finer scale data more appropriate for the management of reservation lands.

During the development of the modified FCCS fuelbed, careful attention was made to incorporate existing landscape management plans and management schemes thus creating a hierarchical framework that would better capture site-specific fuelbed characteristics. The steps associated with the development of the modified fuelbed are summarized by the following steps:

Seral Cluster → *Fire Regime* → *Landscape* = ***Modified Fuelbed***

The first step involves extracting Seral Cluster information from the tribal data sets, then combining fire regime information from both the Forest Service and Tribal Classifications. Landscape designations were also incorporated into the final datasets.

This synthesized assessment is a first of its kind in terms of a crosswalk of data for a tribal nation that links information between the US Forest Service, an organization with the US Department of Agriculture and the BIA, an organization within the Department of Interior. This project was completed in consultation with CSKT tribal forestry staff and received full CSKT Tribal Council approval.

The modified fuelbeds that have been created as a result of this research will serve a dual purpose. Locally, it will establish a database that will enable the utilization of nationally available fire and fuels modeling tools for use at the landscape level. Nationally, this modification will assist the tribe in updating and correcting the mapping conducted under National LANDFIRE. This mapping and the associated fuelbeds were accepted by the BIA and implemented on all reservation. A major consequence is that all fire and fuels funding allocations are now based upon this mapping system.

Key Words: FCCS, CFI, LANDFIRE, CSKT, BIA GIS, TRIBAL, IGERT, SERAL CLUSTER, FUELBED

TABLE OF CONTENTS

INTRODUCTION	1
BACKGROUND	4
RESEARCH GOALS AND OBJECTIVES	21
METHODS	28
FCCS ‘OUTPUT’ REPORTS	40
RESULTS & DISCUSSION.....	44
CONCLUSIONS.....	50
FUTURE IMPACTS.....	51

LIST OF FIGURES

FIGURE 1. MODIFIED FUELBED PATHWAY FORMED BY CROSSWALKIN DATA FROM TRIBAL MANAGEMENT SCHEME, BIA DATA, USFS MODELING PROGRAM AND AN INTERAGENCY MAPPING SYSTEM	2
FIGURE 2. CONFEDERATED SALISH AND KOOTENAI TRIBAL RESERVATION, LOCATED IN NORTHWESTERN MONTANA STATE	5
FIGURE 3. HISTORICAL ACCOUNTING OF FOREST CHANGE ON THE CONFEDERATED SALISH AND KOOTENAI TRIBES' RESERVATION	8
FIGURE 4. SUCCESSIONAL PATTERNS IDENTIFIED FOR TEH CONFEDERATED SALISH AND KOOTENAI TRIBE. INTERIOR SUCCESSIONAL PATTERN (LOOP), IDENTIFY POSSIBLE CYCLES THAT CAN BE FOUND IN A FIRE MAINTAINED SYSTEM	11
FIGURE 5. CONFEDERATED SALISH AND KOOTENAI TRIBES FIRE REGIME CLASSIFICATIONS FOR THEIR RESERVATION.....	17
FIGURE 6. MAJOR FIRES OCCURRING ON THE FLATHEAD RESERVATION 1994-2007	20
FIGURE 7. LANDSCAPE CLASSIFICATIONS ON THE CONFEDERATED SALISH AND KOOTENAI TRIBES RESERVATION	27
FIGURE 8. FUELBED FORM USED TO EXTRACT DATA FROM CONTINOUS FOREST INVENTORY DATA	31
FIGURE 9 FCCS VERSION 2.0 DATA ENTRY PAGE FOR THE CANOPY STRATUM.....	33
FIGURE 10. FCCS VERSION 2.0 DATA ENTRY PAGE TO GENERATE THE CUSTOMIZED FUELBED	34

FIGURE 11. ORIGINAL FCCS FUELBEDS MAPPED IN GIS	36
FIGURE 12. CFI PLOT LOCATIONS ASSIGNED BY SERAL CLUSTER CLASSIFICATION ON THE CONFEDERATED SALISH AND KOOTENAI TRIBES RESERVATION	39
FIGURE 13. FIRE POTENTIAL RATING SCHEME FROM THE FCCS PROGRAM.....	42
FIGURE 14. PRE MODIFICATION VS. POST MODIFICATION TOTAL FUEL LOADINGS, GRAPHED PER FUELBED CATEGORY WITH LINEAR TREND LINE	47
FIGURE 15. SERAL CLUSTER PICTORAL DESCRIPTION OF STAND DENSITY AND STRUCTURE	50

LIST OF TABLES

TABLE 1. TIMBER TYPES FOUND ON THE TRIBAL RESERVATION FOR THE CONFEDERATED SALISH AND KOOTENAI TRIBES	13
TABLE 2. SELECTED EXAMPLES OF FIRE ADAPTATIONS AND VEGETATION RESPONSE (EDMONDS)	15
TABLE 3. FIRE REGIME DESCRIPTIONS FOR THE CONFEDERATED SALISH AND KOOTENAI TRIBES.....	18
TABLE 4. FIRE NAMES AND ACREAGES FOR FIRES IMPACTING TRIBAL LANDS BETWEEN 1994-2007	19
TABLE 5. SERAL CLUSTER CLASSIFICATION AND ASSOCIATED STAND DESCRIPTION	25
TABLE 6. FIRE REGIME CONDITION CLASS CATEGORIES	26
TABLE 7. ORIGINAL FUELBED DESIGNATIONS STEMMING FROM LANDFIRE CLASSIFICATIONS WITHIN FCCS (PRE MODIFICATION)	28
TABLE 8. LISTING OF THE MODIFIED FUELBED DESIGNATIONS.....	38
TABLE 9. PRE MODIFICATION VS. POST MODIFICATION FIRE POTENTIALS REPORT. RESULTS SHOW THE NEED FOR SURFACE FUEL INFORMATION.....	45
TABLE 10. PRE MODIFICATION VS. POST MODIFICATION CARBON LOADINGS AVERAGES	49

Acknowledgements

This research has been supported by: a National Science Foundation's BioEnergy IGERT Fellowship (NSF DGE #0654242), a University of Washington Alumni Association—Multicultural Alumni Partnership's Scholarship, the American Indian College Fund, a Traveler's Scholarship, a Native American Fish & Wildlife Society Scholarship, a Yakama Nation Department of Natural Resources Scholarship, a Washington Indian Gaming Association Scholarship, an Intertribal Timber Council Scholarship, and a UW-College of the Environment Knoblach Fellowship and a School of Environmental and Forest Sciences' R.D. Merrill Forestry Research Scholarship.

Thank you to my committee: Drs. Thomas Hinckley, Stephen West, Daniel Schwartz and Adrian Leighton for providing me with the assistance, patience and guidance that enabled me to complete this stage of my academic career. I'd also like to acknowledge, Dr. Ernesto Alvarado for the assistance in establishing this project.

I thank the Confederated Salish and Kootenai Tribes' (CSKT) Tribal Council, CSKT Forestry department for providing the collaborative agreement to complete this work. In addition, thank you to the Yakama Nation's Fuels department for software and technical support. To the University of Washington's Fire Ecology and Management Group for providing lab/office space, software and technical guidance related to fire and fuels management. Also, thank you to the UW Bioenergy IGERT program for the financial support that allowed this work to be completed.

Additional thanks go to: Dr. Laurie Stephan, Everett Isaac, James Durglo, Rick Hulce, Tony Harwood, Bryan Taylor and Ken Faires for encouragement, support and guidance throughout a very demanding IGERT project. A special thank you to Michelle Trudeau and Amanda Davis too!

Thank you to Katrina Claw, Savannah Benally, Amanda Bruner, Laura Webster Evans, Amber Caracol, Daniel Hernandez and Clarita Begay for friendship, motivational support, guidance and encouragement needed during the writing, review and completion of this document. You are all wonderful friends! To my nephews Brandon Ambrose and Jacob Marquez: your assistance helped make my work possible and I thank you for your willingness help out and support these efforts.

Finally, a huge thank you to my son Joseph James: you are a remarkable young man and your support and patience during my periods of frequent travel while accomplishing this work provided great comfort and strength. Thank you for being such a wonderful son!

INTRODUCTION

This collaborative research project between the University of Washington and the Confederated Salish and Kootenai Tribes began during the 2009-2010 academic year at which time I was leading a team of PhD track students as a part of a National Science Foundation Integrative Graduate Education Research Traineeship (IGERT) program awarded to the University of Washington (UW) entitled ‘UW Bioenergy.’ The IGERT work (not completely described here) provided a pathway to establishing the baseline of information utilized for this MS thesis project.

The UW Bioenergy IGERT focused on partnering with three Northwest tribes, the Confederated Tribes of the Colville Reservation, the Confederated Salish Kootenai Tribes (CSKT), and the Yakama Nation. The specific goal of this partnership was to explore the development of bioenergy from locally based resources (e.g., Richardson et al. 2011). Between September 2009 and June 2010, I worked with an IGERT student group to assess biomass resources for the CSKT. My MS research developed out of this renewable energy work when I identified that the national mapping system was inaccurate for their tribal lands.

Before any research began, two critical steps needed to be completed. First and within the overarching goals of the Bioenergy IGERT, the general objectives of the IGERT needed to be presented to CSKT so that these objectives could be understood and modified to meet tribal concerns. The original objectives had to be transformed into the specific objectives of the Tribal Department of Forest Management and matched with the expertise of the team members assigned to partner with CSKT. Following a series of meetings, specific objectives were provided by the Tribal Department of Forest Management and these drove my MS research. The tribe asked that I:

1. Develop a method to incorporate local data into national programs that model fire and fuels, and
2. Develop a methodology that would allow for future modifications and inclusion of new data.

My task was to take these objectives and arrive at a product that met CSKT's needs. It was clear to me that to accomplish these objectives, datasets from different agencies, collected using potentially different spatial, temporal and technical scales, would need to be merged and provided to CSKT at a scale appropriate to their needs. Figure 1 provides an illustration of the steps I propose to take to create the modified fuelbed maps.

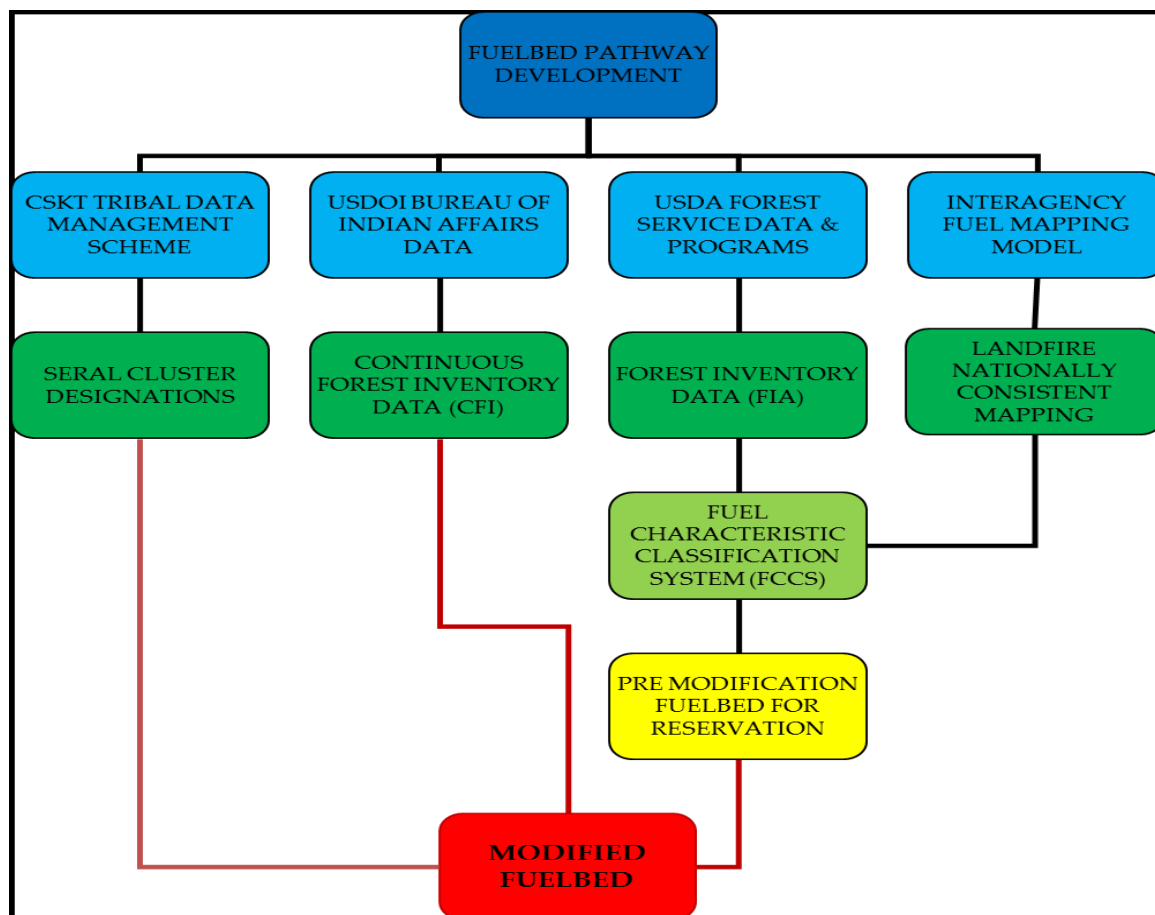


FIGURE 1. MODIFIED FUELBED PATHWAY FORMED BY CROSSWALKIN DATA FROM TRIBAL MANAGEMENT SCHEME, BIA DATA, USFS MODELING PROGRAM AND AN INTERAGENCY MAPPING SYSTEM

The “LANDIFRE” method served as a geospatial base for the IGERT program and allowed for inclusion of historical data, via the Bureau of Indian Affairs (BIA) Continuous Forest Inventory (CFI) database which I’ve now modified within this project using the Fuel Characteristic Classification System (FCCS). First, LANDFIRE data were established to begin queries into biomass data; at the same time I recognized a need to update and incorporate data local to the Confederated Salish & Kootenai Tribes (CSKT) into the national LANDFIRE database. Without the update recently incorporated LANDFIRE data into the CSKT management scheme would produce local estimates that were highly inaccurate when inserted into FCCS, CONSUME, BLUESKY and other USFS fire modeling and management tools. These USFS fire and fuel modeling programs utilize either the defined fuelbeds from FCCS and/or the LANDFIRE GIS coverage and provide numbers for biomass, smoke predictions, and air quality considerations that can be used for forest and fire operations. The use of these programs offer additional benefits to tribal operations including timber resource extraction for both the large scale timber harvests as well as small scale thinning projects, fire suppression and/or pre-suppression activities within the fuels program. This work was completed in a time in which timber markets and the closure of local processing facilities near the CSKT reservation made timber resource extraction at any scale expensive. Thus, the need to have finite, place-based estimates of resources was valuable.

Prior to my work a method to allow for such a crosswalk between BIA-CFI data with USFS—LANDFIRE and FCCS data had not been undertaken. The novel methodology described in this thesis can be used and expanded to serve all tribal forestry programs across the nation. The nationally consistent 30m high-resolution LANDFIRE datasets in combination with the nationally consistent BIA-CFI sampling protocols can serve as the geospatial base for data

modification for any of the tribal nations with forested resources in the US. This research explores the compatibility between the datasets, establishes the steps to complete the modification of existing FCCS fuelbeds to reflect CKST landscapes, and produces a new database that is designed to be compatible with other USFS programs. This project will open a new window of opportunities for the various branches of the CSKT tribal forestry operations including: forest management, wildlife habitat, fire, fuels, air quality, to name a few.

At the end of this thesis, the LANDFIRE datasets will be incorporated into the BIA system to establish fire and fuel funding allocations nationally. Thus, my research could serve as a national model in correcting and updating the LANDFIRE mapping for all tribal reservations across the country. This was an unintended outcome of this research that could not have been forecasted two years ago when my work on the IGERT project was initiated.

BACKGROUND

The IGERT program allowed me an opportunity to become familiar with the Flathead Indian Reservation. As a result, I was engaged with the Tribal Council and tribal forestry department and these engagements helped me gain a great understanding of the cultural, ecological and historical value that is embraced within the CSKT community. Based upon my engagement an understanding of how important the role of fire is to the people of this nation was achieved. The Confederated Salish and Kootenai tribes and the Flathead Indian Reservation were established by the Treaty of Hellgate (Stevens, 1855) in 1859 and include the Bitterroot Salish, Pend d'Oreille and Kootenai tribes. Today, the tribe identifies the treaty and the Allotment Act (24 Stat 388, ch 119, 25 USCA 331) as being two of the greatest disturbance factors to their culture and their lands. The tribe provides a modern day lesson in forest and fire ecology while defining and describing the resources available on their lands within their Forest Management Plan (CSKT,

2000). Ecological processes are meshed with management objectives to include historical and cultural considerations and these comprehensive view is presented on their website under their Fire History Project (Confederated Salish & Kootenai Tribes, n.d.).

The Flathead Indian Reservation boundaries encompass approximately 1.3 million total acres with approximately 459,000 of that in forested acres (Figure 2). Geographically speaking, the eastern boundary of the reservation is formed by the Mission Mountains; the Rattlesnake Mountains form the southeastern boundary; and the Reservation divide forms the southwestern boundary. The western boundary is defined by the eastern edge of the Cabinet Mountains and

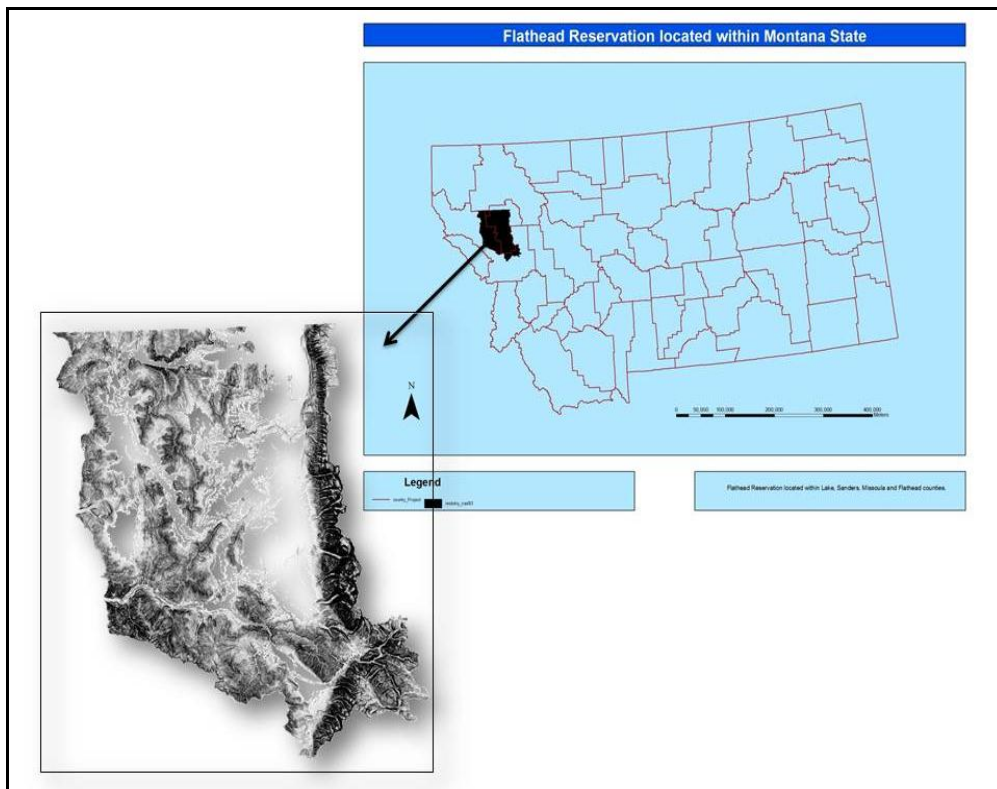


FIGURE 2. CONFEDERATED SALISH AND KOOTENAI TRIBAL RESERVATION, LOCATED IN NORTHWESTERN MONTANA STATE

the northern boundary extends from the Cabinet mountains east across Flathead Lake to the Mission Range.

The CSKT have spent a great amount of time in chronicling their fire history. One major product from their Fire History Project has been the development and publishing of an interactive web site entitled 'Fire on the Land: Native Peoples and Fire in the Northern Rockies' (Confederated Salish & Kootenai Tribes, n.d.). Evidenced gathered from the application of dendrochronology methodologies for dating traditional fire use on their lands suggests that at least 7,000 years ago aboriginal people were engaged in the use of fire as a management tool. Pictorial accounts of their use of fire date from the 1930's. During this time, landscape management existed for native peoples not as active management, but rather as an act of subsistence living. Burning practices of the late 1800's were a direct result of activities associated with the cultural ways of life that included tribal hunting, harvesting of wood, food and materials gathering, which included grasses, roots and berries. Because of seasonal nomadic movements that required tribal people to move up into and out of the mountains for their various resources while at the same time maintaining campsites and their homesteads fire was a part of their existence. Native cultures managed fire to meet their resource needs (Agee, 1993). However, the character of their lands began to change soon after the establishment of their reservation in 1859 when burning as part of a subsistence lifestyle was denied to them.

Scholarship in the last ten years in the U.S. has scrutinized native burning practices and their contributions to forest management and fire history (Kimmerer and Lake 2001, Sprenger and Dunwiddie 2011). Internationally, indigenous burning practices have been reviewed in many countries. The most notable examples of indigenous burning as a method of management in today's society may be found in Australia.

As early as the 1860's, indigenous burning was recognized in Australia (Russel-Smith et.al.). Thereafter, it is believed that the changes stemming from European settlement 'reduced

the capacity of indigenous groups to live within their traditional estates and carry out stewardship in accordance with their traditions' (Russel-Smith et.al., 2009). While indigenous knowledge, theory and practices are debated among forest managers it is known that European settlers played a large role in reshaping the landscapes in tribal communities around the world, directly and indirectly. In the US and on the Flathead Reservation, recent western policies and patterns of burning have shaped the landscape conditions of today. In gaining any understanding of the conditions of today, one needs to review the historical context that shaped these lands and how these conditions were altered over the last 100-plus years by non-natives.

While changes on the landscape were occurring on tribal lands changes were also taking place in the forests that surrounded tribal forests. Nationally, the historical context for fire and forest management begins with the establishment of what is now known as the US Forest Service. The origins of this agency stem back to 1891, when President Cleveland established a system of forest reserves that would later become the current system of national forests (Edmonds, 2011, 2000). In 1898, Gifford Pinchot, grandson of a Pennsylvanian timber baron, brought his European education in forest practices to the United States and became a prominent figure. He became known for timber management, especially for the concept of sustained yield practices throughout the western US. In 1898, Pinchot took the helm of the federal forestry program, which became the Bureau of Forestry in 1901 and the Forest Service in 1905 (Allison-Bunnell, 2002). He was eventually removed from office in 1910. There were some notable large fires that predated the establishment of the Forest Service (such as the Yacolt Burn of 1902); however, it was the "Big Burn" (Cohen, 1978) of 1910 that caused the greatest shift in policy and cost Pinchot his job. This fire burnt approximately 3 million acres in forests of northern Idaho and northwestern Montana. The fire's 2-day firestorm destroyed the

communities of Taft, Haugan, Henderson and DeBorgia killing 85 people (Agee, 1993) including 78 firefighters (Allison-Bunnell, 2002) . In 1935, the '10 AM Policy' (Edmonds, 2011, 2000) became the adopted fire policy that would remain intact for at least, the next 40 years. In later years, policy revisions addressing appropriate response and flexible suppression responses would lead to 'integrated fire management which essentially began a period of site-specific suppression tactics (Edmonds, 2011).

At around the same time in the early part of the 20th century, new forest policies began to take shape and shift the focus around forest management. Furthermore, developments in environmental policies were paralleling those in timber management. In 1904, President T. Roosevelt appointed Joseph Holmes, Director of the US Bureau of Mines to a new position as the Director of US Geological Survey (LeCain, 2009). Holmes was a friend and supporter of Gifford Pinchot and he also shared Pinchot's beliefs pertaining to governmental—private industry partnerships. While at the US Bureau of mines Holmes had begun to recruit and develop metrics for air pollution. As a new agency methods to measure, map and identify a scientific set of standards was necessary if the mining industry would have any type of control in the terrestrial environment. This paralleled needs in the timber industry. The managerial schemes and desired outcomes for some type of control of the forested, terrestrial environment were similar concerns for the Forest Service. Now fire control and suppression went to a policy of total fire exclusion (Figure 3 illustrates these events).

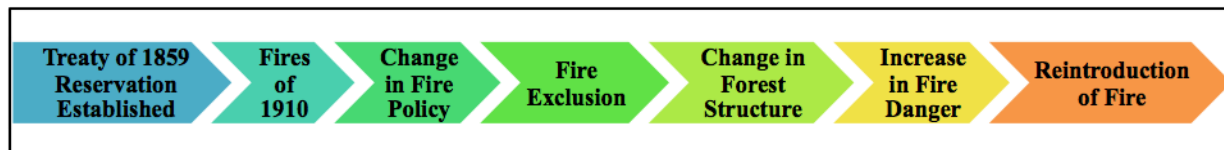


FIGURE 3. HISTORICAL ACCOUNTING OF FOREST CHANGE ON THE CONFEDERATED SALISH AND KOOTENAI TRIBES' RESERVATION

By 1930, the impacts of fire exclusion and the halt of indigenous burning could be seen on the landscape (Confederated Salish & Kootenai Tribes, Fire History Website). The tribe attributes the current loss of diversity, loss of grassland habitat, and loss of forage, along with the increase in tree density and change in forest structure to this almost 100-year policy of fire exclusion. The impacts to their tribal lands, as well as to other western tribal lands, of a century of fire exclusion have been clearly documented (http://www.cskt.org/fire_history.swf).

Changes on the landscape are summarized below.

1. Mid to lower elevations:
 - a. Loss of grassland habitat occurred as fire exclusion allows for tree encroachment
 - b. The open park-like ponderosa pine stands have become replaced with dense young, multi-species stands that are susceptible to insect and disease outbreaks, increased fire hazard and changes in habitat.
 - c. Loss of foraging habitat, occurs with the loss of grassland habitat and increasing tree densities.
2. Impacts on higher elevation forest types: Whitebark pine stands have transitioned to lodgepole pine and subalpine fir resulting in loss of habitat for grizzly and black bears and Clark's nutcrackers
3. Species composition, across the landscape has changed in the last 50-100 years.
4. Without fire: Climax species like Douglas-fir (moderately shade tolerant) have encroached upon ponderosa pine (shade intolerant, seral species) and will eventually outcompete and replace the pine stands on the landscape.

In plant ecology, changes in species composition over time are recognized and best described as ‘Forest Succession.’ The changes that occur with succession can be placed in structural (e.g., stand development: initiation, stem exclusion, understory re-initiation, mature, old growth [Oliver and Larson 1996]) and component contexts (e.g., habitat type). Habitat type describes the dominant overstory tree and understory shrub/herbaceous occurring at a given location in time and space. Furthermore, certain habitat types are recognized by the potential changes in successional patterns when fire is excluded. For example, within many ponderosa pine habitat types that have had fire exclusion, there is a transition in forest succession from ponderosa pine stands, to Douglas-fir / Douglas-fir – grand fir stands (Agee 1992, Crane and Fischer 1986).

The Confederated Salish – Kootenai Tribe has identified an ecological pattern of succession within their forest management plan (CSKT, 2000) and it is illustrated in Figure 4. The development of the concept of succession is discussed at some length in the following paragraphs. An understanding of the historical and ecological context for defining a forest is essential for understanding the role of fire in that environment. Simply stated, forest succession is defined as forest change over time or the ‘replacement of one plant community or forest type, by another (Daniel, 1952). Academically, succession is defined as the “...universal process of directional change in vegetation during ecological time. It can be recognized by a progressive change in species composition of the community” (Krebs, 1994). Additionally, succession can be defined as “the process of change from grassland to forest, or vice versa.” (Edmonds, 2011, 2000) There are two distinct classes of succession; primary and secondary. Secondary succession is the most common. It is rare to find a portion of the landscape that is in the stage of primary succession (obvious exceptions are on recently deglaciated areas in the Cascades and on

the pyroclastic flows of Mt. St. Helens). Secondary succession is a successional pattern that is present after the landscape has been disturbed. These associations are all temporary in nature and require knowledge or determination of historical presence in order to identify the current stage of succession or stand development, as shown in Figure 4.

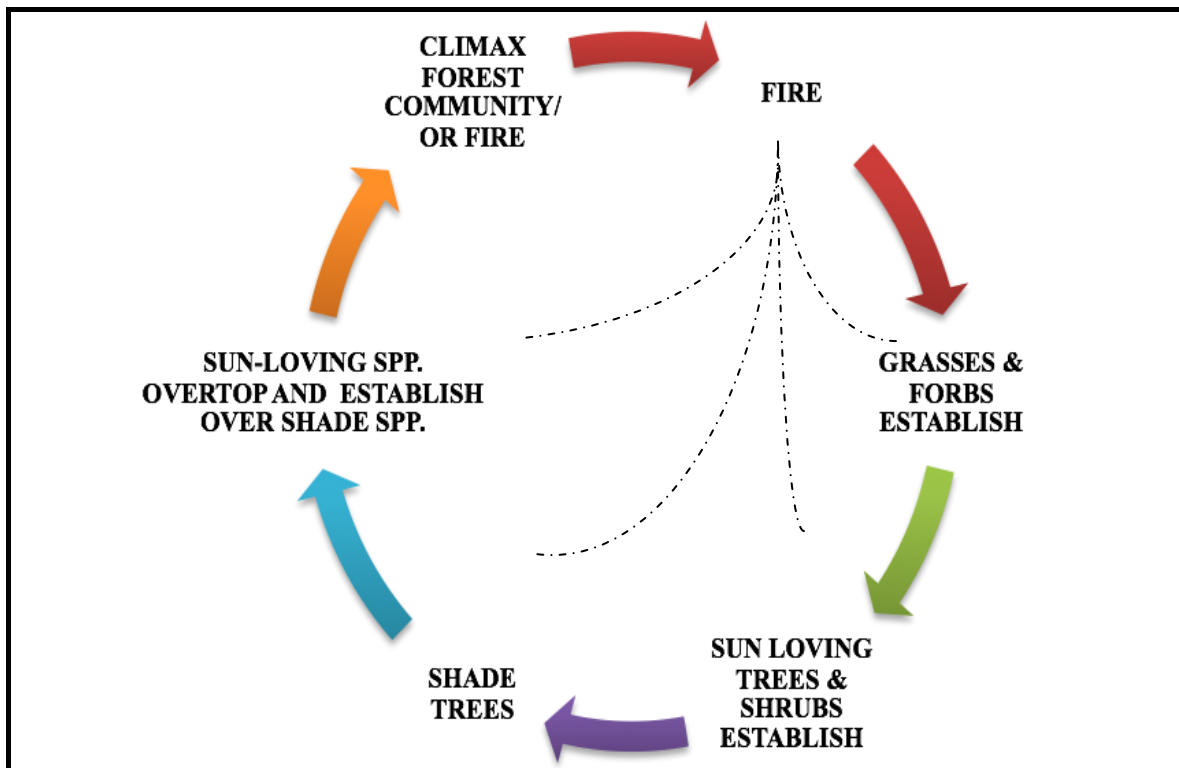


FIGURE 4. SUCCESSIONAL PATTERNS IDENTIFIED FOR TEH CONFEDERATED SALISH AND KOOTENAI TRIBE. INTERIOR SUCCESSIONAL PATTERN (LOOP), IDENTIFY POSSIBLE CYCLES THAT CAN BE FOUND IN A FIRE MAINTAINED SYSTEM

The history of the successional theory begins with the ‘monoclimax’ theory, developed by F.E. Clements in 1916 (Krebs, 1994). This theory assumes that “1) regional macroclimate determines the endpoint of succession (climatic climax); 2) there is only one community, capable of self-perpetuation through regeneration and composed of only one dominant life-form that would eventually dominate the site (hence, monoclimax); and 3) that all other communities now present were in the process of altering their environments, making them more suitable for the

next community “stop” on the successional railroad (called autogenic succession), with the last stop being climatic climax.”(Agee, 1993)

In contrast to the successional theory is the individualistic theory developed by H.A. Gleason in 1926. This theory focused on the notion that there was no set plant ‘community structure’; rather, it was described as, “aggregations of individual species, each with unique character, and largely unpredictable” (Edmonds, 2011, 2000). The Polyclimax theory was developed by A.G. Tansley in 1924. This theory bridged the monclimax and individualistic theories of succession by defining multiple climaxes such as fire climax, biotic climaxes (meadows maintained by grazing), and edaphic climaxes (serpentine soils). In this theory, succession was represented as a mosaic of climax communities as opposed to a single climax community (Agee, 1993). In order for the fire climax forest to exist, there must be fires within the range of frequency and intensity that supported that particular fire climax. With fire suppression and exclusion sequences the successional forest types shown in Figure 4 (above) is altered.

These theories were later modified to include ‘the climax pattern’, developed by R. H. Whittaker in 1953, later recognized as the ‘prevailing climax.’ This modification was never widely used and was specific to the Siskiyou Mountains of Southwest Oregon and NW California. The habitat type concept of R.F. Daubenmire, in 1952, represented another modification of the polyclimax theory. This concept focused on primarily forest and rangeland plant associations of the Pacific Northwest, was widely accepted, and is currently used. The single greatest example of a collection of Daubenmire’s work are the plant associations that are recognized within the *Natural Vegetation of Oregon and Washington* (Franklin and Dyness 1973, 1981)

We do not live in a static environment and there are many pathways to succession that are shaped by disturbance factors within our environment. Fire is one of those factors and it has led to multiple successional pathways. For any given region, successional pathways are defined via the habitat typing associations. Forested plant associations for the Flathead Reservation have not been defined locally; however, there are associations that have been determined regionally via the *Fire Ecology of Montana Forest Habitat Types East of the Continental Divide* (Clayton, 1983). This document draws from a wide range of previously published work regarding habitat types/associations in Montana (Pfister et.al., 1977, Roberts, 1980, and Sibbersen, 1979). Habitat types are designated using a “plant series/type” formation. The series is defined by the dominant (climax) tree species in the stand and “type” refers to the understory vegetative component. Combining Clayton and Fisher’s (1983) document with information from the tribe regarding known tree species and their spatial distribution is assumed to be sufficient to determine a reasonable assessment of forested plant associations of the Flathead Reservation (Appendix B). Tree species identified for the Flathead Reservation are presented in Table 1.

TABLE 1. TIMBER TYPES FOUND ON THE TRIBAL RESERVATION FOR THE CONFEDERATED SALISH AND KOOTENAI TRIBES

Species	Scientific name
Ponderosa pine	<i>Pinus ponderosa</i>
Rocky mountain juniper	<i>Juniperus scopulorum</i>
Douglas fir	<i>Pseudotsuga menziesii</i>
Engelmann spruce	<i>Picea englemannii</i>
Western larch	<i>Larix occidentalis</i>
Lodgepole pine	<i>Pinus contorta</i>
Whitebark pine	<i>Pinus albicaulis</i>
Subalpine fir	<i>Abies lasiocarpa</i>
Mountain hemlock	<i>Tsuga mertensiana</i>
Western white pine	<i>Pinus monticola</i>
Grand fir	<i>Abies grandis</i>
Western hemlock	<i>Tsuga heterophylla</i>
Western red cedar	<i>Thuja plicata</i>
Alpine larch	<i>Larix lyallii</i>

Timber types found on the Flathead Reservation have been defined by the tribe (Confederated Salish & Kootenai Tribes, 2000) and have also been identified and described in the surrounding national forest stands (Lolo National Forest 1983).

Once the forested plant associations are known at the landscape scale, successional pathway predictions at a general scale can be made based upon the autecology of the species within the stand. This level of prediction is considered 'general' because disturbance factors such as fire and floods, also impact the successional pathway. The Flathead Reservation has adapted their plant association information, originally taken from the *Fire Ecology of Montana Forest Habitat Types East of the Continental Divide* (Clayton and Fisher, 1983), by including information from their CFI Plot data, which were cross referenced with this guide. A list of all of the plant associations found on the Flathead Reservation are found in Appendix B.

Fire history has shaped forests across our entire country although active fire and fire exclusion have had a major role in forest succession patterns as well. Knowing the autecology of the species within a forest community allows for more accurate predictions about the response of a given tree species or stand to fire. When fire is a disturbance factor within an environment, a series of species traits or responses appear adaptive. These are listed in Table 2. Stands are dynamic and so are fires burning at varying level of intensities and at different frequencies. Therefore, the information in Table 2 can help in understanding the different responses to fire response for particular species. It must be noted that these responses are highly dependent upon a number of abiotic and biotic factors including the nature of the fire.

TABLE 2. SELECTED EXAMPLES OF FIRE ADAPTATIONS AND VEGETATION RESPONSE (EDMONDS)

Trait	Function	Example of Species
<i>Seed Bank</i>		
Soil	Hard coated seeds remain dormant in soil until fire disturbance	Ceanothus, manzanitas
Tree crown	Late opening, or serotinous cones, remain closed in crown until crown fire.	Lodgepole pine, Black spruce
Thick bark	Protects cambium against heat from fire	Ponderosa pine, Giant sequoia
<i>Sprouting</i>		
Epicormic	Regrowth from dormant buds protected by bark on branches and bole	Oaks, Coast redwood
Basal sprouting	Resprouting from roots, basal buds, rhizomes, lignotubers	Oaks, aspens
<i>Other traits</i>		
Fire stimulated flowering	Increased reproductive effort in immediate postfire years	Grasses, Forbs
Rapid growth	Raises apical meristem above typical fire scorch height	Longleaf pine
Wind borne seeds	Allows colonization of interiors of large burns	Fireweed, Aspen

Fire intensity is defined as a measure of energy/magnitude output of fire. When placing fire into a complex environment one must understand the components of fire intensity and these include fuel consumption and rate of spread. In order to translate fire intensity into fire severity, managers utilize these factors to predict burn severity at the surface and at mid- and upper-canopy layers. This translation requires myriad of mathematical equations, computer programs and computer models from which one might then have sufficient information about burn severity and fire behavior to predict the likelihood of damage and mortality for a given environment, forest stand or particular species.

The term fire regime results from the effects of multiple fires on the forested plant community. If fire was the only disturbance factor to consider it would be a lot easier to make

predictions within these forested environments. Unfortunately, the frequency and severity of fires are not standardized since they are heavily influenced by local topography and the nature of the fuels (structure and type) within the stand, which are variable across the landscape. Fire Regime, has been defined as "...the basic personality of fire for a given vegetation type" (D. Havlina). Fire regimes combine the effects of fire disturbance into broad categories of fire severity based on physical characteristics of historical fire severity and the adaptation of vegetation. Fire regimes are classified as low, mixed and high severity (Edmonds, 2011, 2000). For example, a Ponderosa pine forest is characterized as a low severity, low intensity fire regime (Agee 1993), with a fire return interval of 11-16 years (Edmonds, 2011, 2000).

A great amount of research has been completed in regards to fire regimes (Arno et.al., 2000) (Morgan et.al., 2001) (Swetnam, 1995) (Heyerdahl, 2001) (Falk et.al., 2007). The tribe has applied modern principles via their landscape designation of fire regime scenarios for their reservation (see Figure 5). Their approach mimics approaches used widely by other land managers and represents the stages of severity. In order to move towards management of a given landscape knowledge of how the vegetative component will respond to management via fire (suppression or pre-suppression) on the landscape is essential. The fire regime information gives land managers some scenarios that help predict or react.

The topographic location of fire regimes on the landscapes portrayed in Figure 5 assists in identifying how topography, species and the autecological response of the individual species within the stand can result in complex responses especially when faced with different fire regime scenarios (see Table 3). Decades of fire exclusion have led to the need to develop this type of schematic, which captures a measure of fire intensity and severity as well as the degree of departure from the reference condition established for the area/stand/landscape. This schematic

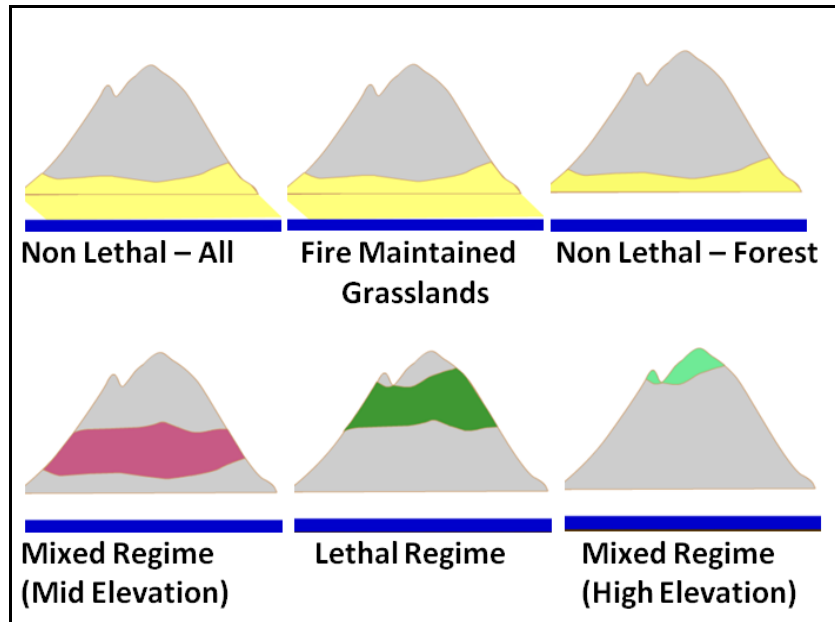


FIGURE 5. CONFEDERATED SALISH AND KOOTENAI TRIBES FIRE REGIME CLASSIFICATIONS FOR THEIR RESERVATION (CSKT FIRE HISTORY WEBSITE)

became the Fire Regime Condition Class (FRCC). Once the fire regime information is known for a portion of the landscape, further study can help determine how disturbance has impacted those lands in order to better predict future events. The FRCC principle is defined via the Forest Service in 3 categories. The FRCC, are typically described in 3 major stages:

1. Class 1: 0-33% departure from average reference condition
2. Class 2: 34-66% departure from average reference condition
3. Class 3: 67-100% departure from average reference condition

The Salish-Kootenai Tribe has described their fire regime information within their forest management plan as follows (Table 3).

TABLE 3. FIRE REGIME DESCRIPTIONS FOR THE CONFEDERATED SALISH AND KOOTENAI TRIBES

	Nonlethal Fire Regime (& Encroached Areas)	Mixed Fire Regime	Lethal Fire Regime	Timberline Fire Regime
Habitat	Dry P. Pine, Dry D.Fir	W.Moist D. Fir, Cool/DryLarch, D.Fir	G.L. P. Pine, Fir, Spruce and Warm S. A. Fir	W. B. Pine and L. P. Pine Cold S. A. Fir
Fuels	Grass and Litter	Grass, Shrubs and Regen.	Regen. and Downfall	Grass, Shrubs and Downfall
Location	Low to Mid-Elevations, Mild Slopes, SE-W Aspects	Low to Mid-Elevations, All Slopes, All Aspects	Mid-to High Elevations, Steep Slopes, All Aspects	High Elevations, All Slopes, All Aspects
Structure	Large Trees, Old Growth, Closed Canopy, Uneven-aged, Seral Stands	Mature Trees, Open/Closed Canopy, Mosaic, Mixed Seral Stands	Mature Trees & Old Growth Closed Canopy, Even-aged, Seral Stands	Mature Trees, Open/Closed Canopy, Mosaic, Climax Stands
Fire Occurrence	Short Interval 5 - 30 years	Variable Interval 30 -100 years	Long Interval 70 - 500 years	Variable Interval 30 -500 years
Fire Behavior	Low Intensity, Large Size, Short Duration	Variable Intensity, Variable Size, Moder. Duration	High Intensity, Large Size, Long Duration	Variable Intensity, Variable Size, Short Duration
Typical Areas	Dry Fork, Jette, Stevens, Seepay, Little Money	Garceau, Hell Roaring, La Moose	Dog Lake, Boulder, S. Fork Jocko, Revais Creek	Moss Pk, Ninemile Divide, Top of Mission Range

Intensive data capture via the FRCC methodologies described in the *Interagency FRCC Guidebook* (Barrett et.al., 2010), has not locally been applied to the Confederated Salish and Kootenai tribal lands; however, information pertaining to the nationwide designations has been captured and included for this study, further described in Table 4. I have incorporated the FRCC

designations available via the LANDFIRE CD (USGS) into the landscape and fuelbed geospatial data layers. Fires have occurred on tribal lands, thus a more detailed study, such as the one described in the FRCC guidebook, could be considered.

TABLE 4. FIRE NAMES AND ACREAGES FOR FIRES IMPACTING TRIBAL LANDS BETWEEN 1994-2007

FIRE	YEAR	ON-RESERVATION	OFF-RESERVATION	TOTAL ACREAGE
Jocko Lakes	2007	36,059	0	38,066
Garceau	2007	3,048	0	5,055
Black Cat	2007	11,757	0	13,764
Chippy Creek	2007	99,524	0	101,531
Ashley Lakes	2006	3,040	0	5,046
Seepay 2	2005	8,198	0	10,203
Mollman	2003	114	0	2117
Crazy Horse	2003	0	11,098	13,101
Mineral Prim Complex	2003	0	16,517	18,520
Irvine	2000	76	0	2076
Clear Creek Divide	2000	14,458	50	16,508
Seepay	2000	7,837	3	9,840
Ninemile Divide Complex	2000	17,911	3,615	23,526
Schley	2000	0	431	2431
Boyer	1998	0	848	2846
Niarada	1994	0	4,345	6,339
Jammer	1981	0	54	2035
Total		202,022	36,961	273,004

Disturbance and active fires (Figure 6) have not only shaped the current environment on the Flathead Reservation, but continue to play a vital role in the future management scenarios that encompass tribal values and traditional practices within forestry, fire and fuels management. With this working knowledge of forest and fire ecology I will incorporate and reflect current conditions utilizing a tool developed by the USFS to define wildland fire ‘Fuelbeds’. This work will eventually help predict fire, smoke, and air quality on tribal lands as well.

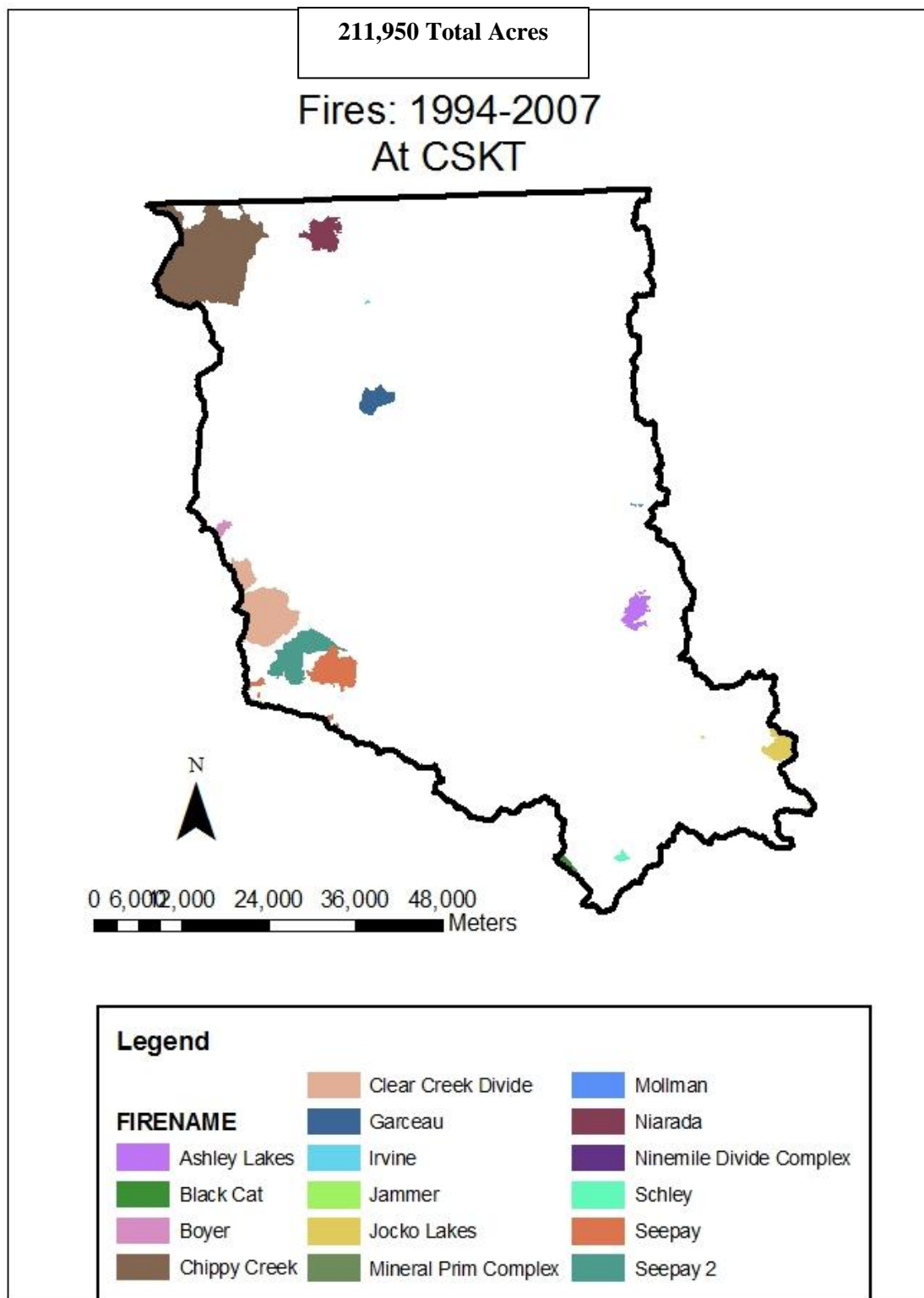


FIGURE 6. MAJOR FIRES OCCURRING ON THE FLATHEAD RESERVATION 1994-2007

RESEARCH GOALS AND OBJECTIVES

The goal of this work was to create a tangible work product that builds upon the protocols established by the Bureau of Indian Affairs to create an updated, computerized methodology of meshing forest inventory datasets with the nationally available USFS programs such as FCCS (USFS PNW FERA). In doing so, this revised dataset will allow for better predictions utilizing USFS, forest, fire and potentially smoke management tools. Based upon this work future application of this data can be utilized to:

1. Update and incorporate locally available CFI data,
2. Complete datasets to help inform management via translation of FCCS Fuelbed to Fire Behavior and Fire Effects and within BEHAVE, CONSUME and BLUESKY, Measureable outcomes will be: A) Fire Potential, B) Fire Behavior (Rate of Spread, Flame Length and Fire Intensity) for use in fire management.

I will begin with extracting the LANDFIRE (USGS) National consistent 30M dataset for the Confederated Salish and Kootenai reservation extent providing the FCCS pre-modification fuelbeds for the entire reservation. This will be completed within the ARCInfo v.9.2 Geographic Information Systems (GIS) mapping platform. Once a GIS base has been established, I will incorporate CFI information into the GIS shapefile data table, further including other tribally provided landscape designations such as seral cluster, fire regime and landscape boundaries. Once this information is completed, I will have the framework for modification of the Fuelbed, within the FCCS program (Figure 7).

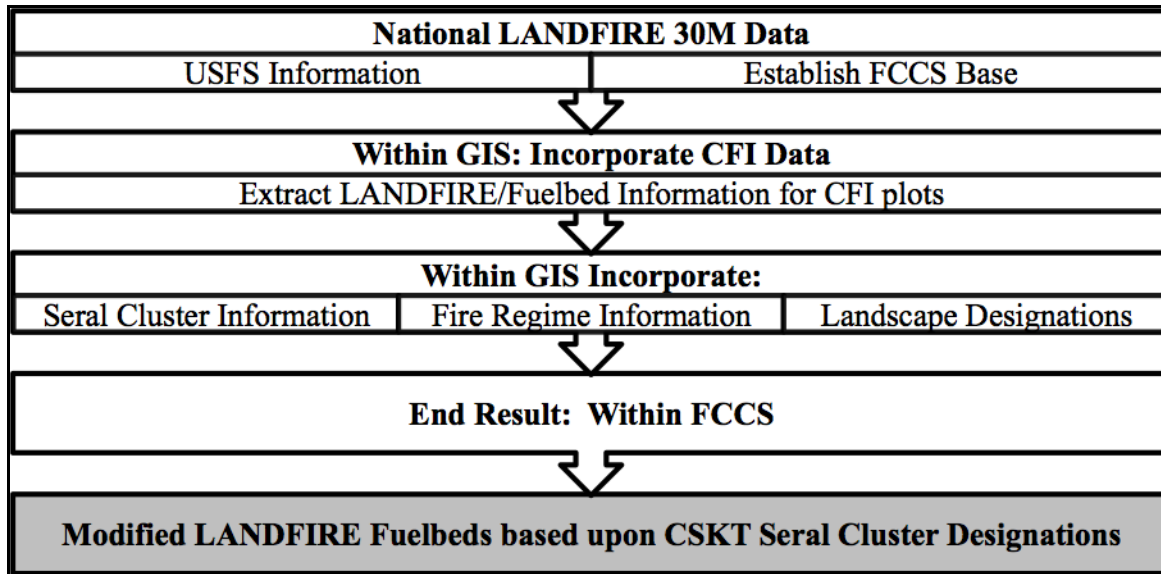


FIGURE 7. STEPS TO ACHIEVING THE FCCS MODIFIED FUELBED

NEED FOR A MODIFIED FUELBED

Aside from the need to reflect actual site conditions, the methodology shown in Figure 7 will allow for greater expansion and application of current and historic plot data from software programs developed by the Nature Conservancy and other land managers (USGS) to work in conjunction with FCCS. These programs are readily available for incorporation into the tribal management system and, with training and development of forestry personnel, a host of additional forest and fire management scenarios not possible before this modification can now be achieved. This could essential change and greatly enhance forest management capabilities across a broad spectrum of forest management operations. Outcomes of the modification process include timber forecasting, forest biomass availability, and smoke predictions to assist forest management activities such as burning, and probably the most important, predictions about fire intensity levels that could assist approaches to forest fire response. Finally, this modification and

the associated improved prediction of fuelbeds should result in corresponding improvements in the allocation of financial resources across Indian lands by the BIA.

MODIFICATION OF FCCS USING CFI DATASETS

The analysis of data will begin with the extraction of all data for lands within the boundaries of the CSKT reservation; this would include portions of zone 19 and zone 10 of the national Landfire zone map. Stemming from the original mapping unmodified FCCS data will be recorded to allow for a baseline assessment of pre-existing conditions as well as providing a base to work from while completing this assessment. All CFI plot data information will be incorporated into the FCCS program including Seral Class Information (Dominant Tree Size, Density measured via Canopy Cover, Overstory Seral Species and Understory vegetation condition). Other variables included in the FCCS definitions are Mode, Ecoregion, Fuelbed #, CFI Plot #.

HIERARCHICAL FRAMEWORK FOR FUELBED MODIFICATION

At the request of the tribe a hierarchy was determined to reflect this particular order of their land classifications on their reservation:

Seral Cluster → Fire Regime → Landscape = *New Fuelbed*

Within this study, I have defined fuelbeds within FCCS utilizing the seral cluster designation and have tacked on the fire regime information within the same geospatial dataset; all are mapped at the CSKT 'landscape' scale.

'SERAL CLUSTER' DESIGNATION ON TRIBAL LANDS

A seral cluster is a group of seral classes which is a simplistic method for classifying timber and vegetation, based upon structure and composition. Variables identified within the seral class designations include:

- size and age for trees, for the most dominant tree layer (first number in CSKT seral designations)
 - 1 = 0 – 4.9 inches
 - 2 = 5 – 9.9 inches
 - 3 = 10 – 20.9 inches
 - 5 = 21 + inches
 - Size Class 4 was not independently established, rather, it was lumped in with size class 3 due to the inability to distinguish from satellite imagery (CSKT FMP)
- stand density (canopy closure) (second number in CSKT seral designations)
 - 1 = 0 – 39% CC
 - 2 = 40 – 69% CC
 - 3 = 70+
- determination of multi or single storied stand and determination of shade tolerant (climax – third number in CSKT seral designations) or shade intolerant (seral – fourth number in CSKT seral designations) species. So the key is utilized for the last two number of the code, for both overstory and understory.
 - 0 = no trees
 - 1 = at least 75% of stand , seral species

- 2 = between 25 & 75% of stand, seral species
- 3 = at least 75% of stand, climax species

The classification methodology above assigns a code for each of the 4 variables resulting in a seral class code which is used within database and mapping protocols. An example of this methodology would be: *EXAMPLE: Seral Class Code = 3230 =*

Size (i.e., age) of most dominant tree layer is 10-20.9 inches; 70%+ canopy closure, 25-75% with 25-75% of stand containing seral species in overstory and no trees in the understory.

Seral Cluster designations for the Flathead Reservation range from A (A1, A2) to L with thirteen categories in all (Table 5).

TABLE 5. SERAL CLUSTER CLASSIFICATION AND ASSOCIATED STAND DESCRIPTION

CLUSTER	DESCRIPTION
Cluster A	Cluster A1: Young and recently disturbed, open canopy, mostly pine & larch
	Cluster A2: Mature and old, frequently disturbed, open canopy, mostly pine and larch
Cluster B	Young, undisturbed since regeneration, moderate canopy, mostly fir
Cluster C	Young, frequently disturbed to undisturbed, moderate canopy, mostly pine and larch
Cluster D	Young, frequently disturbed to undisturbed, closed canopy, mostly pine and larch
Cluster E	Mature undisturbed, moderate canopy mostly fir and spruce
Cluster F	Mature, undisturbed, moderate canopy, mostly pine and larch. Potential lodgepole pine old growth.
Cluster G	Mature, less frequently disturbed, closed canopy, mostly pine and larch. Potential for lodgepole pine old growth.
Cluster H	Mature, undisturbed, closed canopy, mostly fir and spruce
Cluster I	Old, undisturbed, moderate canopy, mostly fir and spruce. Potential for old growth.
Cluster J	Old, undisturbed, moderate canopy, mostly pine and larch. Potential for old growth.
Cluster K	Old, undisturbed, closed canopy, mostly pine and larch. Potential for old growth.
Cluster L	Old, undisturbed, closed canopy, mostly fir and spruce. Potential for old growth.

After describing the seral class codes the ease and simplicity of seral cluster designations can be seen. Seral cluster designation key, created for this research can be found in Appendix C.

FIRE REGIME INFORMATION

As described in earlier sections, the FRCC information was extracted via the LANDFIRE datasets to be included in the database for this study (Table 6). I did not try to utilize the CSKT fire regime designations are already established for their landscape. However, if a full transition is to be made to enable the utilization of all the fire and smoke tools available from the USFS and other fire partners, then the standard definitions may need to be utilized. In addition, since the tribe has a methodology in place and does not have a record of the national designations, this will give them additional resources in determining FRCC codes into the future. If desired, the tribe could employ methodologies for data collection that are described in the FRCC handbook that could help to definitively measure FRCC at the stand and landscape levels. In addition, measurements that are collected for that type of work could greatly enhance data that are entered into the FCCS platform. This would result in greater accuracy within the FCCS output reports.

TABLE 6. FIRE REGIME CONDITION CLASS CATEGORIES

Fire Regime Condition Class (FRCC) - Descriptions		
Code	Label	Description
1	Fire Regime Condition Class I	Low Vegetation Departure
2	Fire Regime Condition Class II	Moderate Vegetation Departure
3	Fire Regime Condition Class III	High Vegetation Departure
111	Water	Water
112	Snow/Ice	Snow/Ice
120	Urban	Urban
131	Barren	Barren
132	Sparsely Vegetated	Sparsely Vegetated
180	Agriculture	Agriculture

It is also my belief that since the reservation is not a static environment additional modifications and/or exclusion of these federal FRCC codes could be switched out with local FRCC type numbers when the updated CFI information is completed. This should occur after my study is complete.

LANDSCAPE DESIGNATIONS FOR CSKT

The reservation is divided into 6 Landscape classifications (Figure 8). As described within the Forest Management Plan, the six classifications are the 1) Salish Mountains, 2) North Missions,

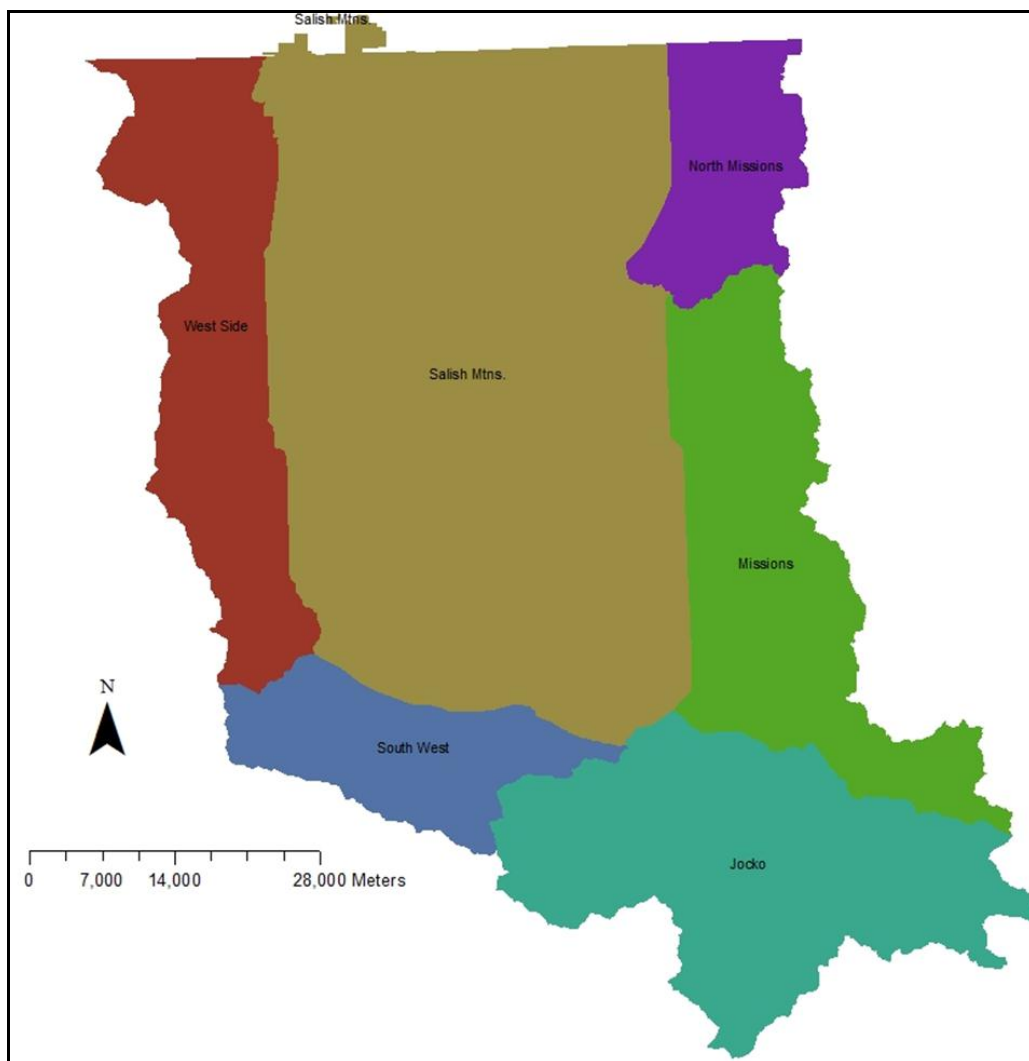


FIGURE 7. LANDSCAPE CLASSIFICATIONS ON THE CONFEDERATED SALISH AND KOOTENAI TRIBES RESERVATION

3) Mission, 4) Jocko, 5) South West and 6) West Side landscape designations.

METHODS

Pre Modification Conditions were established for this Flathead Reservation via extraction of LANDFIRE data from the data CDs (USGS).

1. To begin, LANDFIRE data stemming from ‘Landfire National Data CDs’ (USGS) were gathered for both zone 19 and zone 10.
2. Extraction of fuelbed characteristics occurred at each of the 442 CFI plots within ArcGIS v.9.2 resulting in 24 fuel bed types (see Table 7)

TABLE 7. ORIGINAL FUELBED DESIGNATIONS STEMMING FROM LANDFIRE CLASSIFICATIONS WITHIN FCCS (PRE MODIFICATION)

Pre Modification Fuelbed Types	
22	Lodgepole Pine
28	Pondersoa Pine Savanna
41	Idaho Fescue - Bluebunch Wheatgrass grassland
42	Quaking Aspen/Englemann Spruce Forest
52	Douglas fir - Pacific Ponderosa pine - Oceanspray
54	Douglas fir - White fir - Interior Ponderos pine forest
55	Western juniper - Sagebrush savanna
56	Sagebrush shrubland
57	Wheatgrass - Cheatgrass grassland
59	Subalpine fir - Englemann spruce - Douglas fir - Lodgepole pine
61	Whitebark pine - Subalpine fir forest
66	Bluebunch wheatgrass - bluegrass grassland
224	Quaking aspen forest
237	Huckleberry - Heather shrubland
286	Limber pine - Interior Ponderosa pine
302	Intermountain montane - Subalpine riparian
304	Conifer swamp
305	Red alder
308	Low Sagebrush
311	Salt - desert shrub
313	Mountain mahogany
315	Interior alpine forb grass
319	North pacific avalanche chute shrubland
320	Western larch forest alliance

3. Extraction of LANDFIRE, FCCS data was completed for the Flathead Reservation utilizing Xtools Pro (Data East, LLC).
4. Extraction of FRCC data was completed for the Flathead Reservation utilizing Xtools Pro.
5. A shapefile representing LANDSCAPE designations was provided by the tribe.
6. A seral cluster shapefile was provided by the tribe.
7. Next, the CFI was obtained from the BIA data CD.
 - a. A text file was created containing all the plot information (from the raw data, excel files) then plotted within GIS.

Dataflow

Text files created from each of the fuelbeds within ArcGIS were categorized to provide numbers/acreages to reflect pre modification data. The modification of datasets began with the following steps:

1. Seral Cluster data information were merged with all extraction files within ArcGIS 9.2 resulting in one data table containing: X (coord.), Y (coord), CFI_PLOT, FUELBED, FUEL_LOAD, CLUSTER, SIZE CLASS, CROWN_DENSITY, SERAL_OVER, SERAL_UNDER, FRCC, LABEL, LIVE_TREE, AVG_DBH, BA, FT3_PACRE, BDFT_PACRE, NET_BDFT, SERAL_NUM
2. The resulting data table was exported to a text file and imported into Excel.
3. Once in Excel, data files were merged with CFI data
 - a. CFI plot data was extracted from the tribally provided CFI Program CD. %Cover, Density, Tree Height, DBH and Species

(Overstory) (Understory), Fuel Model and Dominant Habitat Type information was extracted for each plot from the “fltlive” and “fltplotd” Excel files.

- b. The resultant Excel files, were divided by seral cluster type (which is the new format for fuelbed designations) with CFI information. This provided an Excel workbook for each Seral cluster with 3 Excel files contained within PLOT INFO, LIVEDAT and PLD information for each Cluster/Fuelbed.

These steps were utilized to segregate the massive amounts of data available within the CFI information. It organized the fuelbed inputs for the FCCS program. A fuelbed form was created to establish FCCS inputs (Figure 9 below). The resulting fuelbed data file were original Fuelbed files driven by seral cluster designations. The following steps were then performed:

1. CFI plots were categorized, per seral cluster
2. Fire Regime Condition Class designation were identified per plot

FB#									
MOD4	mode			min			max		
percent cover									
height									
hgt to live crown									
density									
dbh									
species									
122 ppine (age unk)									
137 ppine (OG)									
136 ppine (2ndGrowth)									
202 dfir									
73 western larch									
108 lppine									
19 alpine fir									
17 grand fir									
119 western white pine									
242 western red cedar									
101 whitebark pine									
264 mtn hemlock									
231 pacific yew									
370 birch									
746 aspen									
747 black cottonwood									
990 other hardwoods									
0 unknown									
Fuel Model									
dom hab type									
Description									

FIGURE 8. FUELBED FORM USED TO EXTRACT DATA FROM CONTINUOUS FOREST INVENTORY DATA

THE FUEL CHARACTERISTIC AND CLASSIFICATION SYSTEM (FCCS)



In a broad sense, the FCCS program establishes a standardized set of over 200 (Riccardi et.al., 2007) fuelbeds across the country that attempt to quantify fuelbed information for fire effects models (Riccardi et.al., 2007, Ottmar et.al., 2007). These fuelbeds reflect both landscape and environmental variables that measure fire behavior and fire hazard potential while allowing for a methodology that addresses complexity and diversity of wildland fuels for a given target area. Within this FCCS software program, continued modification to account for actual site conditions as a result of forest succession, disturbance and other forest management activities is

allowed. Fuelbeds can be modified to account for particular management or research objectives using photo series, fuel inventories or other fuel data sources (Riccardi et.al., 2007). Each modification is performed by inputting site specific characteristics related to percent cover, depth, height, height to live crown, percent live foliar moisture content, density, diameter at breast height (DBH), loading live, loading dead, fuel area index (dimensionless index of fuel surface area, analogous to leaf area index), packing ratio and optimum packing ratio (Ottmar et.al., 2007). The fuelbed is divided into six major categories that help define the fuel characteristic, including: trees, shrubs, grasses, woody surface fuels, litter (Oi soil horizon) and duff (Oe and Oa soil horizons) with each category further subdivided into subcategories that pertain to combustion properties of the fuel types (Riccardi et.al., 2007). All in all, there are a total of 18 fuelbed categories and 20 subcategories that produce FCCS ‘output’ reports that include: 1) fuel characteristics 2) surface fire behavior and 3) fire potential. These reports also provide a record of emissions and carbon outputs.

For this work, CFI data were utilized to provide specific information for the Flathead Reservation. The specific ‘input’ type described within FCCS literature utilizes the primary structural class and cover type based upon dominant vegetation in combination with seral class designations specific to the Flathead Reservation. This combination of data is possible since the fuelbed FCCS inputs allows for the inclusion of site specific data while the ‘inferred’ variables contained within FCCS are built upon the premise of plant associations or plant ‘type’ designations (Riccardi et.al., 2007). The inferred variables are unable to be modified within the FCCS framework and address the fuel properties such as chemistry, heat content, particle density and bulk density (Figures 10 and 11).

C:\Users\Laurel\Desktop\fccs_conf\fuelbeds\user_fuelbeds\A1102_1.xml

Canopy | Shrubs | Nonwoody fuels | Woody fuels | Litter/lichen/moss | Ground fuels | Environmental/Variables | Customize fuelbeds

Canopy  

Canopy stratum - Trees: Live trees

Total Canopy Cover

Mode	Min	Max
Total percent cover (%)	19.5	40.0

not present

Overstorey

Mode	Min	Max
Percent cover (%)	19.5	40.0
Height (ft)	0.0	0.0
Height to live crown (ft)	43.0	70.0
Density (#/acre)	0.0	0.0
Diameter at breast height (in)	0.0	0.0

Scientific Name

Scientific Name	Rel Cover
Pinus ponderosa	60
Larix occidentalis	40

Total relative cover (%)

100% required for Relative Cover

not present

Understorey

Midstorey

Mode	Min	Max
Percent cover (%)	not present	not present
Height (ft)	not present	not present
Height to live crown (ft)	not present	not present
Density (#/acre)	not present	not present
Diameter at breast height (in)	not present	not present

Scientific Name

Scientific Name	Rel Cover

Total relative cover (%)

100% required for Relative Cover

not present

FIGURE 9 FCCS VERSION 2.0 DATA ENTRY PAGE FOR THE CANOPY STRATUM

Customize fuelbed

If you choose to customize a fuelbed, you can complete this screen in order to document your work. The User information section is optional unless you would like to submit your customized fuelbed to the FCCS national database for consideration.

Fuelbed

FuelbedName: Pine & Larch

FuelbedDescription: Fire-excluded ponderosa pine forest has been selectively thinned to recreate an open stand of pine. Mistletoe-infested trees have been removed and the stand is prepared for prescribed burn treatment. This fuelbed was developed based on data from Lake Roosevelt National Recreation Area.

Ecoregion

CoverType

Vegetation Form

Change Agent

Structural Class: Stand Initiation

Condition Class: Class2

DataQualityRanking

User Info (optional)

Natural Fire Regime: 1

Photo Series ID

Canopy | Shrubs | Nonwoody fuels | Woody fuels | Litter lichen moss | Ground fuels | Environmental Variables | Customize fuelbeds

C:\Users\Laurel\Desktop\fccs_USFS\conf\fuelbeds\User_fuelbeds\A1102_1.xml

FIGURE 10. FCCS VERSION 2.0 DATA ENTRY PAGE TO GENERATE THE CUSTOMIZED FUELBED

The CSKT has adopted the *Fire Ecology of Montana Forest Habitat Types East of the Continental Divide* (Clayton and Fischer, 1983) thus the habitat associations have been identified within the CFI data and collected for the reservation. These associations were readily identifiable within the FCCS inputs framework for shrubs and non-woody vegetation, field parameters. Similar fuelbed modifications have been completed in order to study changes stemming from habitat (Andreu et.al., 2011), or inventory plots (Parresol et.al., 2012) in fire potentials in fuel reduction treatments (Ottmar et.al., 2011; Youngblood et. Al., 2008). Figure 12 illustrates the geographic distribution of pre modified fuelbeds on the Flathead Reservation.

In reference to the geographic distribution, it is clear that the fuelbed that contains the greatest acreage, pre modification, is fuelbed 54; which is the Douglas-fir, white fir and interior ponderosa pine type areas. These species may overlap these pre modification fuelbed polygons however; considering there were fuelbeds that were deemed to have zero Tons/Acre of carbon, within the results section of this report we determined the fuelbed descriptions to be in accurate. In addition, it is known that fuelbeds polygons would change when considering the amount of regionally specific data that was to be included within the FCCS data inputs.

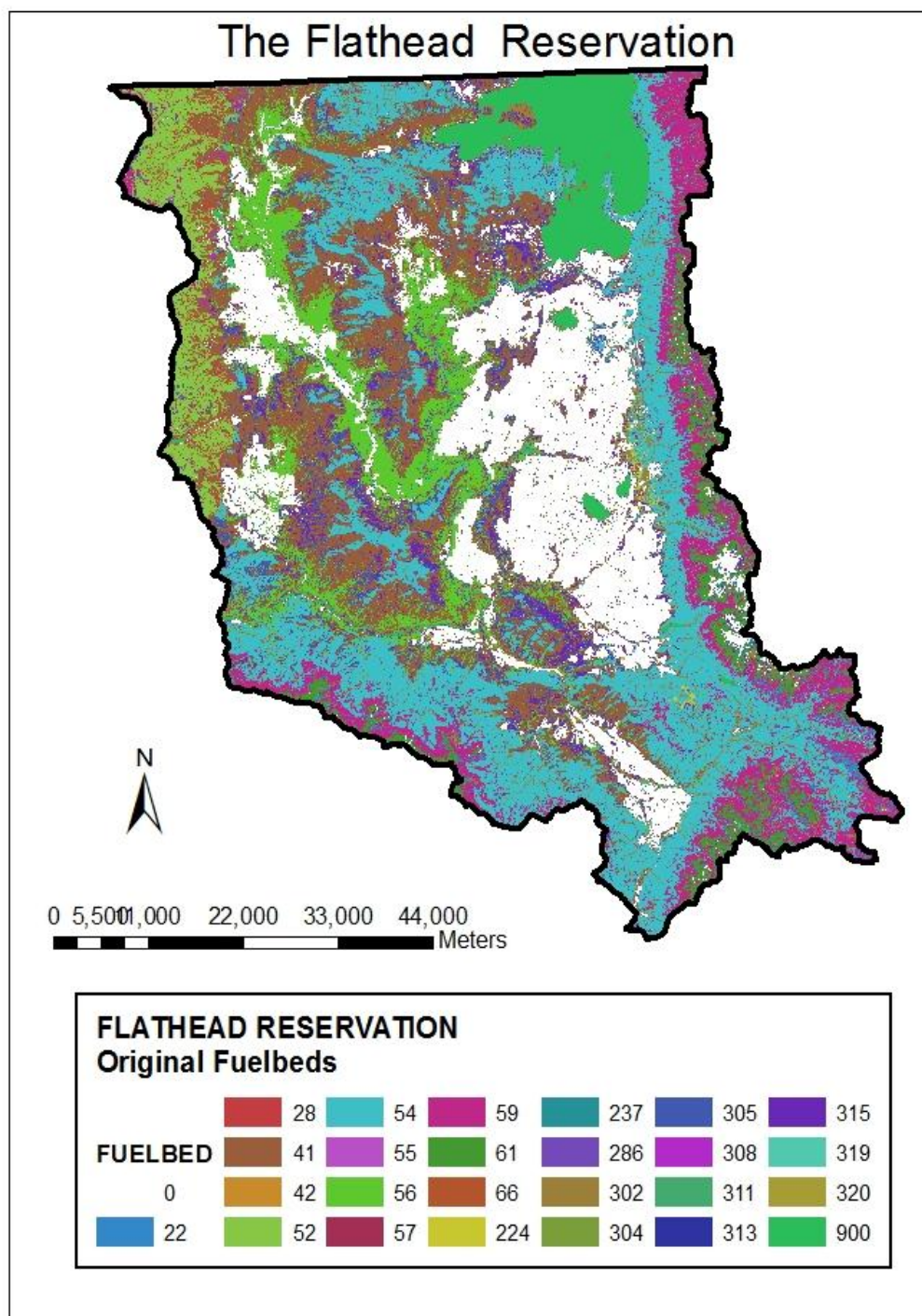


FIGURE 11. ORIGINAL FCCS FUELBEDS MAPPED IN GIS

CONTINUOUS FOREST INVENTORY DATA (CFI)

The Bureau of Indian Affairs Continuous Forest Inventory Analysis (CFI) data originated on the CSKT reservation in 1966 wherein 276 total plots were installed across the reservation. Revisions to this methodology including adding/deleting plots and updating inventory data at least every ten years were achieved in 1971, 1980, 1989, 1999 and 2009. The data used in this study included relevant data up to 1999, with a total of 426 plots, broken down into the new seral cluster fuelbed designations, and shown in Table 8 below.

Permanent plots were established in a $\frac{1}{4}$ acre circular plot (58.9' radius) with a minor plot superimposed over plot center. This minor plot is $\frac{1}{50}$ acre-plot (16.7' radius) and was used to count seedlings, saplings and culturally important plants, as determined by the tribe—this understory data was not made available for this assessment. However, the ability to include this type of data in their next round of CFI will be identified for land managers thus enhancing their measurable variables in FCCS.

Plots were located across the 459,408 forested acres, on trust lands. Each plot was measured to be 5 chains west and 5 chains north of the southeast section corner of the 'section' identified in the Public Land Survey. The Geographic Information System (GIS) files associated with this PLS survey were provided by the tribe for use in this work. The Inventory handbook and associated CFI manual provided the necessary codes to decipher vegetative components present on the Flathead Reservation. All plots were categorized by seral cluster designations and mapped, showing distribution of plot locations across the landscape. This distribution is shown in Figure 13.

TABLE 8. LISTING OF THE MODIFIED FUELBED DESIGNATIONS

FUELBED	NAME	FRCC	CFI PLOTS
1	A1102	1, 2, 3	29
2	A2102	1, 2, 3	46
3	A2103	1, 2	9
4	A2122	1	1
5	A3120	1, 2	16
6	A3130	1, 2, 3	8
7	A4120	1, 2, 3	20
8	A5120	1, 2	11
9	B2203	1, 2	7
10	B2223	1, 2	16
11	C2202	1, 2, 3	21
12	C2222	1, 2, 3	25
13	D2302	1, 2	4
14	D2322	1, 2, 3	10
15	D2323	1, 2	7
16	E3233	1, 2, 3	22
17	E4233	1, 2	7
18	F3222	1, 2, 3	33
19	F3223	1, 2	7
20	F4211	1, 2, 3	12
21	F4222	1, 2, 3	14
22	F4223	1, 2	8
23	G3322	1, 2, 3	11
24	G3323	1, 2	5
25	G4322	1, 2	5
26	G4323	1, 2, 3	5
27	H3333	1, 2	9
28	H4333	1, 2, 3	7
29	I5233	1	1
30	J5222	1, 2, 3	28
31	J5223	1, 2	9
32	K4322	2, 3	3
33	K5323	1, 2	5
34	L5333	1, 2	5
Total			426

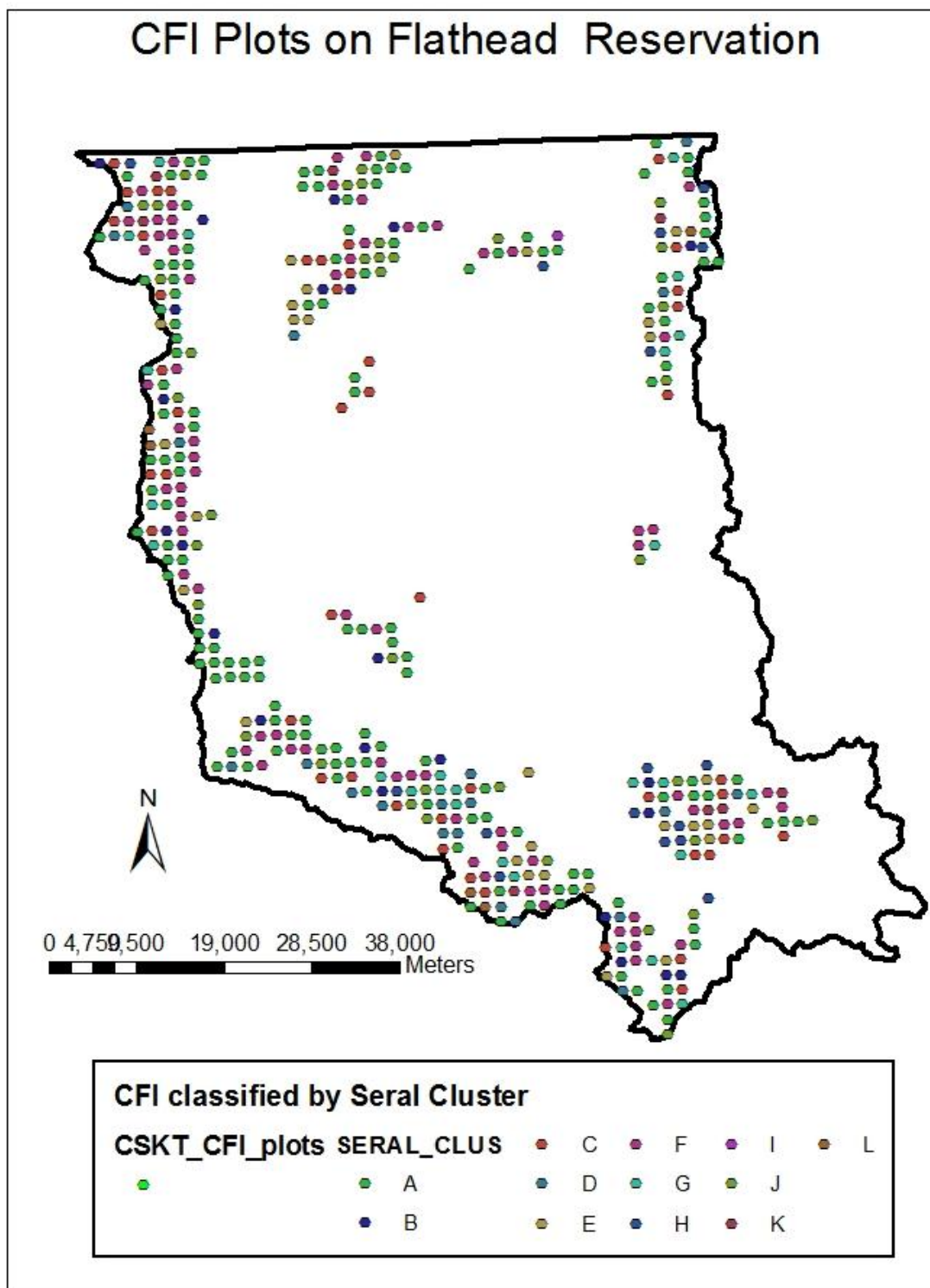


FIGURE 12. CFI PLOT LOCATIONS ASSIGNED BY SERAL CLUSTER CLASSIFICATION ON THE CONFEDERATED SALISH AND KOOTENAI TRIBES RESERVATION

FCCS 'OUTPUT' REPORTS

Within FCCS, seven reports are generated as a result of calculating the new fuel bed variables. These reports are mostly defined in short below and a greater description of these reports can be found in the FCCS User's Guide:

1) Carbon – the carbon report lists fuel loading and total carbon by stratum and category where; C factor is the Proportion of dry weight biomass that is carbon, Loading is the dry weight biomass of fuels by stratum and category measured in Tons/Acre, and Carbon is the total carbon of fuels by stratum and category measured in Tons/Acre.

2) General – the general report displays the basic fuel characteristic of the fuelbed

3) Input – the input report summarizes all fuelbed input data in a printable table.

4) Intermediate results – the Intermediate report is not fully described in the FCCS user's guide and was not utilized in this research. However, the information corresponds with the reports that are generated to be uploaded into CONSUME, another USFS forest/fire management modeling tool.

5) Potentials – the Potentials Report includes calculated FCCS fire potential ratings and their definitions

6) SFB – the Surface Fire Behavior report includes calculated surface fire intensity, rate of spread and flam length based on input slope, midflame wind speedk, and moisture scenario. This report also includes crosswalk to one of the 13 original Fire Behavior Prediction Systems (FBPS) fuel models and one of the 40 standard fuel models (Scott and Burgan 2005) based on calculated rate of spread and flame length.

7) Stratcat – the Strata and Categories report summarizes calculated and input fuelbed characteristics by stratum and category

The reports that I've focused on within this thesis include the carbon, general and potentials reports. Measurable outcomes of the FCCS fuelbed modifications can be seen in the Fire Potential and Fire Behavior predictions which include Rate of Spread, flame length and fire intensity. These specific reports have been selected because modifications within FCCS can best be examined when reviewing these variables.

These outputs can be used by the forest managers/practitioners when developing various management scenarios that could impact timber sales, thinning projects, fuels treatment project activities and fire suppression/pre-suppression activities. A full set of pre modification FCCS fuelbed output reports have been provided to Jim Durglo, the CSKT Forest Manager for their records and use in comparison to the newly established fuelbed files.

FIRE POTENTIALS SUMMARY REPORT

Fuels have had a number ranking system that is readily recognizable by fire managers for their potential fire behavior and for planning purposes (Sandberg, 2001). FCCS essentially allows for a means to address complex environments with known parameters that are derived from direct or indirect observation via inventory data, expert knowledge or inference (Sandberg, 2007). The Fire Potential reports will provide a series of numbers that relate to three main criteria: Fire Behavior Potential, Crown Fire Potential and Available Fuel Potential. These three categories have a corresponding value ranging from 0-9 (low-high) that indicate the level of Potential.

FCCS calculates fire potentials within 3 categories (see Figure 14). The surface fire concepts stems from fire spread equations (Albini, 1976, Rothermel, 1991) which produce mathematical models for rate of spread and flame length via classified fuels.

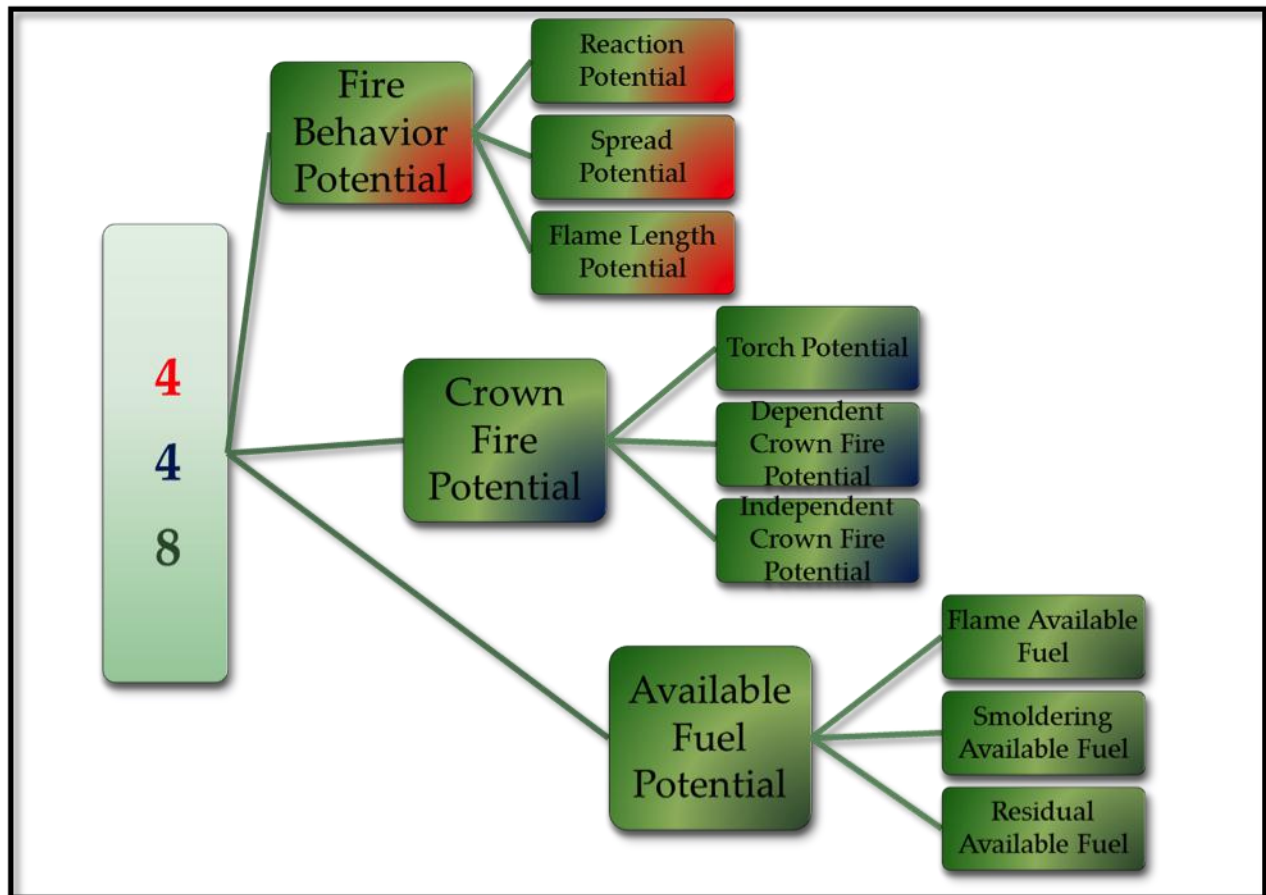


FIGURE 13. FIRE POTENTIAL RATING SCHEME FROM THE FCCS PROGRAM

A reformulation of Rothermel's fire spread model was completed to address site specific fuelbed characteristics and to calculate surface fire behavior potential (Sandberg et.al., 2007). This fuel category is impacted by the physical and chemical characteristics of the fuelbed as defined below (Sandberg et.al., 2007).

- The Reaction Potential (RP) reflects the reaction intensity ($\text{kW}\cdot\text{m}^{-2}$) and is defined as “the reactive volume of fuels per unit of ground surface, depth of the surface fuelbed strata, heat of combustion, and a scaling factor”.
- The Spread Potential (SP) reflects the proportional rate of spread ($\text{m}\cdot\text{min}^{-1}$) and is defined as the “function of reaction intensity, propagating energy flux, the heat sink calculated for the unburned fuels in advance of the spreading flame, and a scaling factor”.
- The Flame Length Potential (FP) reflects the proportion of the predicted flame length, (m) and is defined as “the product of reaction intensity, rate of spread and flame residence time”.

The crownfire potential (CFP) is based upon the fuelbed parameters calculated in the surface fuel information and is a semi-empirical model that describes crown fire initiation and propagation in vegetative canopies based upon fireline intensity required to ignite lower canopy fuels (Sandberg et.al., 2007).

Available fuel potential (AFP), reflects the fuel loading of all fuelbed components, expressed in $10 \text{ tonnes}\cdot\text{ha}^{-1}$. Generally, it provides an estimate of combustible biomass in each of the three stages of combustion: flaming, smoldering and residual smoldering.

- Flame available fuel (FA) is defined as the sum of mass ($\text{tonnes}\cdot\text{ha}^{-1}/10$), within $\frac{1}{2}$ inch of the surface of the fuel element which, equals the sum of:
 - Flame reactive surface available fuel (FAR) = mass of fuel consumed in the flaming from of a spreading surface fire that contributes to forward energy transfer. (shrub, non woody, woody and litter-lichen-moss strata).

- Flame available postreactive fuel (FAP) = remainder of flame available surface fuel after the passage of the flaming front, plus available fuel in the ground stratum
- Flame available canopy fuel (FAC) = the mass of foliage and fire twigs in the flammable tree canopy.

CARBON LOADINGS REPORTS

The carbon loadings report lists the fuel loading and total carbon by stratum. Carbon is represented as the proportion of dry weight biomass of fuels by stratum, where stratum is identified as one of six layers of strata: 1) trees, 2) shrubs, 3) nonwoody fuels, 4) woody fuels, 5) litter-lichen-moss, and 6) ground fuels. Each of those corresponds with the data inputs screen for FCCS. These data are available from the author of this thesis.

RESULTS & DISCUSSION

The goal of the research was to examine the changes in the fire potentials information to assist the tribe in gaining an accurate reflection of their landscape, within the FCCS modeling framework. In addition to that, this research would provide the tribe an opportunity to expand upon their management capabilities by allowing FCCS fuelbed designations, output reports etc... to be utilized within other USFS fire management modeling tool.

In terms of the Fire Potentials, this was examined even though useful numbers were not generated for my thesis. It was determined during the data mining phase that the information exists and can be incorporated during the tribe's next computerized update of their CFI database. This is currently underway.

In terms of the fire potentials information a lack of data issue arose for the understory vegetative component. This information was described in the CFI Handbook and was assumed to be contained within the computerized data tables associations with the CFI plots for the reservation. In fact, the handbook identifies categories related to the data collection; however, the information was not uploaded into the computerized database as the tribe had no current use to further expand an already extensive computerized dataset. Thus, the current information contained within the CFI addresses only 'presence' of species and has no quantitative data available to provide within the FCCS fuelbed development.

This issue will be addressed in the future by the tribe/BIA and the database will be updated to reflect all data inputs necessary to model surface fire behavior for the post modification conditions. The timing and content of my research will also allow for this methodology to be incorporate into the next round of CFI data interpretation. Specifically, the BIA and Tribe have, as a result of the 2009 survey, an additional 10 years of data collection. Thus, 1999 and 2009 surface fuel information will greatly enhance the prediction of historic and existing conditions of surface fuel vegetation across their landscape.

Without incorporating these understory data, the pre- and post-modification information for reaction, spread and flame length potential indicate a significant difference in value of and variation in index ratings for each category as shown in Table 9. The lack of responsiveness

TABLE 9. PRE MODIFICATION VS. POST MODIFICATION FIRE POTENTIALS REPORT. RESULTS SHOW THE NEED FOR SURFACE FUEL INFORMATION

Pre vs. Post Fire Potentials Report Index		
Index scale ranges from 0-9		
	Pre Modification	Post Modification
Reaction Potential	1.7 - 7.1	0.2 - 0.3
Spread Potential	0.1 - 9.0	0.5 - 0.9
Flame Length Potential	0.6 - 5.0	0.3 - 0.4

in the post-modification fire potentials suggests that understory data are critical in developing fuelbed characteristics.

In terms of this research, one important aspect of my assessment is the establishment of a methodology and FCCS fuelbed that can be updated with each decadal cycle of the Continuous Forest Inventory data collection by CSKT. The tribe just completed their latest round of data collection in 2009; therefore, the opportunity exists to use my methodology to incorporate and update with current data and thereby immediately expand their fuelbed information and management capabilities. This is useful because it will allow both a historical and present day assessment of fuels in assessing fire behavior, fuels presence, biomass quantities, smoke emissions potential and any associated air quality concerns. The opportunities are considerable once this modeling framework was established.

The areas of my research that contained useable data pertained to the total carbon (biomass) fuel loading categories. Fuel loadings, measured in bone dry tons/acre provided a clear association between fuelbed type and seral cluster designations. This was determined in plotting both pre modification and post modification averages of carbon loadings, as shown in Figure 14.

Despite the change in type and quantity of fuelbeds for the pre=modification and post-modification datasets, there would be a common trend detected when plotting the carbon averages across each fuelbed and those totals or the resulting trend line should be similar. I have graphed in Figure 14 in ascending order, the carbon loading totals for each pre- and post-modification fuelbed. The categories measured in FCCS variables for canopy, tree and overstory fuels show a trend in data increasing from 10 tons/acre to nearly 65 tons/acre; and there is clearly

a trend line present. Also in Figure 14, when comparing data for the same categories the pre-modification fuel loadings range from 0 tons/acre to nearly 50 tons/acre for each of the 33 fuelbeds. In addition, nine fuelbeds (out of 33) registered 0 tons/acre of total carbon fuel loadings. The pre-modification data does not accurately represent landscape conditions since these fuelbeds have no cumulative fuel loadings. This is significant because the pre-modification data contain the surface fuels data within the LANDFIRE defined fuelbed; thus, there should be data represented across all categories and we should not see a cumulative total fuel loading of zero for nine different fuelbeds.

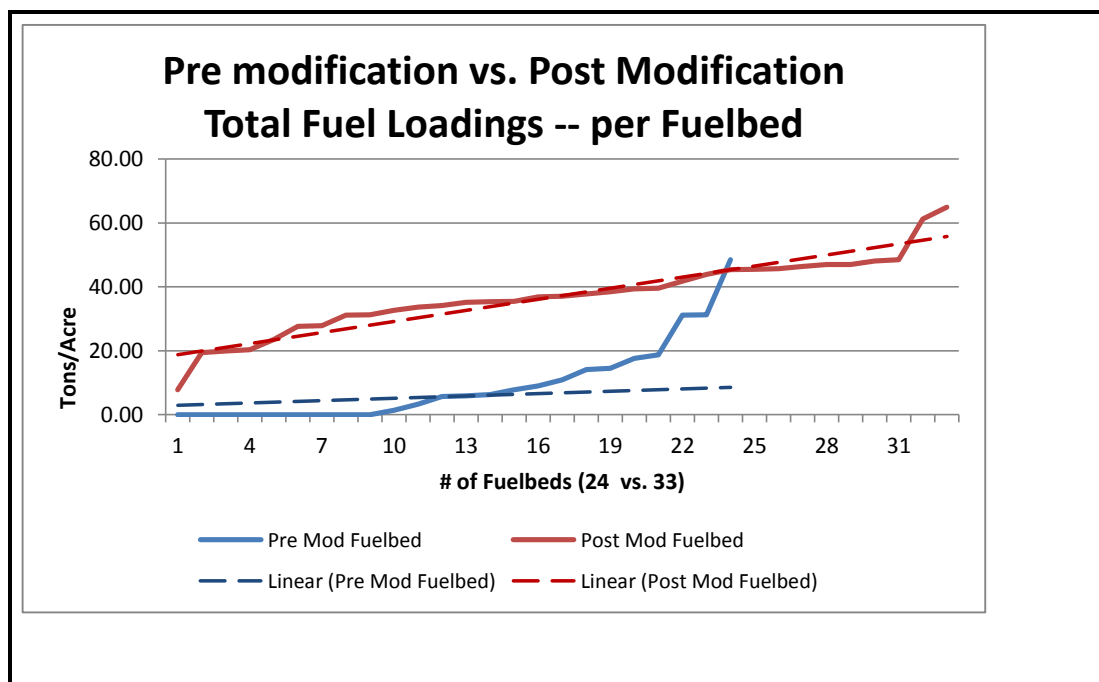


FIGURE 14. PRE MODIFICATION VS. POST MODIFICATION TOTAL FUEL LOADINGS, GRAPHED PER FUELBED CATEGORY WITH LINEAR TREND LINE

Within Table 11 below, I've highlighted the fuelbeds that have zero total fuel loadings within the fuelbeds are described as:

1. 52,485 acres- Fuelbed #315- Interior Alpine Forb Grassland

2. 0.2 acres - Fuelbed #311 - Salt desert shrub
3. 1,542 acres - Fuelbed #308 - Low sagebrush,
4. 52,741 acres – Fuelbed #302 - Intermountain montane – subalpine riparian
5. 1,761 acres - Fuelbed #237 - Huckleberry – heather shrubland
6. 1 acre – Fuelbed #66 - Bluebunch wheatgrass – bluegrass grassland
7. 75 acres – Fuelbed #57 - Wheatgrass – cheatgrass grassland
8. 109,320 acres – Fuelbed #56 - Sagebrush shrubland
9. 223,884 acres – Fuelbed #41 - Idaho fescue – bluebunch wheatgrass grassland

While these habitat types, according to their description would reasonably be lower in total fuel loadings they would not rival biomass/fuel loading amounts of large timbered stands. However, given the acreages associated with each of these fuelbed types, you would expect to see total fuel loadings that are low for an individual fuelbed polygon within GIS and not cumulatively equaling zero, for the extent of the fuelbed across the entire geographic extent of the reservation. All nine fuelbeds represent 351,809 total acres. In addition, several of these fuelbed types are known for their fire potential (e.g., sagebrush shrubland).

In assessing the fuel loadings for the canopy level type data, it is obvious that a trend has been established for the CSKT inventory data. This is easily explained when you consider the seral class/cluster designation methodology for classifying stands of trees. As you proceed from seral class A into seral class L, as shown in Figure 15, you have an increase in fuel components in the tree bole, limbs and canopy levels that are represented in the canopy, tree and overstory categories. Thus, there is a correlation between the seral class information and the new fuelbed and seral cluster data utilized as the FCCS inputs.

In terms of the pre-modification conditions, I was able to identify that there is no clear association in the pre-modification data that ties the fuelbed classifications to the stand structure and/or density component of each fuelbed. In reference to the CSKT methodology of defining seral clusters for their landscape, there should be a correlation between the pre- and post-modification datasets.

TABLE 10. PRE MODIFICATION VS. POST MODIFICATION CARBON LOADINGS AVERAGES

Pre Mod Fuelbed	Canopy	Trees	Overstory	Total	Post Mod Fuelbed	Canopy	Trees	Overstory	Total
315	0.00	0.00	0.00	0.00	D2302	4.52	1.8	1.45	7.77
311	0.00	0.00	0.00	0.00	A5120	8.41	5.68	5.33	19.42
308	0.00	0.00	0.00	0.00	A2103	8.58	5.86	5.51	19.95
302	0.00	0.00	0.00	0.00	A3130	8.73	6	5.65	20.38
237	0.00	0.00	0.00	0.00	A4120	9.8	7.07	6.72	23.59
66	0.00	0.00	0.00	0.00	A3120	11.14	8.41	8.06	27.61
57	0.00	0.00	0.00	0.00	A2122	11.2	8.48	8.13	27.81
56	0.00	0.00	0.00	0.00	F4223	12.32	9.6	9.25	31.17
41	0.00	0.00	0.00	0.00	A2102	12.35	9.62	9.27	31.24
313	0.71	0.71	0.01	1.43	F3222	12.82	10.09	9.74	32.65
319	1.16	1.16	0.99	3.31	D2323	13.17	10.44	10.09	33.7
55	2.24	2.24	1.25	5.73	B2223	13.32	10.59	10.24	34.15
28	4.59	0.92	0.38	5.89	E3233	13.65	10.93	10.58	35.16
22	2.17	2.06	2.06	6.29	E4233	13.71	10.99	10.64	35.34
304	4.16	2.11	1.51	7.78	C2202	13.76	11.04	10.68	35.48
286	6.74	1.88	0.37	8.99	B2203	14.23	11.51	11.16	36.9
42	3.97	3.64	3.34	10.95	J5222	14.31	11.58	11.23	37.12
59	11.04	2.93	0.17	14.14	C2222	14.52	11.79	11.44	37.75
320	6.23	4.46	3.85	14.54	J5223	14.77	12.04	11.69	38.5
52	10.14	6.76	0.69	17.59	D2322	15.05	12.32	11.97	39.34
305	7.43	6.71	4.64	18.78	F4222	15.13	12.41	12.06	39.6
61	21.58	5.72	3.84	31.14	H3333	15.86	13.13	12.78	41.77
224	16.13	10.54	4.56	31.23	G4323	16.56	13.84	13.49	43.89
54	34.00	12.88	1.67	48.55	K5333	17.06	14.33	13.98	45.37
					F4211	17.09	14.374	14.02	45.484
					G3323	17.16	14.43	14.08	45.67
					K5322	17.4	14.67	14.32	46.39
					F3223	17.6	14.87	14.52	46.99

G4322	17.61	14.88	14.53	47.02
G3322	17.95	15.23	14.88	48.06
I5233	18.11	15.39	15.04	48.54
L5333	22.36	19.64	19.29	61.29
H4333	25.58	19.86	19.51	64.95

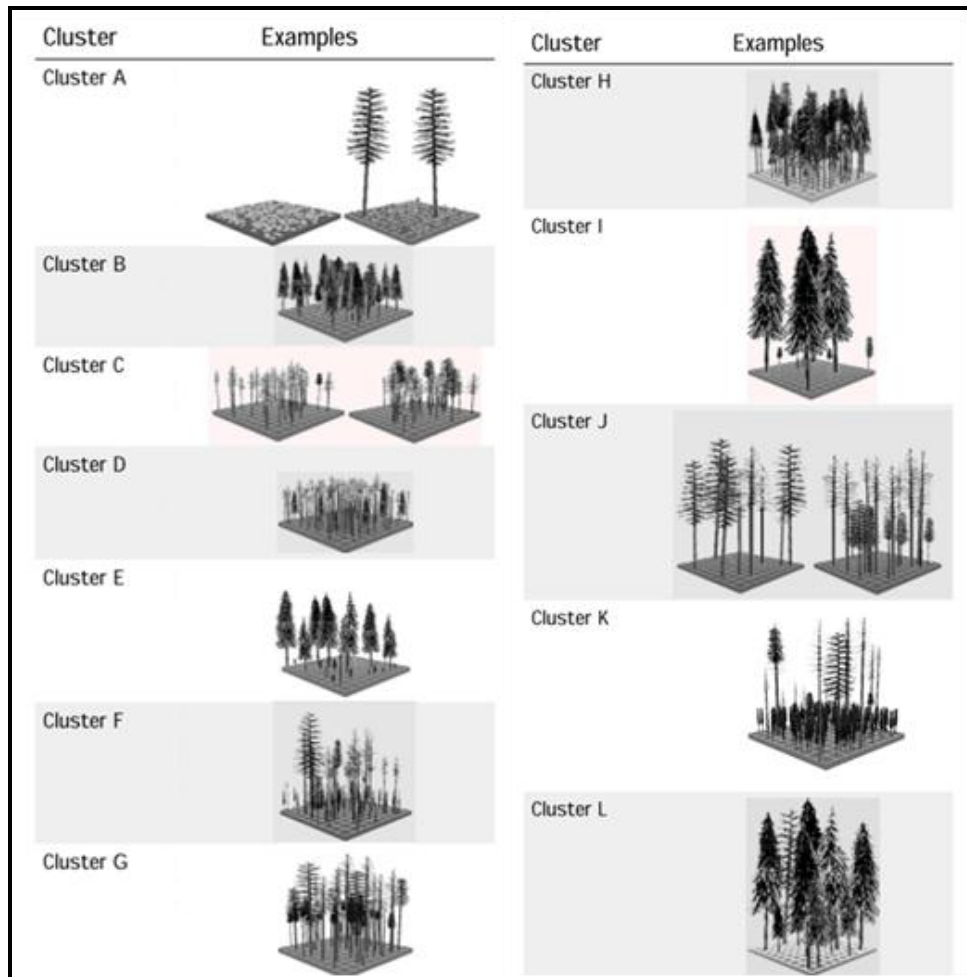


FIGURE 15. SERAL CLUSTER PICTORAL DESCRIPTION OF STAND DENSITY AND STRUCTURE

CONCLUSIONS

This research stemmed from 1999 CFI data capture. There was an additional data capture completed in 2009 and detailed surface fuel data were collected, as identified within the CFI manual. Once this modeling is completed for the 1999 surface fuel behavior reports, the

next round of CFI data can be updated with FCCS . This will allow surface fuels fire potentials numbers to be generated. This will be a huge modification and I predict results similar to those that are graphed for fuel and carbon loadings.

In addition to the incorporation of the surface, woody and non woody data strata; the tribe will have an opportunity to update and define within the FCCS framework the fuel models that help predict fire behavior can be utilized. In addition, as an output of the FCCS program; reports are automatically generated from FCCS in the proper formatting to be used in CONSUME; another modeling program developed out of the Pacific Northwest Research Station that is used to address fuel consumption, emissions and combustion information. This will greatly assist fire managers preparing burn plans and smoke management requirements.

FUTURE IMPACTS

In light of recent developments in tribal governmental operations this work will provide a framework for updating the national LANDFIRE mapping. This will be necessary if the tribes wish to recapture previous forest fire and fuels funding allocations. This was an unintended benefit of this research and could not have been predicted. A detailed description of the process to update the modified fuelbeds with the 2009 data will be completed. In addition, a plan to provide necessary information to update the national LANDFIRE mapping will also be completed for the tribe prior to turning over all modified data files.

In Fiscal Year 2012, the Confederated Salish and Kootenai Tribes experienced an initial slash in funding from their original \$1+ million dollar federal allocation via the Bureau of Indian Affairs, to less than \$100,000 for fire and fuels planning. This dramatic decrease in funding identifies the impact of this research. It is my hopes that the Tribe is able to fully implement this

research into their forest and fire management planning in time to stabilize their planning and staffing levels.

Bibliography

24 Stat 388, ch 119, 25 USCA 331. "Dawes Act." US Congress, February 8, 1887.

Agee, James K. *Fire Ecology of Pacific Northwest Forests*. Washington: Island Press, 1993.

Allison-Bunnell, Stephen, Stephen F. Arno. *Flames in our Forest*. Washington: Island Press, 2002.

Andreu, Anne G., Dan Shea, Bernard R. Parresol, Roger D. Ottmar. "Evaluating fuel complexes for fire hazard mitigation planning in the southeastern United States." *Forest Ecology and Management* (2011): In Press.

Arno, Stephen F., David P. Parson, and Robert E. Keane. "Mixed Severity Fire Regimes in the Northern Rocky Mountains: Consequences of Fire Exclusion and Options for the Future." *Wilderness science in a time of change: Wilderness ecosystems, threats and management. Proceedings RMRS_P_14-VOL-5*. Ed. Stephen F. McCool, William T. Borrie, and Jennifer O'Loughlin David N. Cole. Ogden: USDA Forest Service, 2000. 225-232.

Arroyo, Lara A., Cristina Pascual, Jose A. Manzanera. "Fire models and methods to map fuel types: The role of remote sensing." *Forest Ecology and Management* (2008): 1239-1252.

Bailey, Robert J., Robert D. Pfister and Jan A. Henderson. "Nature of land resource classification - a Review." *Journal of forestry* (1978): 650-655.

Barrett, S. D. Havlina, J. Jones, W. Hann, C. Frame, D. Hamilton, K. Schon, T. Demeo, L. Hutter, and J. Menakis. "National Interagency Fuels, Fire and Vegetation Technology Transfer (NIFTT)." Vers. 3. 2010. *Interagency Fire Regime Condition Class*. Online Document. <<http://www.frcc.gov>>.

Berg, Erik. "Characterizing and classifying complex fuels – A new approach." *Canadian Journal of Forest Research*: 37 (12) (2007): 2381-2382

Bilgili, Ertugrul. "Stand development and fire behavior." *Forest Ecology and Management* (2003): 333-339.

Campbell, John, Dan Donato, David Azuma, and Beverly Law. "Pyrogenic carbon emissions from a large wildfire in Oregon, United States." *Journal of Geophysical Research* 112 (2007).

Clayton, Bruce D., and William C. Fischer. *Fire Ecology of Montana Forest Habitat Types East of the Continental Divide*. General Technical Report. Ogden: USDA Forest Service, 1983.

Cohen, Don Miller and Stan. *The Big Burn: The northwest's great forest fire of 1910*. Missoula: Pictorial Histories Publishing Company, Inc, 1978.

Confederated Salish & Kootenai Tribes. *Continuous Forest Inventory Handbook*. Pablo: Unpublished manual, n.d. available from Jim Durglo, CSKT Forestry Manager.

Confederated Salish & Kootenai Tribes. *Fire History Project*. Pablo: Web, n.d. <http://www.cskt.org/fire_history.swf>.

- Crane, Marilyn F. and William C. Fischer. "Fire ecology of the forest habitat types of central Idaho." USDA Forest Service, General Technical Report INT-218 (1986).86 pp.
- CSKT. *Flathead Indian Reservation: Forest Management Plan; An Ecosystem Approach to Tribal Forest Management*. Ed. David Rockwell. Pablo: CSKT, 2000.
- Daniel, Theodore W., John A. Helms, and Frederick S. Baker. *Principles of Silviculture*. New York: McGraw-Hill Publishing Company, 1952.
- Department of Interior. *Flathead Indian Reservation, 199-2000 Continuous Forest Inventory Program Operating Instructions*. Browning. Portland: DOI Northwest Regional Office 2002.
- Dyrness, C.T., Jerry F. Franklin *Natural Vegetation of Oregon and Washington*. Corvallis: Oregon State University Press, 1988.
- Edmonds, Robert L., James K. Agee and Robert I. Gara. *Forest Health and Protection*. 2nd Edition (2011), 1st Edition (2000). Long Grove: Waveland Press, Inc, 2011.
- Falk, Donald A., Carol Miller, Donald McKenzie, and Anne E.Black. "Cross-scale analysis of fire regimes." *Ecosystems* 10 (2007): 809-823.
- Havlina, D., et.al. *Fire Research and Management Exchange System (FRAMES)*. Vers. <http://www.frames.gov/portal/server.pt/community/frcc/309/home/1397>. 2010. <<http://frcc.gov>>.
- Heyerdahl, Emily K., Linda B. Brubaker, and James K. Agee. "Spatial controls of historical fire regimes: a multiscale example from the interior west, USA." *Ecology* 82.3 (2001): 660-678.
- Hollingsworth, LaWen T., Laurie L. Kurth, Bernard R Parresol, Roger D. Ottmar, Susan J. Prichard. "A comparison of geospatially modeled fire behavior and fire management utility of three data sources in southeastern United States." *Forest Ecology and Management* (2011): In Press.
- Hollis, J.J., S. Matthews, R.D. Ottmar, S.J. Prichard, A. Slijepcevic, N.D. Burrows, B Ward, K.G. Tolhurst, W.R. Anderson, J.S. Gould. "Testing woody fuel consumption models for application in Australian southern eucalypt forest fires." *Forest Ecology and Management* (2010): 948-964.
- Justice, Erin, Brandon Cheung, William Danse, Kyle Myrick, Matthew Willis, Susan Prichard. PhD, Jw. Skiles, PhD. "Effect of fuel treatments on carbon flux during a wildfire using satellite imagery: Okanogan-Wenatchee National Forest." *ASPRS 2010 Annual Conference*. San Diego, 2010.
- Keane, Robert E., Tracey Frescino, Matthew C. Reeves, and Jennifer L. Long. *Mapping wildland fire across large regions for the LANDFIRE prototype project*. General Technical Report. Fort Collins: USDA Forest Service, 2006.
- Kimmerer, Robin Wall, Frank Kanawaha Lake. "Maintaining the mosaic: The role of indigenous burning in land management." *Journal of Forestry*, 2001, Vol. 99 (11): 36 – 41.
- Krebs, Charles J. *Ecology: The experimental analysis of distribution and abundance*. New York: Harper Collins College Publishers, 1994.
- LeCain, Timothy J. *Mass Destruction: The men and giant mines that wired america and scarred the planet*. New Brunswick: Rutgers University Press, 2009.

- Leuschen, Rose Davis and Mariah. *The great 1910 Fires of Idaho and Montana*. 2010 Commemoration. USDA Forest Service, 2010.
- Lolo National Forest. *Trees of the Lolo National Forest*. Missoula: USDA Forest Service, 1985.
- Mason, Larry, Germaine White, Gary Morishima, Ernesto Alvarado, Louise Andrew, Fred Clark, Mike Durglo Sr., Jim Durglo, John Eneas, Jim Erickson, Margaret Friedlander, Kathy Hamel, Colin Hardy, Tony Harwood, Faline Haven, Everett Isaac, Laurel James, Robert Kenning, Adrian Leighton, Pat Pierre, Carol Raish, Bodie Shaw, Steven Smallsalmon, Vernon Stearns, Howard Teasley, Matt Weingart, and Spus Wilder. "Listening and Learning from Traditional Knowledge and Western Science: A dialogue on Contemporary Challenges of Forest Health and Wildfire." *Journal of Forestry* Vol. 110 (4) (2012): 187-193
- McKenzie, D., C.L. Raymond, L.-K.B. Kellogg, RA. Norheim, A.G. Andreu, A.C. Barnard, K.E. Kopper, and E. Elman. "Mapping fuels at multiple scales: landscape application of the Fuel Characteristic Classification System." *Canadian Journal of Forest Research* (2007): 2421-2437.
- Meigs, Garrett W., Daniel C. Donato, John L. Campbell, Jonathan G. Martin, and Beverly E. Law. "Forest Fire Impacts of Carbon Uptake, Storage, and Emission: The Role of Burn Severity in the Eastern Oregon Cascades, Oregon." *Ecosystems* (2009): 1246-1267.
- Morgan, Penelope, Colin C. Hardy, Thomas W. Swetnam, Matthew G. Rollins, and Donald G. Long. "Mapping fire regimes across time and space: Understanding coarse and fine scale fire patterns." *International Journal of Wildland Fire* 10 (2001): 329-342.
- Munchak, Leigh A., Bret A. Schichtel, Amy P. Sullivan, Amanda S. Holden, Sonia M. Kreidenweis, William C. Malm, Jeffrey L. Collett Jr. "Development of wildland fire particulate smoke marker to organic carbon emission ratios for the conterminous United States." *Atmospheric Environment* (2011): 395-403.
- Ohmann, Janet L., Michael C. Wimberly, Jeremy S. Fried. A novel approach to regional fuel mapping: Linking inventory plots with satellite imagery and GIS databases using the gradient nearest neighbor method. Final Report. US Forest Service. Missoula: Joint Fire Science Program, 2005.
- Oliver, Chadwick Dearing, and Bruce C. Larson. *Forest Stand Dynamics*, 1996. Updated Edition. John Wiley and Sons, New York. 521 pp.
- Ottmar, Roger D., Clint S. Wright and Susan J. Prichard. "A suite of fire, fuels and smoke management tools." *Fire Management Today* (2009): 34-39.
- Ottmar, Robert D., David V. Sandberg, Cynthia L. Riccardi, and Susan J. Prichard. "An overview of the Fuel Characteristic Classification System - Quantifying, classifying and creating fuelbeds for resource planning." *Canadian Journal of Research* (2007): 2383-2393.
- Ottmar, Roger D., David V. Sandberg, Susan J. Prichard, Cynthia L. Riccardi. "Fuel Characteristic Classification System." 2003.
- Ottmar, Roger D., John I. Blake, William T. Croll. "Using fine-scale fuel measurements to assess wildland fuels, potential fire behavior and hazard mitigation treatments in the southeastern USA." *Forest Ecology and Management* (2011): In Press.

- Ottmar, Roger D., Susan J. Prichard. "Fuel treatment effectiveness in forests of upper Atlantic Coastal Plain - An evaluation at two spatial scales." *Forest Ecology and Management* (2012): In Press.
- Ottmar, Roger D., Susan J. Prichard, Robert E. Vihnanek, and David V. Sandberg. *Modification and Validation of Fuel Consumption Models for Shrub and Forest Lands in the Southwest, Pacific, Northwest, Rockies, Midwest, Southeast and Alaska*. Final Report. Pacific Northwest Research Station. Seattle, WA: USDA Forest Service, 2006.
- Parresol, Bernard R., Joe H. Scott, Anne Andreu, Susan Pritchard, Laurie Kurth. "Developing custom fire behavior fuel models from ecologically complex fuel structures for upper Atlantic Coastal Plain forests." *Forest Ecology and Management* (2012): In Press.
- Parresol, Bernard R., John I. Blake, Andrew J. Thompson. "Effects of overstory composition and prescribed fire on fuel loading across heterogenous managed landscape in southeastern USA." *Forest Ecology and Management* (2011): In Press.
- Peterson, David L, Louise Evers, Rebecca A. Gravenmier, and Ellen Eberhardt. *Analytical and Decision Support for Managing Vegetation and Fuels: A Consumer Guide*. General Technical Report. Portland, OR: US Department of Agriculture, 2007.
- Pfister, Robert D. and Stephen F. Arno. "Classifying forest habitat types based on potential climax vegetation." *Forest Science* Vol. 26 (1) (1980): 52-70.
- Pfister, Robert D. "Development of a vegetation-based approach to site classification." 1984. 74-76.
- Pfister, Robert D. "Development of a vegetation-based approach to site classification." *The prairie: past, present and future: Proceedings of the Ninth North American Prairie Conference*. Ed. and Gary K. Clambey Richard H. Pemble. Moorhead: Tri-College University Center for Environmental Studies, 1986. 74-76.
- Pfister, Robert D., Bernard L. Kolvalchik, Stephen F. Arno and Richard C. Presby. *Forest habitat types of Montana*. General Technical Report. Intermountain Forest and Range Experiment Station. Ogden: US Forest Service, 1977.
- Prichard, Susan J., Roger D. Ottmar, David V. Sandberg, Paige C. Eagle, Anne G Andreu, and Kjell Swedin. FCCS User's Guide. Pacific Northwest Research Station. Seattle, WA: USDA Forest Service, 2011.
- Raymond, Crystal L., Lara-Karena B. Kellogg, and Donald McKenzie. "Mapping Fuels on the Okanogan and Wenatchee Forests." *RMRS-P-41*. Fort Collins: USDA Forest Service, 2006. 293-204.
- Riccardi, Cynthia L., David V. Sandberg, Susan J. Prichard, Roger D. Ottmar. *Calculating physical characteristics of wildland fuels in the Fuel Characteristic Classification System*. Pacific Northwest Research Station. Seattle, WA: USDA Forest Service, n.d.
- Riccardi, Cynthia L., Roger D. Ottmar, David V. Sandberg, Anne Andreu, Ella Elman, Karen Kopper, and Jennifer Long. "The fuelbed: a key element of the Fuel Characteristic Classification System." *Canadian Journal of Forest Research* (2007) Vol 37: 2394-2412.
- Riccardi, Cynthia L., Susan J. Prichard, David V. Sandberg, and Roger D. Ottmar. "Quantifying physical characteristics of wildland fuels using the Fuel Characteristic Classification System." *Canadian Journal of Forest Research* (2007). Vol 37: 2413-2420.

- Richardson, Jeffrey J., Kurt A. Spies, Steve Rigdon, Sara York, Valerie Lieu, Lloyd Nackley, Betzaida Batella Garcia, Rodney Cawston, and Daniel T. Schwartz. "Biomass supply estimates: Lessons from a Yakama Nation case study." *Biomass and Bioenergy* (2011). Vol. 35 (8): 3698 – 3707.
- Roberts, D.W. *Forest Habitat Types of Bear's Paw Mountains*. Thesis. Missoula: University of Montana, 1980.
- Russel-Smith, Jeremy, Peter Whitehead and Peter Cooke. *Culture, Ecology and Economy of Fire Management in North Australian Savannas: Rekindling the Wuurk Tradition*. Collingwood: CSIRO Publishing, 2009.
- Sandberg, David V., Cynthia L. Riccardi, and Mark D. Schaaf. "Fire potential rating for wildland fuelbeds using the Fuel Characteristic Classification System." *Canadian Journal of Forest Research* (2007) Vol 37: 2456-2463.
- Sandberg, David V., Cynthia L. Riccardi, and Mark D. Schaaf. "Reformulation of Rothermel's wildland fire behaviour model for heterogeneous fuelbeds." *Canadian Journal of Forest Research* (2007) Vol 37: 2438-2455.
- Schaaf, Mark D., David V. Sandberg, Maarten D. Schreuder, and Cynthia L. Riccardi. "A conceptual framework for ranking crown fire potential in wildland fuelbeds." *Canadian Journal of Forest Research* (2007): 2464-2478.
- Sibbernsen, J.I., D.W. Roberts *Forest and woodland habitat types of North Central Montana, Vol. 2: the Missouri River Breaks*. Final Report, Contract No. YA-512-CT6-84. Billings: US Bureau of Land Management, 1979.
- Sprenger, Carson B., Peter W. Dunwiddie. "Fire history of a Douglas-fir—Oregon oak woodland, Waldron Island, Washington." *Northwest Science*, 2011, Vol. 85 (2): 108 – 119.
- Stevens, Isaac I. *Treaty of Hellgate*. Treaty. 12 Stat. 975. Hellgate, July 15, 1855.
<www.cskt.org/documents/helgatetrety.pdf>.
- Swetnam, Thomas W., Anthony C. Caprio "Historical fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California." *Symposium on fire in Wilderness and Park Management: Park Lessons and Future Opportunities*. Ogden: Citeseer, 1995.
- Urbanski, Wei Min Hao and Shawn. *Automated Forecasting of Smoke Dispersion and Air Quality Using NASA Terra and Aqua Satellite Data (Task 5)*. Final Report. Rocky Mountain Research Station Fire Lab. Missoula: USDA Forest Service, 2003.
- USFS PNW FERA. *Fuel Characteristic Classification System*. Prod. Roger Ottmar. Seattle, n.d. Online.
<<http://www.fs.fed.us/pnw/fera/fccs/index.shtml>>.
- USGS. "LANDFIRE Data Products." *LANDFIRE National DATA*. Salt Lake city: USFS Remote Sensing Applications Center, January 2008. CD.
- Youngblood, Andrew, Clinton S. Wright, Roger D. Ottmar, James D. McIver. "Changes in fuelbed characteristics and resulting fire potentials after fuel reduction treatments in dry forests of the Blue Mountains, northeastern Oregon." *Forest Ecology and Management* (2008): 3151-3169.

Zhang, Chi, Hanqin Tian, Yuhang Wang, Tao Zeng, Yongqiang Liu. "Predicting response of fuel load to future changes in climate and atmospheric composition in Southern United States." *Forest Ecology and Management* (2010): 556-564.

Appendix A: List of acronyms

It's always wise to define all of the acronyms you are using in one place for easy reference.

AFP:	Available Fuel Potential
BIA:	Bureau of Indian Affairs
CFI:	Continuous Forest Inventory
CFP:	Crown fire potential
CSKT:	Confederated Salish and Kootenai Tribes
DBH:	Diameter at breast height
FA:	Flame Available
FAC:	Flame available canopy fuel
FAR:	Flame reactive surface available
FAP:	Flame available post reactive fuel
FCCS:	Fuel Characteristic Classification System
FERA:	Fire and Environmental Research Applications Team
FMP:	Forest Management Plan
FP:	Flame Length Potential
GIS:	Geographic Information Systems
IGERT:	Integrative Graduate Education & Research Training
USFS:	United States Forest Service
USGS:	United States Geological Survey
PLS:	Public Land Survey
PNW:	Pacific Northwest
RP:	Reaction Potential
SP:	Spread Potential

Appendix B: Habitat Associations for the Confederated Salish and Kootenai Tribes Landscape

Habitat Associations for the Flathead Reservation

pipo/feid -feid A	pinus ponderosa/festuca idahoensis	ponderosa pine/idaho fescue
pipo/syal -syal A	pinus ponderosa/symphoricarpus albus	ponderosa pine/snowberry
psme/agsp A	pseudotsuga menziesii/agropyron spicatum	douglas fir/bluebunch wheatgrass
psme/feid A	pseudotsuga menziesii/festuca idahoensis	douglas fir/idaho fescue
psme/fesc A	pseudotsuga menziesii/festuca scabrella	douglas fir/rough fescue
psme/vaca C	pseudotsuga menziesii/vaccinium caespitosum	douglas fir/huckleberry
psme/phma C	pseudotsuga menziesii/physocarpus malvaceus	douglas fir/ninebark
psme/vagl C	pseudotsuga menziesii/vaccinium globulare	douglas fir/blue huckleberry
psme/libo D	pseudotsuga menziesii/linnaea borealis	douglas fir/twinflower
psme/syal B	pseudotsuga menziesii/symphoricarpus albus	douglas fir/snowberry
psme/caru B	pseudotsuga menziesii/calamagrostis rubescens	douglas fir/pinegrass
psme/spbe C	pseudotsuga menziesii/spiraea betulifolia	douglas fir/white spiraea
abgr/xete D	abies grandis/xerophyly tenax	grand fir/beargrass
abgr/clun D	abies grandis/clintonia uniflora	grand fir/queencup beadlilly
thpl/clun D	thuja plicata/clintonia uniflora	western red cedar/queencup beadlilly
abgr/libo D	abies grandis/linnaea borealis	grand fir/twinflower
abla/clun E	abies lasiocarpa/clintonia uniflora	subalpine fir/queencup beadlilly
abla/vaca E	abies lasiocarpa/vaccinium caespitosum	subalpine fir/huckleberry
abla/libo -libo F	abies lasiocarpa/linnaea borealis	subalpine fir/twinflower
abla/mefe E	abies lasiocarpa/menziesia ferruginea	subalpine fir/menziesia
tsme/mefe E	tsuga mertensiana/menziesia ferruginea	mountain hemlock/menziesia
abla/xete E	abies lasiocarpa/xerophyllum tenax	subalpine fir/beargrass
tsme/xete F	tsuga mertensiana/xerophyllum tenax	mountain hemlock/beargrass
abla/vagl F	abies lasiocarpa/vaccium globulare	subalpine fir/huckleberry

Appendix C: Table used as CSK seral cluster designation key

CSKT SERAL #			
1ST DIGIT	2ND DIGIT	3RD DIGIT	4TH DIGIT
Dominant Tree Size (DBH)	Density (CC)	Overstory (Climax Sp.)	Understory (Seral Sp.)
1 = 0 – 4.9 in. DBH	1 = 0 – 39%	0 = no trees	0 = no trees
2 = 5 – 9.9 in. DBH	2 = 40 – 69%	1 = 75% of climax sp.	1 = 75%
3 = 10 – 20.9 in. DBH	3 = 70 – 100%	2 = 25 – 75%	2 = 25 - 75%
5 = 21+ DBH		3 = 75%	3 = 75%

Appendix D: Pre-modification fire Potential averages

Pre Modification Fuelbed	Reaction Potential	Spread Potential	Flame Length Potential
308	4.30	0.10	0.60
311	3.30	1.00	1.50
313	2.80	2.40	2.00
319	1.70	2.60	1.60
22	2.60	3.00	2.10
302	2.70	3.40	2.20
57	1.90	3.60	1.70
54	2.70	3.80	2.50
61	4.20	3.80	3.10
42	3.90	4.00	2.90
305	2.40	4.00	2.30
286	4.00	4.30	3.30
320	4.70	4.40	3.80
59	4.50	4.70	3.70
304	2.50	4.70	2.60
52	4.10	5.00	3.50
55	5.10	5.90	3.80
237	5.20	7.10	4.50
28	7.10	7.20	5.10
224	5.50	7.50	4.40
315	6.10	8.50	4.60
41	4.80	9.00	4.30
56	7.10	9.00	5.60
66	4.30	9.00	4.30

Appendix E: Post-modification fire Potential averages

Modified Fuelbed	Reaction Potential	Spread Potential	Flame Length Potential
A3120	0.2	0.5	0.3
A2102	0.3	0.9	0.4
A2103	0.3	0.9	0.4
A2122	0.3	0.9	0.4
A3130	0.3	0.9	0.4
A4120	0.3	0.9	0.4
A5120	0.3	0.9	0.4
B2203	0.3	0.9	0.4
B2223	0.3	0.9	0.4
C2202	0.3	0.9	0.4
C2222	0.3	0.9	0.4
D2302	0.3	0.9	0.4
D2322	0.3	0.9	0.4
D2323	0.3	0.9	0.4
E3233	0.3	0.9	0.4
E4233	0.3	0.9	0.4
F3222	0.3	0.9	0.4
F3223	0.3	0.9	0.4
F4211	0.3	0.9	0.4
F4222	0.3	0.9	0.4
F4223	0.3	0.9	0.4
G3322	0.3	0.9	0.4
G3323	0.3	0.9	0.4
G4322	0.3	0.9	0.4
G4232	0.3	0.9	0.4
H3333	0.3	0.9	0.4
H4333	0.3	0.9	0.4
I5233	0.3	0.9	0.4
J5222	0.3	0.9	0.4
J5223	0.3	0.9	0.4
K5322	0.3	0.9	0.4
K5333	0.3	0.9	0.4

Appendix F: Pre- vs. post-modification fire Potential averages. Pre-modification numbers show the complexity of fuelbeds depicted in graph vs. a graph that represents only a presence of species recognized in the understory. Measure of vegetation is necessary, per seral cluster in order to determine surface fire behavior issues.

