Silviculture Prescription and Regeneration Analysis:

An Investigation of the Creighton Compartment of the Paul Smith's College Forest Management Plan

---

Submitted by: Nicholas Day

Mentor: Damon Hartman

Forester - Prentiss & Carlisle

Date of Submission: 12/3/12

A paper submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Ecological Forest Management at Paul Smith's College

Abstract:

Paul Smith's College, being an environmental college, has a unique opportunity to explore the newest research to find the best methods of silviculture treatments to meet regeneration goals while sustaining forest structure. This study investigated the Creighton Compartment of the PSC forest management plan specifically examining the silviculture prescriptions and regeneration. Seedling and sapling regeneration data was compared with the management plan to determine whether regeneration goals were met. Overall, the hardwood stands were regenerating in vast amounts of undesired American beech (*Fagus grandifolia*) and not meeting the preferred goal of red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), black cherry (*Prunus serotina*) and yellow birch (*Betula alleghaniensis*). The softwood stands were regenerating in vast amounts of undesired balsam fir (*Abies balsamea*) and not meeting the preferred goal of eastern white pine (*Pinus strobus*) and red spruce (*Picea rubens*). Based on extensive research, it has been determined that a variable sized group selection harvest was the best solution to regenerate the preferred hardwoods and a two-cut shelterwood system with at least 40 percent light scarification should be conducted to favor regeneration of preferred softwoods.

Acknowledgements:

There are several people whom I would like to acknowledge for aiding me throughout this project:

Damon Hartman was my mentor and met with me on a bi-weekly basic to discuss any issue or concerns I had with my project. He helped me narrow down my project goals and helped me better understand which aspects of a management plan to concentrate on.

Elizabeth Olsen was my capstone planning instructed who provided useful feedback and questions to help my advancement through the planning stage. Elizabeth also gave me the contact information for Damon.

Dr. Janet Mihuc was my capstone project instructor. Janet had also provided feedback that helped me narrow down my research. She had also been considerate with modifications that had to be done with my project.

Dr. Jeff Walton, the Dean of the Forestry and Natural Resources School at Paul Smith's College, who supplied me with every revised year of the management plan that I requested and allowed me to sit in an office next to his to work from the original printed management plan.

Jim Burtis, Paul Smith's College's Forest Manager, for meeting with me in the spring of 2012 to discuss the forest management plan as to the present implementations and future potentials.

Heather Miller, for listening to me recite many pages of my project and giving thoughtful comments regarding wording and grammar.

Table of Contents:

List of Tables and Figures

List of Appendices

Introduction:

Colleges of environmental science have a unique opportunity to explore the latest techniques in order to achieve sustainable forest management while meeting silvicultural goals. Paul Smith's College is a small college in Franklin County, New York that has a wide variety of majors including Forest Management, Biology and Arboriculture. Paul Smith's College (PSC) has this opportunity to use the latest research to practice the most sustainable, effective forest management. Many colleges, such as SUNY ESF and University of Maine (UMaine), have forest management plans that display state of the art technology and research, as well as long-term silviculture. Environmental science universities such as ESF, UMaine and PSC should use their forest management plans as teaching tools and apply the recent findings in forestry. As an environmental college, whose primary objective of harvesting is not income but rather research and education, Paul Smith's College has the ability to explore the newest research while sustaining long term silviculture.

The PSC management plan was created in December 2000 by Northwood's Forest Consultants in cooperation with Forest Stewardship Council (FSC) Certification and the plan originally spanned 20 years (Appendix C). The managed area covers 8,899 acres of commercial FSC Certified land across two counties (Franklin and Essex County). It contains 14 compartments (large tracts of land), the smallest being Osgood (225 acres) and the largest being the VIC (2,734 acres). The Creighton compartment, which is the concentration of this research, is 2,240 acres with 1973.4 acres of commercial forest land. The 20 year plan stresses the importance of uneven-aged forest systems but states that the majority of the stands do not have the stand diameter distribution to convert them to uneven-aged; therefore they will remain even-aged. There are three major harvest types that are being used within the management plan: selection cut (single and group), shelterwood and improvement harvest/balsam fir salvage. The improvement harvests are not easily definable and the prescription varies depending on the stand. The plan was strictly area controlled annual allowable cut until 2012 when they implemented sustained yield harvest level calculations which take into account cord volume extracted annually. The 20 year plan originally called for an annual allowable cut of 445 acres per year for the 8,899 acres of FSC commercial forest land but now is slightly modified annually for cord volume output.

Paul Smith's College is the college of the Adirondacks and strives for sustainability. The Society of American Foresters' Dictionary of Forestry defines sustainability as "the capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity, and overall integrity, in the long run, in the context of human activity and use" (1998, p. 181). In order to achieve sustainable forest management, a management plan should incorporate every aspect of the ecosystem. The Maine Council for Sustainable Forest Management best describes sustainable forest management as, "enhances and maintains the biological productivity and diversity, thereby assuring economic and social opportunities for this and future generations." (1996, p. 33) The PSC forest management plan should be an exemplary example of sustainable forest management that incorporates the most modern research for best management techniques. This study will investigate the Creighton Compartment of the PSC forest management plan specifically examining the silviculture prescriptions and regeneration. The study will incorporate the education I have accumulated over the 4 years at Paul Smith's College to give my analysis and possible alternatives to silviculture prescriptions to the Creighton Compartment of the management plan. My research question is asking if the silviculture prescriptions are sustainable and if they are meeting the regeneration goal. The primary objective of this research is to examine the Creighton Compartment and determine if the current prescriptions are meeting the regeneration goals, and if not, are there possible alternatives to increase the chances of meeting the desired regeneration.

Literature Review-

Introduction:

Sustainable forest management practices are essential to successfully manage forests continuously. Research into sustainable forest practices has been ongoing for decades in order to find the optimum combination of regeneration goals and sustained yield. Forest management plans have been around for over 100 years and are the tool that foresters use to set goals and objectives. Generally, forest management plans not only include forest objectives but the entire ecosystem including wildlife and wetlands. Forest management plans, especially created by colleges of environmental science, should include the most recent research so it can reach regeneration goals and improving the quality of the ecosystem.

The PSC's forest management plan should incorporate up-to-date research in order to reach long term sustainability. Three of the primary objectives of a forest management plan include: establishing a regulation strategy, defining regeneration goals and deciding on a silviculture treatment that will obtain the regeneration goals. Establishing a regulation strategy includes defining the control type (i.e. area vs. volume) and stand structure (i.e. uneven on even-aged management). Strategy is usually a preliminary decision than is made prior to creating regeneration and prescription goals. Defining regeneration goals is essential in a management plan because it is the future structure of the forest. Regeneration goals are generally based upon current stand structure and landowners objectives. In order to achieve the regeneration goals, a silvicultural prescription must be made and applied via timber harvest. The silvicultural prescription and most importantly the implementation of the plan via harvest are the most important factors to meeting regeneration goals. Due to the fact regeneration goals and silviculture prescriptions are the most important parts of a forest management plan, they will be further discussed below; specifically discussing the topics within northeastern hardwood and softwood forests. Also, because there is a presumed understanding that Forest Stewardship Council (FSC) certifications correlates with sustainable forest practices, and that PSC forest lands are FSC certified, FSC forest's ecologic and economic characteristics will be examined.

Forest Stewardship Council Certification:

Forest Stewardship Council was the first international certification program for sustainable forest management (Foster, Wang & Keeton, 2008). The FSC involves soft laws that require certificate recipients to promote biodiversity, ensure Best Management Practices (BMPs) are in place, and protect wildlife and wetlands (Foster et al., 2008). Although only approximately 6% of the total forest land in North America is FSC certified, it has grown more than 15 times greater than it was in 1996 (Foster et al., 2008), and PSC is currently one of the FSC certified forest.

Foster, Wang and Keeton conducted a comparison in 2008 on the ecological and economic characteristics of FSC certified and uncertified northern hardwood forests in Vermont. Their goal was to discover if being FSC certified actually increases the economic and ecological characteristics of a forest. After the post-harvest comparison it was found that above ground carbon storage, tree structure and productivity were similar in certified and uncertified forests. Net present value of sugar maple (*Acer saccharum*) with a 10 year projection was lower on certified forests but this was not statistically significant (Foster et al., 2008). The only difference found in the research was, "certified stands contained higher coarse woody debris volume that will likely offer ecological benefits" (Foster et al., 2008, p. 187). Some of these ecological benefits may include increased habitat for snag and log dependent species and increased carbon storage (Foster et al., 2008). The certified forests were also the only forests that had pre and post-harvest data for coarse woody debris (Foster et al., 2008). Overall being FSC certified can potentially increase ecological value and promote sustainable forest practices.

Regeneration and Prescription:

Regeneration is one of the primary objectives of a forest management plan. Regeneration can be thought of as the future assets of a stand, therefore the management plan is created to ensure the future assets will be reached. Regeneration can also be used as a biodiversity tool and to encourage wildlife. Even though a harvest has to happen before regeneration occurs, regeneration is usually the objective and the harvest prescription is create to meet the regeneration goals. The species that will be addressed are the primary desired regeneration in the PSC management plan; these species include: Eastern White Pine (*Pinus strobus*), Red Spruce (*Picea rubens*), Yellow Birch (*Betula alleghaniensis*), Red Maple (*Acer rubrum*) and Sugar Maple (*Acer saccharum*).

Eastern White Pine-

Eastern white pine is typically known for its ability to be within any successional stage of a forest including pioneer through climax species (Wendel & Smith, 1990; Ostry, Laflamme & Katovich, 2010). White pine prefers well drained, moist, sandy soils (Wendel & Smith, 1990). White pine has intermediate shade tolerance and thrives with increased sunlight (Wendel & Smith, 1990). Good seed crops occur every 3 to 5 years and in order to obtain successful natural regeneration, prescriptions need to be implemented during or within a year after a good seed crop (Wendel & Smith, 1990; Ostry et al., 2010). Trees 90 years old will produce five times as many seeds at trees 60 years old (Wendel & Smith, 1990). Stand density also correlated to seed crop; high density and low density (187 ft^2/ac and 80ft^2/ac) will product over 30 percent less seed crop than an intermediate density stand (120ft^2/ac) (Wendel & Smith, 1990).

Seeds can germinate on disturbed and undisturbed soils but in order to compensate for competition and mineral soil availability, scarification can be conducted. "Site disturbance that exposes mineral soil, especially tip-up mounds, recent burns and eroded areas are generally favorable to seedling establishment and early growth." (Ostry et al., 2010, p. 334). Preferably, at least 40% of the stand should have exposed mineral soil (Ostry et al., 2010). A shelterwood system with a disturbance of the understory can protect seedlings during early development by giving adequate sunlight while keeping the mineral soil moist (Wendel & Smith, 1990). Removal of slash and bush will also favor white pine seedling by allowing for more sunlight (Wendel & Smith, 1990; Ostry et al., 2010). Silviculture treatments that will result in successful white pine regeneration include clearcut, patch clearcut, shelterwood and seed-tree (Wendel & Smith, 1990; Ostry et al., 2010). Each of these silviculture treatments will be most effective when advanced regeneration is abundant in the stand (Wendel & Smith, 1990; Ostry et al., 2010). The two-cut shelterwood system has been found to be the most successful overall silviculture method for white pine regeneration (Wendel & Smith, 1990; Ostry et al., 2010). The two-cut shelterwood system involves a seed cutting to create the disturbance followed by a removal cutting to remove the remaining shelter trees (Nyland, 2007). The two-cut shelterwood, depending on intensity, allows for enough light intensity (over 40%), protect the seedling and also keeps the mineral soil moist (Wendel & Smith, 1990; Ostry et al., 2010).

Red Spruce-

Red spruce is common in lowland swamp areas of the Creighton Compartment. Red spruce is known to grow on sites that are generally undesirable to other species that growth within the same range (Blum, 1990). Good seed crop occur between 3 and 8 years and is dependent on site conditions (Blum, 1990). The largest factor for successful germination is adequate soil moisture (Blum, 1990). Establishment of red spruce is heavily dependent on good seed crop year and desired conditions (Prevost et al., 2010) During germination, light intensity can be as low as 10 percent, which can allow for appropriate soil moisture, but once established red spruce requires 50 percent light intensity (Blum, 1990). During seedling stage, red spruce is sensitive to full sunlight; adequate light should be between 10 and 40 percent (Potheir & Prevost, 2008). Once red spruce grows from sapling to pole stage it can withstand, and prefer, full sunlight (Blum, 1990).

According to Pothier and Prevost (2008), the optimum red spruce regeneration occurred when 60% of the initial basal area is removed. This type of basal area removal can be done with a shelterwood method (Pothier & Prevost, 2008). “This treatment is an attractive alternative to clear-cutting in such lowland stands where watering-up is anticipated after final harvest.” (Pothier & Prevost, 2008, p. 31). Essentially, a shelterwood method harvest can be done in lowland softwoods for red spruce regeneration as long as scarification of soils occur (Pothier & Prevost, 2008).

Yellow Birch-

Yellow birch is a moderately shade tolerant and has the highest timber value out of all the birch species (Erdmann, 1990). Well-drained loams and moderately well-drained sandy loams are the preferred soil types (Erdmann, 1990). Yellow birch does not produce significant seed crop until 40 years old and maximum seed crop is achieved at 70 years (Erdmann, 1990). Good seed crop occurs every 2 to 3 years and is an important factor when regenerating yellow birch. Similar to red spruce, harvesting needs to occur before or during good seed crop years (Falk et al., 2010). Due to the fact that yellow birch is a slow growing species, removal of advanced regeneration of other species is required as site preparation (Erdmann, 1990; Prevost, Raymond & Lussier, 2010). Scarification not only reduces competition, but also mixes the humus layer which provides a favorable seed bed (Erdmann, 1990; Prevost et al., 2010; Falk, Elliott, Burke &

Nol, 2010). Optimum light level for seedlings is between 45 and 50 percent sunlight (Erdmann, 1990).

Prevost et al. (2010) conducted an experiment studying regeneration response of yellow birch to patch clearcuts (group selection) and scarification. It was found that the highest response of yellow birch occurred on the 98 ft. diameter patch with light scarification compared with a 98 ft. non-scarified, 65 ft. scarified and non-scarified and 131 ft. scarified and non-scarified plots (Prevost et al., 2010). Falk et al. (2010) did a similar study finding that gap opening between 65-82 ft. diameter were favorable to yellow birch with scarification included. Within the Silvics of North America, Erdmann states that group selections of 74.5-91.2 ft. diameter will create suitable growing habitat for seedlings along with shallow scarification (1990). Gaps smaller than 82-98 ft. diameter with increase shade and have been found to increase balsam fir over yellow birch (Prevost et al., 2010). "It (yellow birch) cannot regenerate under a closed canopy; it must have soil disturbance and an opening in the canopy." (Erdmann, 1990).

Red Maple and Sugar Maple-

Red maple and sugar maple are in the same genius and have similar environmental/growths requirements; therefore they will be discussed together. One major difference that should be noted is that red maple can grow on less desirable sites than sugar maple (Walters & Yawney, 1990). Red maple prefers moderately well drained to moist soils and can withstand flooding while sugar maple only grows well on well-drained loams and is very susceptible to flooding (Godman, Yawney & Tubbs, 1990; Walters & Yawney, 1990). Good seed crop occurs every 2 years for red maple and 2 to 5 years for sugar maple depending on site conditions (Godman et al., 1990; Walters & Yawney, 1990). Seeds of maples have a germination rate of over 90% (Godman et al., 1990; Walters & Yawney, 1990). The greatest yield of seed crop occurs between 70 and 100 years old for sugar maple and 60-80 years for red maple (Godman et al., 1990; Walters & Yawney, 1990). Red maple would be considered more shade tolerant than yellow birch but less shade tolerant than sugar maple (Walters & Yawney, 1990). Sugar maple prefers 45 percent sunlight during seedling stage (Godman et al., 1990).

Gasser et al. conducted a study on sugar maple and yellow birch regeneration in 2010; during this study, it was found that liming had little to no effect on regeneration, therefore it is not economically justifiable. Also found in the study was that removal of understory competition had no effect on sugar maple (Gasser et al., 2010). Small patch cuts (32 ft. diameter) have been found to encourage sugar maple regeneration when crop trees are already established throughout the area (Gasser et al., 2010). Site factors, such as litter layer and soil chemistry are good indicators of seedling survival (Cleavitt, Fahey & Battles, (2011). Another alternative is the selection system; extraction of sugar maple logs can be sustainable when 20 to 30 percent of the initial basal area is removed on a 20 year rotation.

The issue with selection systems is that the amount of entries is typically higher than other harvest types and it has been found that primary and secondary machinery tracts negatively affect fine root growth of sugar maple (Malo & Messier, 2011). “Fine root growth of maple was reduced fivefold in both primary (multiple trip) and secondary (only one trip) machinery tracts compared with the control." (Malo & Messier, 2011, p. 892). With selection systems, 15%-25% of the stand is covered with machinery tracks, thus potentially creating an issue with the survival of remaining maple trees (Malo & Messier, 2011).

Conclusion:

Sustainable forest practices are vital tools that need to be used to create a stable, healthy forest ecosystem. Becoming FSC certified can increase ecological characteristics within a forest and will set up soft laws that call for sustainable management (Foster et al., 2008). Meeting regeneration goals using sustainable practices will insure benefits on a long temporal scale. Regeneration is typically the primary goal of a timber harvest and basic knowledge of a species can help determine the silviculture prescription needed for successful regeneration. Harvesting can achieve the regeneration goals set in a forest management plan but can also have detrimental effects on root hairs and the residual stand (Malo & Messier, 2011). Minimizing the amount of entries and reducing the machinery tracts can potential increase the health of the residual trees (Malo & Messier, 2011). All of these aspects of a forest management plan can work together to achieve common goals such as even wood flow, sustained yield and a stable long-lived forest.

Methods:

Stand Organization-

The first step was to convert all cruise and prescription data into Microsoft Excel format in order to conduct analysis and interpretation (Appendix A). The data inserted into the Excel spread sheets include 14 attributes: stand number, forest type, average DBH (diameter at breast height) of stand, total acres, basal area (BA) per acre, BA per acre AGS (acceptable growing stock), trees per acre, trees per acres AGS, cords per acre, inventory year (overstory and understory), management system, harvest type, and harvest year. There are 92 stands within Creighton compartment that are in the management plan; which averages to about 22 acres per stand. There are several stands larger than 100 acres that skews the average; many of the stands are between 5 and 15 acres. These 92 stands were then categorized into fewer, larger stands (Appendix B). There are two reasons for condensing the 92 stands into fewer, larger stands; one is that it is easier to manage larger stands and second, more importantly, silviculture treatments cannot be effectively conducted on a small scale and results would be better reflected on large scale implementation. The stands were categorized by seven main criteria in order of importance: forest type, BA, cords per acre, average diameter, average DBH and management type.

Once the stands were condensed they were each analyzed specifically by forest type, BA, average DBH and other factors that are considered for a silviculture prescription. These condensed stands could then be examined as larger groups and prescriptions could then be established. Rather than assign a rotation length for the entire compartment, establishing a rotation length for each stand/tract would allow for slower growing species to have longer rotation lengths in order to grow to maturity.

Silviculture/Regeneration-

The first step was to define what the "improvement harvest" was for each stand within Creighton compartment so they could be analyzed; which involves putting the improvement harvests into a specific prescription type. Once the improvement harvest was defined, each prescription could be analyzed based on regeneration data given within the management plan. The regeneration data was compiled using Excel. All of the regeneration data was then compared with the prescription goals and graphs were created to compare preferred species regeneration to actual regeneration. Based on how accurate the regeneration was to the goals, modifications were made to the un-harvested stands in order to create a higher chance of meeting the goals. These modifications were based on the silvics of each species as well as peer-reviewed articles released within the last 8 years. Silvics, as defined by the Dictionary of Forestry, is "the study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors, as a basis for the practice of silviculture" (1998, p.166-167). The overall assessment of the silviculture prescriptions was also conducted based on proper forest management, sustainability and regeneration goals. In order to eliminate any additional costs associated with regeneration, the only recommended prescriptions will be using natural regeneration only. Planting seedlings has not been a practice done by PSC therefore planting will not be recommended.

Results

There is approximately 1720 acres of land that has or will be harvested during the management plan. Northern Hardwood is the largest forest type at 48% of the harvestable acres (Table 1). Spruce-Fir-Pine forest types are the next largest type, accounting for 31% of the harvestable acres. Within the management plan, as a majority, the hardwood stands have a preferred species composition of Red Maple, Sugar Maple, Yellow Birch and Black Cherry (Table 3). The softwood stands, as a majority, have a preferred species composition of Eastern White Pine, Red Spruce, Yellow Birch and Balsam Fir (Table 3). Overall, eastern white pine, red spruce, yellow birch and red maple amount to 68% of the preferred species when stands are considered equal and stand size is not taken into account. When only including stands greater than 50 acres, which total 57% of the total acres, red maple, sugar maple and yellow birch total 62% of the preferred species.

Table 1: Forest Types within Creighton

Forest Types	Acres	Percent
Northern Hardwood	831	48%
Spruce-Fir	339	20%
Mixedwood	260	15%
Pine-Spruce	149	9%
Hardwood-Hemlock	81	5%
Spruce-Pine	27	2%
Pine	19	1%
Cedar	14	1%
	1720	100%

Table 2: Tree Species with Abbreviations

Species Type	**Abbreviations**
AMERICAN BEECH	AB
BLACK CHERRY	BC
BALSAM FIR	BF
BLACK SPRUCE	BS
EASTERN HEMLOCK	EM
RED MAPLE	RM
RED PINE	RP
RED SPRUCE	RS
SUGAR MAPLE	SM
TAMARACK	TAM
WHITE ASH	WA
WHITE BIRCH	WB
WHITE CEDAR	WC
WHITE PINE	WP
YELLOW BIRCH	YB

Since this management plan was implemented in 2000, 844 acres of Creighton has been harvested, which is approximately 49% of the compartment's total acres. The 844 acres were harvested between 2004, 2006, 2007, 2009 and 2011. Of the five dates, regeneration data was recoverable for 2004, 2006, 2007 and 2009.

Table 3: Seedling regeneration on harvested stands represented by percentage. Harvest types within harvested stands included thinning (TH), Improvement Harvest (IMP), Balsam Fir Salvage (BF) and Shelterwood (SHWD).

Stand (s)	**Forest Type**	**Acres**	**Harvest Year**	**Harvest Type**	**Preferred Species**	**Seedlings/ Acre**	**Ground Regen**
201	SPR-PIN	7	2009	TH	BF,WP,RS	2115	82% YB, 9% RM, 9% WB
202	NHD	22	2009	TH	RM,BC,YB	2588	53% YB, 26% RM, 7% BF, 3% WP, 3% AB
209	SPR-FIR	37	2009	IMP/BF	WP,RS,EH,YB	18991	60% BF, 34% RS, 4% WP, 2% YB, 1% RM
210, 211	PIN-SPR	22	2009	IMP/BF	WP,RS,RP	7500	57% BF, 42% RS, 0.8%WP
**212*	*NHD*	*11*	*2009*		*RM,BC,YB*	*1634*	*88% AB, 6% BC, 6% BF*
314	MX	27	2007	IMP/TH	YB,RS,WP	18776	46% BF, 27% YB, 8% RS, 8% RM, 7% WP, 4% EH
317, 319, 342	PIN-SPR	21	2007	IMP	RS,WP,HRD	18270	41% BF, 31% RS, 9% YB, 9% TAM, 7% RM, 4% WP
321	CD	12	2007	IMP/BF	RS,RM,WP	5846	49% BF, 26% YB, 17% RS, 5% RM, 1% WP, 1% WC
322	MX	64	2007	BF SALV	BF,YB,WP	13526	50% YB, 26% BF, 12% RS, 11% RM, 0.7% WP, 0.2% TAM
340	SPR-FIR	10	2007	BF SALV	SPR,WP,BF	2116	82% BF, 18% RS
342	CD	2	2007		WC,SPR,BF	1538	50% RM, 50% BF
402, 408	SPR-FIR	30	2009	IMP/BF	SPR,WP,HRD	3792	46% RS, 39% BF, 15% RM
404, 411	PIN-SPR	53	2009	IMP/BF	WP,RS,HRD	2820	92% BF, 5% RS, 3% WP
406, 407	PIN	19	2009	TH	WP,BF,BC	1539	32% WP, 29% BF, 29% AB, 11% RM
420, 422, 425	MX	55	2006	IMP/BF	RS,BF,WP	4476	74% BF, 21% RS, 4% YB
424, 426, 427, 428, 229, 430	SPR-FIR	19	2006	IMP/BF	WP,RS,RM	8036	96% BF, 4% YB
431	NHD	184	2006	SHWD	SM,BC,RM	5276	77% AB, 10% RM, 10% BC, 2% YB
434	PIN-SPR	8	2004	BF SALV	WP,RS,YB	0	N/A
435	MX	3	2004	BF SALV	RS,YB,BF	0	N/A
437	NHD	220	2004	IMP/TH	SM,RM,BC	0	N/A
438	MX	7	2009		RM,BC,YB,WP	10770	59% BF, 27%WP, 9% RS, 4% YB, 2% AB
439	SPR-FIR	11	2009		WP,RS,YB	1539	75% BF, 25% RS

In order to further understand the regeneration, the harvested stands were broken into three types: hardwood, softwood and mixedwood. The hardwood stands account for 426 of the 844 acres already harvested and include the forest type northern hardwood. Within the hardwood stands red maple, black cherry, yellow birch and sugar maple were the preferred species. The sapling regeneration data indicated that the top four species regenerating in the harvested stands include American beech, balsam fir, red maple and sugar maple (Figure 1). The prescriptions used on the hardwood stands were thinning, shelterwood and improvement harvest.

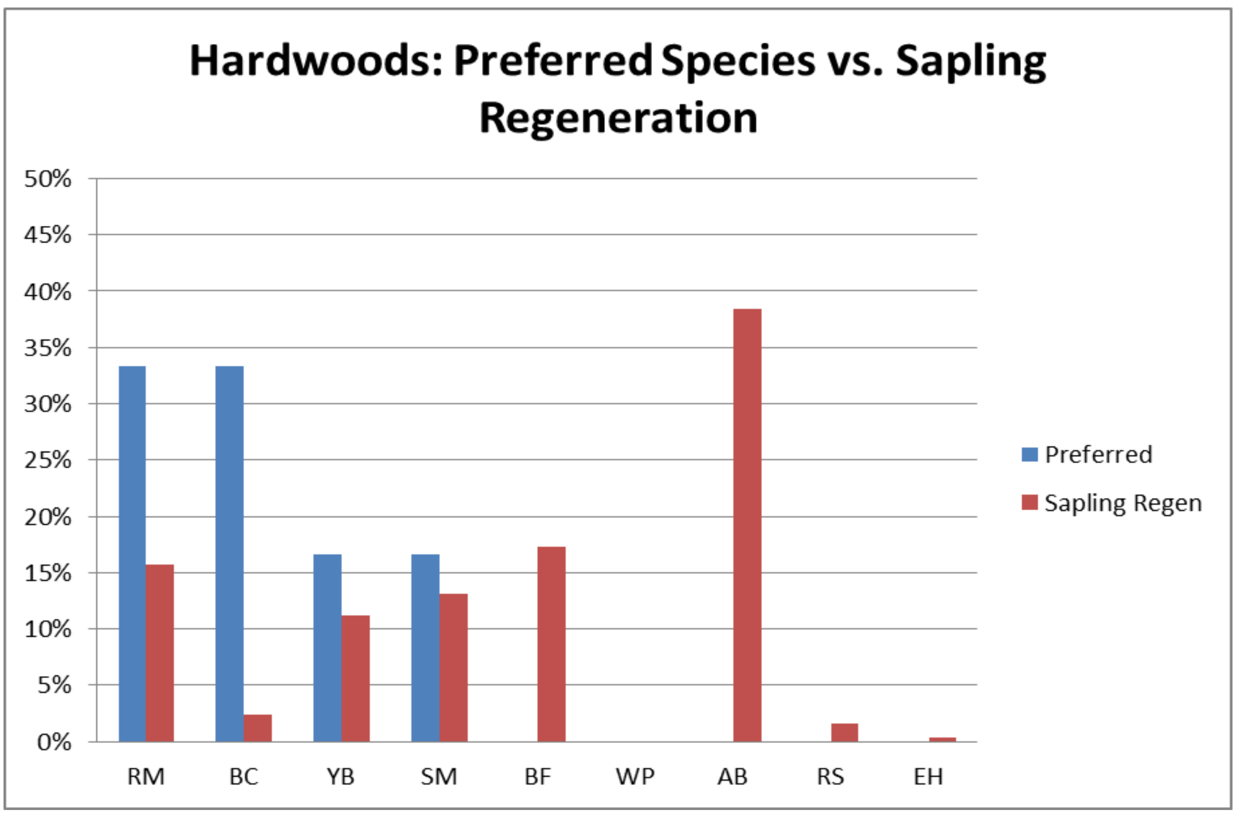

Figure 1: Hardwood sapling regeneration in relation to preferred species within hardwood stands.

The softwood stands consists of 251 of the 844 already harvested acres and include forest types: spruce-pine, spruce-fir, pine-spruce, cedar and pine. Within the softwood stand eastern white pine, red spruce, balsam fir and yellow birch are the preferred species. The sapling regeneration indicated that the top four species regenerating include balsam fir, red spruce, yellow birch and white birch. The prescriptions used on the softwood sites were improvement harvest, balsam fir salvage and thinning.

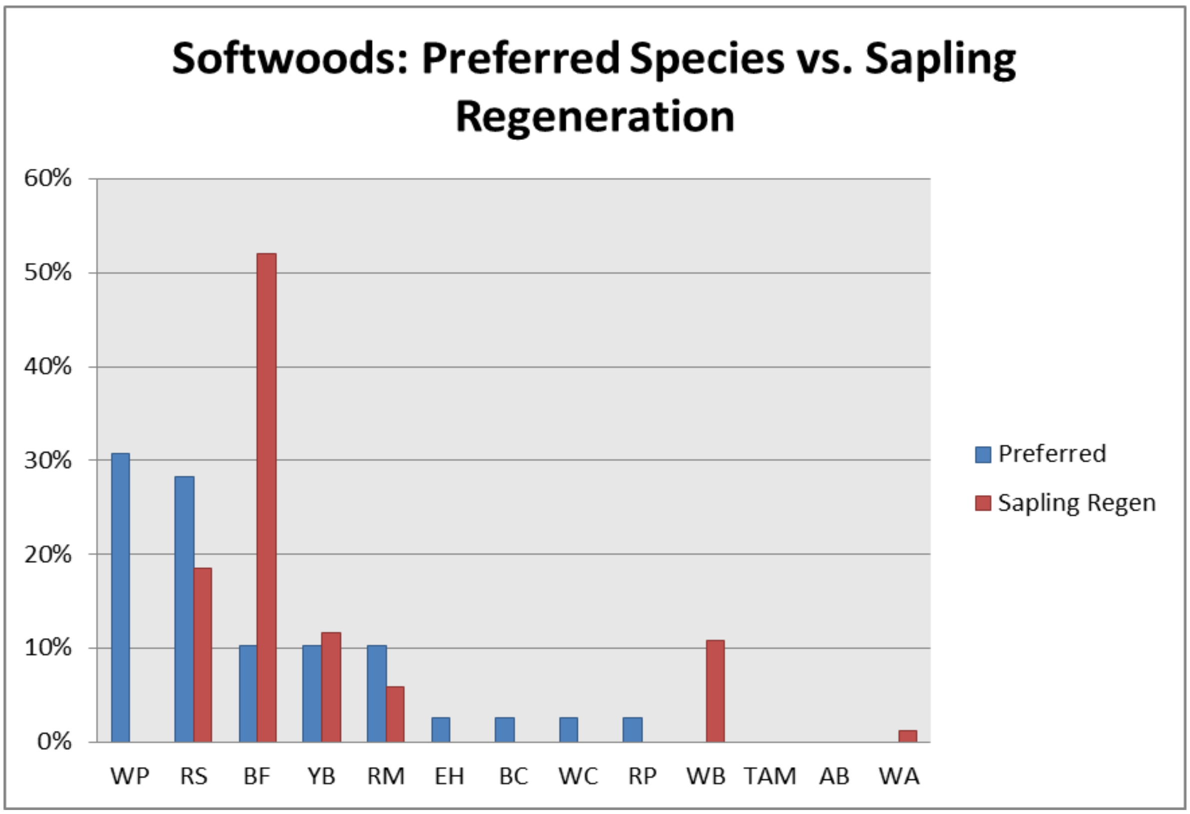

Figure 2: Softwood sapling regeneration in relation to preferred species within softwood stands.

The mixedwood stands account for 156 acres and contain forest type mixedwoods. Yellow birch, white pine, red spruce and balsam fir are the preferred species. The sapling regeneration data indicated that balsam fir, yellow birch, red spruce and red maple were the most common species regenerating. The harvest prescriptions in the mixwoods were improvement harvest, balsam fir salvage and thinning.

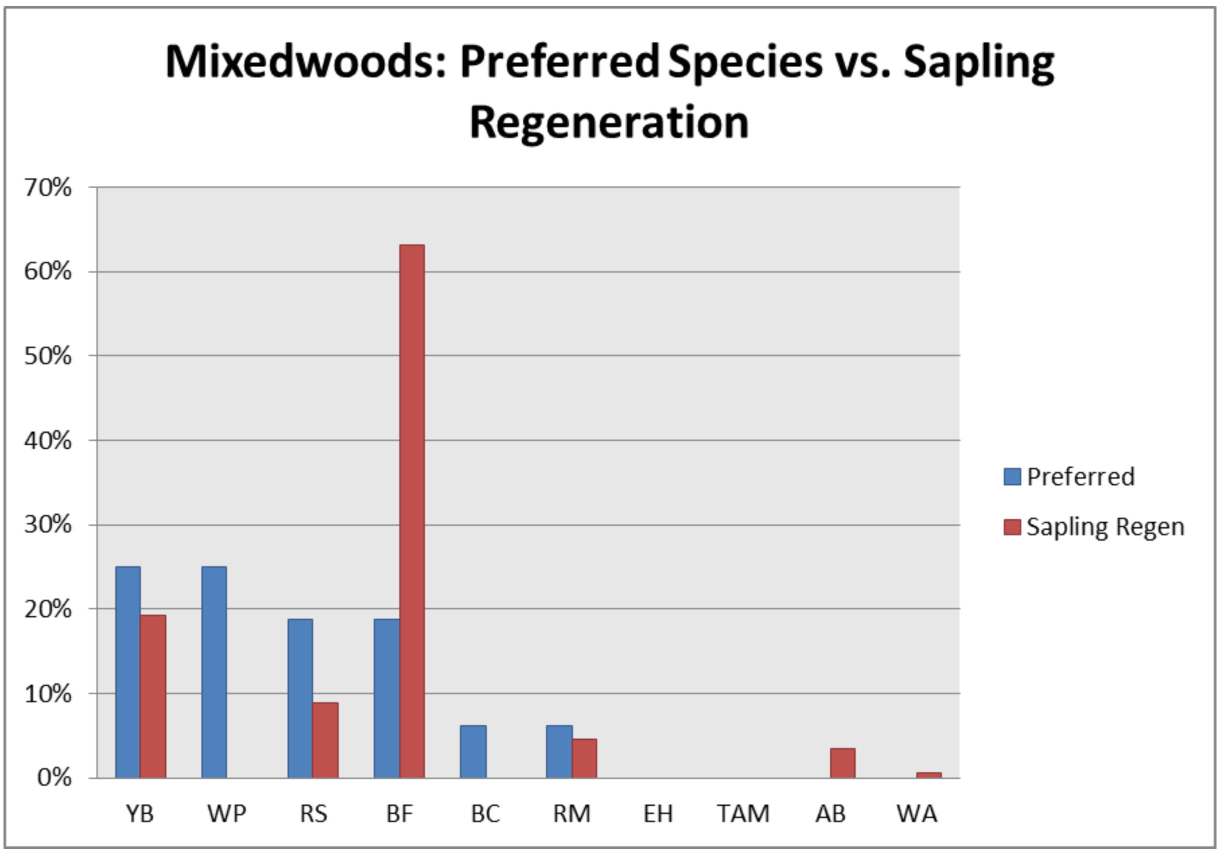

Figure 3: Sapling regeneration in relation to preferred species within mixedwood stands.

As shown above, the harvest techniques are failing to meet regeneration goals. The main focus from the hardwood regeneration is the lack of red maple and black cherry growth along with yellow birch and sugar maple. Another result that stands out is the amount of American beech sapling regeneration. Beech is not a preferred species because of its low timber value and because the majority of beech won't exceed pole stage due to the beech bark disease; yet over 35 percent of the regeneration in all of the hardwood stands is American beech regeneration.

Within the softwood stands, over 30 percent of preferred species is eastern white pine but the harvest techniques are resulting in 0 percent sapling regeneration. The current prescriptions are also not meeting the percent of red spruce preferred along with five other species: red maple, eastern hemlock, black cherry, white cedar and red pine, respectively. The prescriptions are also resulting in over 50 percent balsam fir regeneration when about 10 percent is the preferred size.

The mixedwood stands are experiencing similar results as the softwood stands. They are regenerating 0 percent eastern white pine when 25 percent is preferred. The prescriptions are also not meeting yellow birch, red spruce, black cherry or red maple preferred amounts. Also similar to the softwood stands, the mixedwoods are regenerating huge amounts of balsam fir saplings, over 60 percent of the stand when less than 20 percent is preferred.

Discussion-

The research question asked if the silviculture prescriptions are sustainable and if they are meeting the regeneration goal. As shown in the results, the prescriptions are not meeting the regeneration goals. In regards to the sustainability aspect, the majority of the prescriptions are light to moderate intensity harvests, combined with the 20 year harvest cycle, would be sustainable (Malo & Messier, 2011). The issue with the majority of prescriptions is that they do not imitate early succcessional forests. Single tree selection and improvement harvests do not change the stand structure. Early succession forests are a required habitat for a variety of wildlife. Having a variety of stand structure also encourages biodiversity in regards to understory vegetation and wildlife. As stated in the methods, in order to eliminate any additional costs associated with regeneration, the only recommended prescriptions will be using natural regeneration only.

Hardwood Stands:

The hardwood stands (northern hardwood and hardwood-hemlock) account for 53 percent of the forest types within Creighton. Forty-seven percent of the hardwood stands have already been harvested during the implementation of the management plan; leaving 53 percent not harvested and available for prescription modification. Red maple, sugar maple, yellow birch and black cherry are the preferred species of the hardwood stands; silviculture treatments to encourage regeneration will be addressed for these species.

There has been two hardwood stands harvested; stand 431 (184 acres), and stand 437 (220 acres). According to the management plan stands 431 and 437 were the same stand (stand 431 from 2000-2008) until 2009 when they were split up. As stand 431, the area was harvested in 2006. One issue is that the management plan states that the new stand 431 had a shelterwood harvest in 2006 while stand 437 was harvested in 2004 with and improvement/thinning harvest. The best estimate is that the southern portion of old stand 431 (new stand 437) was similar to a shelterwood but once they split up the forester determined it would be best suited as an improvement/thinning. Both stands have similar basal areas, both have the same remaining species composition in the overstory and both removed nearly all American beech.

The shelterwood treatment in stand 431 brought the basal area to approximately 30 ft^2/ac. The overstory species composition left after harvest was red maple (46.7%), sugar maple (42.2%), black cherry (4.4%), yellow birch (4.4%) and American beech (2.2%). An improvement/thinning harvest in stand 437 resulted in a basal area of approximately 30 ft^2/ac. The overstory species remaining in the stand were sugar maple (51.8%), red maple (28.6%), black cherry (14.3%) and yellow birch (5.4%). The regeneration occurring in both seeding and sapling stages is mostly American beech followed by balsam fir, red maple and sugar maple.

An important factor for regenerating yellow birch and black cherry is that the harvest must occur before or during good seed crop years (Marquis, 1990; Falk et al., 2010). Yellow birch especially requires removal of advanced regeneration of competition and scarification (Erdmann, 1990; Prevost et al., 2010). Black cherry has large seeds that can germinate under low light conditions but need high levels of light to successfully grow from seedling to sapling (Marquis, 1990). For the hardwood species, shade intolerance is highest in black cherry followed by yellow birch, red maple and sugar maple being the highest in shade tolerance (Marquis, 1990; Erdmann, 1990; Walters & Yawney, 1990). Several studies show that group selection harvests have been most successful for regeneration of yellow birch and can also be successful for maples (Falk et al., 2010; Prevost et al., 2010; Erdmann, 1990; Godman et al., 1990). Based on several studies, a diameter opening of 65-80 feet would favor yellow birch with a light scarification and combined with a good seed year (Falk et al., 2010; Prevost et al., 2010; Erdmann, 1990).

Black cherry establishes best on a two-cut shelterwood system where the overstory removal occurs 5 to 10 years after the seed cut (Marquis, 1990). If the overstory is not removed within 10 years, the cherry regeneration will decline due to its extreme shade intolerance (Marquis, 1990). The current management plan has the removal cut (removal of overstory) occurring 20 years after the seed cut (initial harvest of shelterwood). The 20 year interval would be too much shade for cherry regeneration and result in unsuccessful establishment. Although black cherry typically does not germinate well in un-even aged systems, such as single-tree selection, it has been found to be somewhat successful with small clearcut patches or group selection (Marquis, 1990). Red and sugar maple can also be successful with group selection; most successfully found in small patches about 32 feet in diameter (Gasser et al., 2010). The traditional method of maple regeneration is the use of single tree selection. Bedard and Majcen (2003) found that if 21-32 percent of the stand is removed using single tree selection, it can sustainably be done every 20 years. This research coincides with the current management plan's 20 year harvest cycle. The issue with single tree selection, as stated in the literature review, is that 15-25 percent of the stand is covered with machine tracks which causes fine root growth of maples to reduce fivefold (Malo & Messier, 2011).

When considering all of the factors between the four favored species, it has been determined that a variable sized group selection harvest is the best solution to regenerate red maple, sugar maple, black cherry and yellow birch. The diameter size of the opening should be determined by parent tree location; if an area has a high amount of yellow birch and black cherry parent trees, then openings of 80 feet will be created to encourage yellow birch and black cherry. The harvest should also align with good seed crop years which can easily be established by monitoring for several years. The edges and south sides of the opening could see red and sugar maple regeneration because they favor more shade initially. Light scarification via machine tracks should occur on approximately 60 percent of the stand to encourage yellow birch while the non-scarified area would favor black cherry. If a greater amount of black cherry is desired then selecting areas with high amounts of established seedling is recommended because they thrive with a release. If areas only have maples in the overstory then the group selection should have a diameter opening of 35 feet to give germinating maples the adequate amount of shade they required. Scarification does not need to occur to see germination and in fact should be avoided so that parent tree's roots are not injured. The group selection harvests, especially the 80ft diameter openings, will create early succession forest and therefore will encourage early succession wildlife species. Over time, these openings, that will be created in 20 year gaps, will create variety in stand structure and increase biodiversity. The group selections will create openings in 25 percent of the stand. It will take about four cycles for the entire stand to be treated resulting in an 80 year span between harvests for individual openings. Since all of the desired hardwood species have reached maturity by 80 years and are of timber value, this rotation age and treatment is sustainable (Erdmann,1990; Godman et al., 1990; Marquis, 1990).

Softwood Stands:

The softwood stands (spruce-fir, pine-spruce, spruce-pine, pine and cedar) account for 33 percent of the forest type within Creighton. Approximately 46 percent of the softwood stands have been harvested, leaving 54 percent available for prescription modification. From the regeneration data, the current harvest treatments are resulting in 0 percent white pine sapling regeneration. There is some white pine regeneration in the seedling stage but the highest amount is 7 percent of the individual stand. Eastern white pine is the most preferred species followed by red spruce, yellow birch and balsam fir. The sapling regeneration data shows that balsam fir has the highest success rate (52%) follow by red spruce (19%) yellow birch (11%) and white birch (11%). The majority of prescriptions for softwoods are improvement harvest/balsam fir salvage or selection harvest (either single tree or group). The most vital issue for the softwood stands is the lack of white pine and the high amount of undesirable balsam fir.

White pine has a good seed crop every 3 to 5 years; similar to yellow birch, prescriptions need to be implemented before or during a good seed crop year (Wendel & Smiths, 1990). In order to reduce competition and to increase mineral soil availability, scarification of the soil should be done (Ostry et al., 2010). The optimum silviculture treatment for white pine would be a two-cut shelterwood system with scarification of the soil and slash removal (Wendel & Smith, 1990; Ostry et al., 2010).

Good seed crop for red spruce occur every 3 to 8 years (Blum, 1990). Good seed year can be narrowed down by monitoring sites within the compartment. The greatest factors for red spruce germination are moist seed beds and good seed crop year during harvest (Prevost et al., 2010). Initially, red spruce can germinate in as little as 10 percent sun, which allows for the desired soil moisture (Blum, 1990). Once established a shelterwood, removing 60% of the basal area, will allow enough sunlight for red spruce to successfully regenerate (Pothier & Prevost, 2008).

After studying the requirements for successful white pine and red spruce regeneration, it has been determined that a two-cut shelterwood system with at least 40 percent light scarification should be conducted to favor regeneration of white pine and red spruce. The softwood stands that have already been harvested are improvement harvest/balsam fir salvage and only reducing the basal area to between 80 and 90

ft^2/ac. Balsam fir favors small openings, such as the improvement harvests and not enough sunlight is reaching the forest floor to encourage white pine regeneration (Prevost et al., 2010). After good seed crop years have been established, the seed cutting stage of the shelterwood should be conducted with a residual basal area between 35 and 45 ft^2/ac. Along with the seed cutting, a light scarification of 40 to 50 percent of the soil should occur. The residual basal area will give the required amount of light for both red spruce and white pine. A shelterwood method will create early succession forests and therefore encourage biodiversity of wildlife and understory vegetation.

Mixedwood Stands:

The mixedwood stands account for 14 percent of the forest types within Creighton. Approximately 60 percent of the stand has already been harvested. The mixedwood stands are similar to the softwood stands, where yellow birch, white pine, red spruce and balsam fir are the highest preferred species. Also similar to the softwood stands, the mixedwoods are not regenerating any white pine and balsam fir is over 60 percent of the regeneration. Two mixedwood stands have been harvested and both used an improvement/balsam fir salvage prescription.

Each remaining mixedwood stand's prescription should be determined based on overstory species composition. For example, stands 311, 313, and 314 have white pine as the major species in the overstory; therefore shelterwood systems should be implemented to favor white pine regeneration.

Both the variable sized group selection and the two-cut shelterwood system create early succession forests and over time will create a variety of stand ages throughout the compartment thus creating biodiversity.

References

Blum, B. M., (1990). Red Spruce. *In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 1. Conifers.* Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Bédard, S., & Majcen, Z. (2003).Growth following single-tree selection cutting in Québec northern hardwoods. *Forestry Chronicle*, 79(5), 898-905.

Cleavitt, N. L., Fahey, T. J., & Battles, J. J. (2011). Regeneration ecology of sugar maple (Acer saccharum): seedling survival in relation to nutrition, site factors, and damage by insects and pathogens. *Canadian Journal Of Forest Research*, 41(2), 235-244.

Erdmann, G. G. (1990). Yellow Birch. *In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 2. Hardwoods.* Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Falk, K. J., Elliott, K. A., Burke, D. M., & Nol, E. (2010).Early seedling response to group selection harvesting in a northern hardwood forest. *Forestry Chronicle*, 86(1), 100-109.

Foster, B. C., Wang, D., & Keeton, W. S. (2008). An exploratory, post-harvest comparison of ecological and economic characteristics of forest stewardship council certified and uncertified northern hardwood stands. *Journal Of Sustainable Forestry*, *26*(3), 171-191.

Gasser, D., Messier, C., Beaudet, M., & Lechowicz, M. J. (2010). Sugar maple and yellow birch regeneration in response to canopy opening, liming and vegetation control in a temperate deciduous forest of Quebec. *Forest Ecology & Management*, *259*(10), 2006-2014.

Godman R. M., Yawney, H. W., & Tubbs, C.H. (1990). Sugar Maple. *In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 2. Hardwoods.* Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Helms, J. A. (1998). *The dictionary of forestry*. Bethesda, MD: Society of American Foresters.

Maine Council on Sustainable Forest Management (1996). Sustaining Maine's Forests: criteria, goals, and benchmarks for sustainable forest management. Augusta, ME: Dept. of Conservation; p. 33

Malo, C., & Messier, C. (2011). Impact of primary and secondary machinery tracks on fine root growth of sugar maple after selection cutting.Canadian Journal Of Forest Research, 41(4), 892-897.

Marquis, D. A., (1990). Black Cherry. *In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 2. Hardwoods.* Washington, D.C.: U.S. Department of Agriculture, Forest Service.

McDill, M. E., (1999). *Forest Resource Management*- Ch10: Area and Volume Control

Nyland, R.D. (2007). Silviculture: Concepts and applications (2nd edition). Long Grove, Illinois:Waveland Press, Inc.

Ostry, M. E., Laflamme, G. G., & Katovich, S. A. (2010). Silvicultural approaches for management of eastern white pine to minimize impacts of damaging agents. Forest Pathology, 40(3/4), 332-346.

Pothier, D., & Prévost, M. (2008).Regeneration development under shelterwoods in a lowland red spruce – balsam fir stand. Canadian Journal Of Forest Research, 38(1), 31-39.

Prévost, M., Raymond, P., & Lussier, J. (2010). Regeneration dynamics after patch cutting and scarification in yellow birch – conifer stands. Canadian Journal of Forest Research, 40(2), 357-369.

Walters, R. S., Yawney, H. W., (1990). Red Maple. *In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 2. Hardwoods.* Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Wendel, G. W., & Smith, H. C. (1990). Eastern White Pine. *In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 1. Conifers.* Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Appendix A

Creighton Compartment stand data in Excel format

Stand (s)	Forest Type	Ave. Dia	Total Acres	BA	BA AGS	Trees/Ac	Trees/Ac AGS	Cords/Ac	Overstory Inv.	Understory Inv.	Harvest Type	Mng Sys	Year	Top 3/80%	NOTE
102, 104	PIN-SPR-FIR	10.5	34	128.7	113.1	173.5	154.9	14.17	2000	2000	IM	UN	2016	WP-RS-BF	
103	HRD-HEM-PIN	10.7	37	130.2	103.3	175.4	143.8	23.2	2000	2000	IM	UN	2016	WB-RM-EM	
105	SPR-FIR	6.8	5	75	70	263.5	238	11	2000	2000	TH	UN	2016	BS-WP	
107	SPR-FIR	6.2	6	25	22.5	116.9	104.2	5.23	2000	2000	NH-W	WLD		BS-LR	
108	SPR-FIR	10.8	54	54.6	30.08	268	73.1	9.2	2009	2009	SE	M-A	2023	RS-BF	
109	PIN-SPR-FIR	14.7	3	45	34.7	6.8	3.4	8.7	2009	2009	SE	M-A	2023	RP-WP	
110	HEM-HRD	11	44	68.8	49.2	89.1	67.1	14.8	2009	2009	SE	M-A	2023	RM-EH-RS	
111, 112	HEM-HRD	8.6	7	141.8	125.5	260.7	241	28.79	2000	2000	ST			EM-RM-BF	
201	MX-PIN	9.2	7	95	72.5	167.3	133.4	13.96	2000	2000	RI	AS	2012	BF-WP-WB	
202	NHD	9.8	22	96	76	167.7	138.3	18.42	2000	2000	RI	EV	2012	RM-BC-AB	
204	SPR-FIR	6.6	56	49.9	45.7	191.7	176.2	9.89	2000	2000	NH-W	EV		LR-BS-BF	
206	CD	6.9	1.4	90	90	336.6	336.6	12.6	2000	2000	NH-W	EV		WC	
207	RPIN	8.7	2	125	115	296.1	264.4	20.63	2000	2000	NO	EV		RP-WB	
209	SPR-FIR	9.3	37	132.3	103.3	247.9	181	16.04	2000	2000	RI	M-A	2012	RS-BF	
210, 211	SPR-FIR-PIN	9.7	22	118.7	108.7	189.3	164.3	13.58	2000	2000	RI	M-A	2012	WP-RP-BF	
212	NHD		11								RI	EV	2012		NOT FSC
213	WASTE-WAT-FAC		5												NOT FSC
301	WPIN	7.5	7	172.5	115	231.4	128	10.07	2000	2000	IM-BS	M-A	2013	WP-BF	
302, 305, 308	SPR-FIR-PIN	9	15	105.4	74.4	190.7	120.5	9.99	2000	2000	BS-TH	M-A	2013	RS-WP-BF	
303	MX	8.2	12	110.1	73.4	257.3	184.4	14.05	2000	2000	IM-BS	M-A	2013	YB-RM-BF	
304, 309	SPR-FIR	8.4	34	97.7	65.2	231.3	147.5	12.83	2000	2000	IM-BS	M-A	2013	RS-BF	
307	SPR-FIR	6.7	12	65.5	44.6	230.1	162.7	7.99	2000	2000	IM-BS	EV	2013	BS-RS-BF	
310, 313	MX	7.5	21	100.6	39.4	256.9	120.4	13.4	2000	2000	IM-BS	M-A	2013	BF-RM-RS	
311	WPIN	19.2	14	97.5	47.5	254.6	217.4	4.07	2000	2000	IM-BS	M-A	2013	WP	
312	MX	2.3	7	118.3	57.5	1302.7	952.6	4.8	2000	2000	TH	EV	2013	WP	
314	MX	8.2	27	110.1	73.4	257.3	184.4	14.05	2000	2000	RI	M-A	2012	YB-RM-BF	
316	NHD	9.4	121	78	42	133.2	73.2	11.65	2000	2000	SW	EV	2012	AB-SM-RM	
317, 319, 341	SPR-FIR-PIN	9	18	105.4	74.4	190.7	120.5	9.99	2000	2010	RI	M-A	2012	RS-WP-BF	
320	MX-S	11.1	5	120	90	171.9	116.9	24.51	2000	2010	RI	EV	2012	WC-BF-BS	
321	SPR-FIR	8.4	14	97.7	65.2	231.3	147.5	12.83	2000	2010	RI	M-A	2012	RS-BF	
322	MX	7.5	64	99.8	38.6	255.5	119	13.24	2000	2010	RI	M-A	2012	BF-RM-RS	
323	NHD	9.9	59	23.3	22.5	24.5	23.9	3.8	2008	2008	POR	EV	2018	RM-SM-AB	
324	NHD	10.5	96	30.2	28.8	44.5	43.3	6.2	2007	2007	TH	UN	2022	RM-SM	
325	NHD	9.9	53	80.1	62.7	133.7	112	13.9	2000	2000	SW	EV	2011	AB-RM-SM	
326	NHD	10.2	68	95.8	62.9	148.2	108.3	17.98	2000	2000	SW	EV	2011	AB-SM-RM	
327, 329	SPR-FIR	6.7	7	65.5	44.6	230.1	162.7	7.99	2000	2000	IM-BS	EV	2012	BS-RS-BF	
328	SPR-FIR	8.4	15	97.7	65.2	231.3	147.5	12.83	2000	2000	IM-BS	M-A	2012	RS-BF	
332, 335, 336	SPR-FIR-PIN	9	5	105.4	74.4	190.7	120.5	9.99	2000	2000	BS-TH	M-A	2018	RS-WP-BF	
334, 338	SPR-FIR	8.4	14	97.7	65.2	231.3	147.5	12.83	2000	2000	IM-BS	M-A	2018	RS-BF	

Stand (s)	Forest Type	Ave. Dia	Total Acres	BA	BA AGS	Trees/Ac	Trees/Ac AGS	Cords/Ac	Overstory Inv.	Understory Inv.	Harvest Type	Mng Sys	Year	Top 3/80%	NOTE
339	*SPR-FIR*	*6.7*	*3*	*65.5*	*44.6*	*230.1*	*162.7*	*7.99*	*2000*	*2000*	*NH-W*	*EV*		*BS-RS-BF*	
340	SPR-FIR	6.7	10	65.5	44.6	230.1	162.7	7.99	2000	2000	RI	EV	2012	BS-RS-BF	SAME AS 339
342	WC	10.8	2	30	30	46.6	46.6	2.57	2000	2010	RI	EV	2012	WC	
343	NHD	9.9	69	MISS	MISS	MISS	MISS	MISS	2000	2000	SW	EV	2018		NO DATA
344	NHD	10.2	22	95.8	62.9	148.2	107.3	17.98	2000	2000	SW	EV	2012	AB-HM-RM	
345	SPR-FIR	8.4	7	97.7	65.2	231.3	147.5	12.83	2000	2000	IM-BS	M-A	2011	RS-BF	
401, 410	*SPR-FIR*	*6.7*	*8*	*55*	*55*	*218.3*	*218.3*	*10.57*	*2000*	*2000*	*RI*	*EV*	*2012*	*BS-LR*	
402, 408	SPR-FIR	8.4	30	94.2	85.7	224.7	210.2	13.72	2000	2000	RI	M-A	2012	BS-BF-RS	
404, 411	PIN-SPR-FIR	9.9	53	136.8	90	206.1	143	14.01	2000	2000	RI	M-A	2012	WP-RS-FIR	
405	NHD	8.2	27	92.5	82.5	222.8	181.4	21.23	2000	2000	TH	EV	2018	BC-RM	
406, 407	PIN-HRD	10	19	68	58	107.6	87.8	11.64	2000	2000	RI	EV	2012	WP	
409	MX	9.3	18	69.9	48.4	134.2	108.5	13.22	2000	2000	TH	EV	2018	BF-RS-RM	
412, 415	PIN-SPR-FIR	9.9	11	136.8	90	206.1	143	14.01	2000	2000	IM-BS	M-A	2014	WP-RS-BF	
413, 417	SPR-FIR-PIN	7.9	36	144	89	371	246.6	12.66	2000	2000	IM-BS	M-A	2014	BF-WP-BS	
414	SPR-FIR	3.4	34	146	130	1759.1	1695.1	8.58	2000	2000	TH	EV	2014	BF-RS	
416	MX	7.9	9	114	76	290.3	215.5	9.19	2000	2000	POR	EV	2014	BF-RM	
418	MX	6.8	36	128	88	443.6	344.1	11.94	2000	2000	TH	EV	2014	BF-RM-BC	
420, 422, 425	MX	9	55	100	41.8	199.8	82.8	12.13	2000	2009	RI	M-A	2011	BF-RS-ASPN	
421	NHD	8.6	29	148	56	339.7	154.8	23.7	2000	2000	SW	EV	2014	RM-BF-BC	
424, 428, 430	SPR-FIR	8.4	15	97.7	65.2	231.3	147.5	12.83	2000	2009	RI	M-A	2011	RS-BF	
426, 429	SPR-FIR	6.7	3	65.5	44.6	230.1	162.7	7.99	2000	2009	RI	EV	2011	BS-RS-BF	
427	SPR-FIR-PIN	9	1	105.4	74.4	190.7	120.5	9.99	2000	2000	RI	M-A	2011	RS-WP-BF	
431	NHD	11.1	184	85.4	57.8	139.5	92.9	14.07	2000	2009	RI	EV	2011	SM-AB-RM	
433	*SPR-FIR*	*8.4*	*7*	*97.7*	*65.2*	*231.3*	*147.5*	*12.83*	*2000*	*2000*	*NH-W*	*EV*		*RS-BF*	
434	MX	8.1	8	22.5	12.5	54.3	26.3	3.7	2009	2009	SE	M-A	2019	WP-RS-BF	
435	MX	8.4	3	35	30	79	54	5.4	2009	2009	SE	M-A	2019	RS-YB-RM	
437	NHD	11.1	220	35	30.1	45.8	39.8	5.3	2009	2009	SE	UN	2019	SM-RM	
438	MX	9.9	7	109	57	178	77.5	19.9	2009	2009	RI	M-A	2012	BF-RM-BC	
439	SPR-FIR	9.6	11	69	40.3	117.5	57.5	12.3	2009	2009	RI	M-A	2012	RS-BF-WC	

Appendix B

Table 6: Creighton stands reorganized with new forest types

Stand (s)	Forest Type	New For. Type	Ave. Dia	Total Acres	BA	BA AGS	Trees/Ac	Trees/Ac AGS	Cords/Ac	Overstory Inv.	Understory Inv.	Harvest Type	Mng Sys	Year	Top 3/80%	NOTE
342	WC	CD	10.8	2	30	30	46.6	46.6	2.57	2000	2010	RI	EV	2012	WC	
206	*CD*	CD	*6.9*	*1.4*	*90*	*90*	*336.6*	*336.6*	*12.6*	*2000*	*2000*	*NH-W*	*EV*		*WC*	
321	MX-S	CD	11.6	12	106	94	132.2	118.7	18.9	2012	2012	SE	M-A	2022	WC-RS	
110	HEM-HRD	HRD-HEM	11	44	68.8	49.2	89.1	67.1	14.8	2009	2009	SE	M-A	2023	RM-EH-RS	
103	HRD-HEM-PIN	HRD-HEM	10.7	37	130.2	103.3	175.4	143.8	23.2	2000	2000	IM	UN	2016	WB-RM-EM	
111, 112	*HEM-HRD*	HRD-HEM	*8.6*	*7*	*141.8*	*125.5*	*260.7*	*241*	*28.79*	*2000*	*2000*	*ST*			*EM-RM-BF*	
435	MX	MX	8.4	3	35	30	79	54	5.4	2009	2009	SE	M-A	2019	RS-YB-RM	
420, 422, 425	MX	MX	9.9	55	46	29.9	77.5	54	8	2011	2011	SE	M-A	2026	RS-BF-RM	
322	MX	MX	11.1	64	65.8	41.7	82.5	54.6	10.71	2012	2012	SE	M-A	2022	RM-YB-RS	
313	MX	MX	8.6	6	70	35	146.2	47.9	9.5	2012	2012	SE	UN	2012	WP-RS-RM	
314	MX	MX	11	27	84.6	67.4	102.6	71	12	2012	2012	SE	M-A	2022	WP-RD-RM	
311	PIN-MX	MX	9.6	22	96.4	51.3	145.6	89.2	14.3	2012	2012	SE	UN	2012	WP-BF-YB	
303,310	MX	MX	9.7	31	104.5	51	177.3	77.6	15.5	2012	2012	SE	M-A	2012	BF-RM-YB	
438	MX	MX	9.9	7	109	57	178	77.5	19.9	2009	2012	RI	M-A	2014	BF-RM-BC	
416	MX	MX	7.9	9	114	76	290.3	215.5	9.19	2000	2000	OR/TH	EV	2014	BF-RM	
418	MX	MX	6.8	36	128	88	443.6	344.1	11.94	2000	2000	TH	EV	2014	BF-RM-BC	
323	NHD	NHD	9.9	59	23.3	22.5	24.5	23.9	3.8	2008	2008	POR	EV	2018	RM-SM-AB	
324	NHD	NHD	10.5	96	30.2	28.8	44.5	43.3	6.2	2007	2007	TH	UN	2022	RM-SM	
431	NHD	NHD	12.8	184	34.6	17	34.9	17.3	5.5	2011	2011	POR	EV	2026	RM-SM	
437	NHD	NHD	11.1	220	35	30.1	45.8	39.8	5.3	2009	2009	SE	UN	2019	SM-RM	
316	NHD	NHD	9.4	109	77	42	130.3	73.2	11.65	2000	2000	ST	EV		AB-SM-RM	STDNT AREA
325	NHD	NHD	9.9	53	80.1	62.7	133.7	112	13.9	2000	2000	RI	EV	2016	AB-RM-SM	
343	NHD	NHD	9.9	69	80.1	62.7	133.7	112	13.9	2000	2000	SW	EV	2018		
312	NHD	NHD	10.2	4	85	65	127.9	101.5	13	2012	2012	IM	EV	2012	YB-RM-BC	
405	NHD	NHD	8.2	27	92.5	82.5	222.8	181.4	21.23	2000	2000	TH	EV	2018	BC-RM	
326	NHD	NHD	10.2	68	95.8	62.9	148.2	107.3	17.98	2000	2000	RI	EV	2016	AB-SM-RM	
344	NHD	NHD	10.2	22	95.8	62.9	148.2	107.3	17.98	2000	2000	ST	EV		AB-HM-RM	
202	NHD	NHD	9.8	22	96	76	167.7	138.3	18.42	2000	2012	RI	EV	2014	RM-BC-AB	
212	*NHD*	NHD	*9.8*	*11*	*96*	*76*	*167.7*	*138.3*	*18.42*	*2000*	*2012*	*RI*	*EV*	*2014*	*RM-BC-AB*	*NOT FSC*
421	NHD	NHD	8.6	29	148	56	339.7	154.8	23.7	2000	2000	SW	EV	2014	RM-BF-BC	
406, 407	PIN-HRD	PIN	10	19	68	58	107.6	87.8	11.64	2000	2012	RI	EV	2014	WP	
207	*RPIN*	PIN	*8.7*	*2*	*125*	*115*	*296.1*	*264.4*	*20.63*	*2000*	*2000*	*NO*	*EV*		*RP-WB*	
301	WPIN	PIN	7.5	7	172.5	115	231.4	128	10.07	2000	2000	ST	M-A	2013	WP-BF	STDNT AREA
434	MX	PIN-SPR	8.1	8	22.5	12.5	54.3	26.3	3.7	2009	2009	SE	M-A	2019	WP-RS-BF	
317, 319, 342	PIN-SPR-FIR	PIN-SPR	11.8	21	87.6	73.9	88	60.3	9	2012	2012	SE	M-A	2022	WP-RS	
210, 211	SPR-FIR-PIN	PIN-SPR	9.7	22	118.7	108.7	189.3	164.3	13.58	2000	2012	RI	M-A	2014	WP-RS-BF	
102, 104	PIN-SPR-FIR	PIN-SPR	10.5	34	128.7	113.1	173.5	154.9	14.17	2000	2000	IM	UN	2016	WP-RS-BF	
404, 411	PIN-SPR-FIR	PIN-SPR	9.9	53	136.8	90	206.1	143	14.01	2000	2012	RI	M-A	2014	WP-RS-FIR	
412, 415	PIN-SPR-FIR	PIN-SPR	9.9	11	136.8	90	206.1	143	14.01	2000	2000	TH	M-A	2014	WP-RS-BF	BF SALV

Stand (s)	Forest Type	New For. Type	Ave. Dia	Total Acres	BA	BA AGS	Trees/Ac	Trees/Ac AGS	Cords/Ac	Overstory Inv.	Understory Inv.	Harvest Type	Mng Sys	Year	Top 3/80%	NOTE
107	SPR-FIR	SPR-FIR	6.2	6	25	22.5	116.9	104.2	5.23	2000	2000	NH-W	WLD		BS-LR	
424, 426, 427, 428, 229, 430	SPR-FIR	SPR-FIR	7.6	19	47.9	30.13	128.4	100.1	7.2	2011	2011	SE	M-A	2026	RS-BF	
204	SPR-FIR	SPR-FIR	6.6	56	49.9	45.7	191.7	176.2	9.89	2000	2000	NH-W	EV		LR-BS-BF	
108	SPR-FIR	SPR-FIR	10.8	54	54.6	30.08	268	73.1	9.2	2009	2009	SE	M-A	2023	RS-BF	
401, 410	SPR-FIR	SPR-FIR	6.7	8	55	55	218.3	218.3	10.57	2000	2000	RI	EV	2014	BS-LR	
327, 329	SPR-FIR	SPR-FIR	6.7	7	65.5	44.6	230.1	162.7	7.99	2000	2000	ST	EV		BS-RS-BF	
339	SPR-FIR	SPR-FIR	6.7	3	65.5	44.6	230.1	162.7	7.99	2000	2000	NH-W	EV		BS-RS-BF	
340	SPR-FIR	SPR-FIR	6.7	10	65.5	44.6	230.1	162.7	7.99	2000	2010	RI	EV	2012	BS-RS-BF	SAME AS 339
439	SPR-FIR	SPR-FIR	9.6	11	69	40.3	117.5	57.5	12.3	2009	2012	RI	M-A	2014	RS-BF-WC	
409	MX	SPR-FIR	9.3	18	69.9	48.4	134.2	108.5	13.22	2000	2000	TH	EV	2018	BF-RS-RM	
304, 309	SPR-FIR	SPR-FIR	9	34	70	45.7	138.5	100.8	9.4	2012	2012	SE	UN	2012	RS-BF	
105	SPR-FIR	SPR-FIR	6.8	5	75	70	263.5	238	11	2000	2000	TH	UN	2016	BS-WP	
402, 408	SPR-FIR	SPR-FIR	8.4	30	94.2	85.7	224.7	210.2	13.72	2000	2012	RI	M-A	2014	BS-BF-RS	
328	SPR-FIR	SPR-FIR	8.4	15	97.7	65.2	231.3	147.5	12.83	2000	2000	ST	M-A		RS-BF	
334, 338	SPR-FIR	SPR-FIR	8.4	14	97.7	65.2	231.3	147.5	12.83	2000	2000	IM-BS	M-A	2018	RS-BF	
345	SPR-FIR	SPR-FIR	8.4	7	97.7	65.2	231.3	147.5	12.83	2000	2000	IM-BS	M-A	2011	RS-BF	RI-2016
433	SPR-FIR	SPR-FIR	8.4	7	97.7	65.2	231.3	147.5	12.83	2000	2000	NH-W	EV		RS-BF	
302, 305, 308	SPR-FIR-PIN	SPR-FIR	10	22	108.7	70	175.1	117.7	12.3	2012	2012	SE	UN	2012	RS-BF-WP	
209	SPR-FIR	SPR-FIR	9.3	37	132.3	103.3	247.9	181	16.04	2000	2012	RI	M-A	2014	RS-BF	
413, 417	SPR-FIR-PIN	SPR-FIR	7.9	36	144	89	371	246.6	12.66	2000	2000	SE	M-A	2014	BF-WP-BS	BF SALV
414	SPR-FIR	SPR-FIR	3.4	34	146	130	1759.1	1695.1	8.58	2000	2000	TH	EV	2014	BF-RS	
307	SPR-FIR	SPR-PIN	10.1	12	25	10	40.8	9.4	3.5	2012	2012	POR	EV	2012	RS-WP	
109	PIN-SPR-FIR	SPR-PIN	14.7	3	45	34.7	6.8	3.4	8.7	2009	2009	SE	M-A	2023	RS-WP	
201	MX-PIN	SPR-PIN	9.2	7	95	72.5	167.3	133.4	13.96	2000	2012	RI	AS	2014	BF-WP-WB	
332, 335, 336	SPR-FIR-PIN	SPR-PIN	9	5	105.4	74.4	190.7	120.5	9.99	2000	2000	BS-TH	M-A	2018	RS-WP-BF	
213	WASTE-WAT-FAC	WASTE-WAT-FAC		5												NOT FSC

Appendix C

Link to the newest version of the Paul Smith's College Forest Management Plan:

http://www.paulsmiths.edu/psc/forest_plan.php

Appendix D
Capstone Proposal

Visual Depiction and Analysis of Paul Smith's College Forest Management Plan

Nick Day

FEFM

Proposal Submission: 4/16/12
Starting Date- 1/30/12
Completion Date- 12/10/12

Abstract

This project with analyze the Paul Smith's College forest management plan with a concentration on Annual Allowable Cut (AAC), regeneration, and timber sales. The primary research question is asking whether volume control is a feasible alternative to strict area control for AAC regulation. The project is also asking if the silvicultural techniques are suitable for the forest types/regeneration goals of each tract. I will be studying the management plan as well as collecting field data in order to simulate an AAC based on volume control. I will also field check the regeneration of harvested stands to determine if they meet the expected goals of the management plan.

Visual Depiction and Analysis of Paul Smith's College Forest Management Plan

Introduction:

Paul Smith's College is a small college in Franklin County, New York that has a wide variety of majors including Forest Management, Biology, and Arboriculture. Paul Smith's College (PSC) has a unique opportunity, similar to other universities who own several thousand acres of forest, to use the latest technology and findings to practice the most sustainable, effective forest management. Many colleges, such as SUNY College of Environmental Science and Forestry (ESF) and University of Maine (UMaine), have forest management plans that display state of the art technology and research. Environmental science universities such as ESF, UMaine and PSC should use their forest management plans as teaching tools and study areas for the recent findings in forestry. The PSC forest management plan should contain the same knowledge as these other universities; the issue at hand is that PSC's plan does not encompass the most up-to-date practices.

Forest management plans are long, complex documents that are full of professional jargon which can be hard to decipher; PSC's forest management plan is no different. The PSC management plan was created in December 2000 by Northwood's Forest Consultants in cooperation with Forest Stewardship Council (FSC) Certification and the plan spans 20 years. The managed area covers 8,899 acres of commercial FSC Certified land across two counties (Franklin and Essex County). It contains 14 compartments (large tracts of land), the smallest being Osgood(225 acres) and the largest being the VIC(2,734 acres). The management plan stresses the importance of uneven-aged forest systems but states that the majority of the stands do not have the stand diameter distribution to convert them to uneven-aged. The harvest types are broken down into three main types: selection cut (single and group), shelterwood and "improvement harvest." The improvement harvests are not easily definable and the prescription varies depending on the stand. The annual allowable cut being used in the PSC management plan is strictly area based control. The 20 year plan calls for an annual allowable cut of 445 acres per year for the 8,899 acres of FSC commercial forest land.

Paul Smith's College is the college of the Adirondacks and strives for sustainability. I believe that the PSC forest management plan should be an exemplary example of sustainable forest management that incorporates the most modern research for best management techniques. This study will investigate how the PSC forest management plan is implemented over the 20 year span using visual aid. The study will incorporate the education I have accumulated over the 4 years at Paul Smith's College to give my analysis and possible alternatives to the management plan. My research question is asking if there is a better alternative than using strict area control for annual allowable cut. I also want to look at other alternatives to single tree selection and the amount of entries into the stands. The primary objective is to represent the plan in a way that all people can see and understand what is resulting and whether it correlates to what I have been taught as sustainable management practices.

Major Questions:

There are several major questions that are being asked with the concentration being on Annual Allowable Cut (AAC). The primary research question is asking whether volume control is a feasible alternative to strict area control for AAC regulation in the PSC management plan. Regeneration is also going to be discussed; are the "improvement harvests" and other harvest types achieving the regeneration goals stated in the management plan?Are the silvicultural techniques suitable for the forest types/regeneration goals of each tract? Examining the process of the timber sales on PSC lands is a potential research question based on time constraints.

Project Goals and Objectives:

The objective of this research is to create growth and yield models for PSC forests that can be used to convert the AAC regulation from area control to volume control. Volume control regulation adjusts the AAC in accordance to the growth of each stand; it limits the AAC in areas where annual volume growth is slower and will increase AAC in areas where annual volume growth is faster. Volume control will regulate the AAC so that each stand will be able to achieve a particular volume before being harvested. Another goal is to study the silviculture requirements for the desired species and whether they correlate with the harvest treatments in the plan.

Assumptions:

One key assumption is that volume control is the better alternative than strict area control for annual allowable cut (AAC). It is assumed that volume control will regulate the AAC so that each stand will be able to achieve a particular volume before being harvested. With regards to regeneration, it is assumed that the "improvement harvests" are definable for each stand in the management plan and the regeneration goals for said stands will be clearly stated. The silviculture treatments in each stand are clearly defined in the management plan is also an assumption.

Scope and Limitations:

The greatest potential limitation is the acquisition of raw data from the forester who implemented the cruise data and wrote the management plan. It has been difficult up until this point to acquire any of the raw data and may continue to be. Another limitation is the acquisition of the GIS data. Several emails have already been sent out in attempt to acquire the GIS data with no results. Time is going to be a limitation to the extent of the analysis being conducted. Because the management plan covers almost 9,000 acres, there is a lot of data to crunch and growth and yield tables to construct; because of this, time will limit how in-depth the analysis will be.

Project Plan:

Visual Depiction-

The purpose of the visual depiction aspect is to represent the Paul Smith's forest management plan, primarily the harvest cycle, so that the resulting effects of the forest management plan are clear to all.I will create a series of maps using aerial photos as well as symbology to represent the harvests for the years 2012-2028. Essentially, I will represent each harvest based on harvest type on the aerial photo and I will supply ground photos of each harvest type to aid in the visual understanding of the harvests. The ground photos will be used as a key to the symbology. This section will be conducted during the Spring 2012 semester within the GIS 420 course. I will use ArcGIS 10.0 software to complete the visual depiction. Microsoft Excel may also be used to organize the harvest schedule.

The first step will be to obtain recent aerial photos and topographic maps of Paul Smith's lands, GIS shapefiles of all compartments and associated forest types, andshapefiles of each stand in each compartment. Next I will analyze the forest management plan and break down the harvest schedule on a yearly basis. Once the analysis is completed, the harvests from each year will be represented by silviculture prescription (harvest method) and maps will be created for each of the first 5 years, then years 10, 15, and 20. The final map will display what the PSC lands will look like after the 20 year plan has finished. The older harvests will be displayed as specific regeneration stages.

Annual Allowable Cut-

The analysis section of my capstone will be the primary focus. The purpose of the analysis is to find a better alternative to the AAC currently being used. Microsoft Excel will be used to organize data and forestry software may have to be found as well, depending on the growth and yield models that will be constructed.

The first step will be to define what the "improvement harvest" is for each stand within Creighton Hill compartment so they can be analyzed; which involves putting the improvement harvests into a typical silviculture treatment. The defining of improvement harvests will be done so that once the volume tables are created, I can conduct the volume control harvest scenario based on the PSC management plans goals and I will know exactly what the goals of the improvement cuts are. The next step will be to obtain the raw cruise data from 10+ years ago. Cruise data usually involves basic data such as basal area per acre, basal area per acre of acceptable growing stock, trees per acre, and average diameter at breast height. This data (primarily basal area per acre and trees per acre) can be used to construct growth and yield tables which can further be used to construct the volume controlled AAC.

Based on time constraints, the Creighton compartment will be the main focus of this research. This means that Creighton will be used to construct the growth and yield tables along with the volume controlled harvests. Creighton was selected because it has the largest forested area (1,972 acres) and has a relatively even distribution of northern hardwoods, softwoods and mixed woods. Also, the majority of Creighton has not been harvested during the existence of the current management plan.

The next step will be collected field data in each forest type within the Creighton compartment. Randomly placed variable radius plots within each forest type will be used to collect the field data. Bases on stand variability, the number of plots per forest type will range from 3-10 plots. Equipment such as a Cruz-All, compass, and clinometer may be used to collect field data. Basic data such as basal area per acre and trees per acre will be needed. This data will be used along with the old cruise data to construct the growth and yield tables. Then, the growth and yield tables will be used to create a scenario for annual allowable cut based on volume control.

Regeneration and Timber Sale Scenario-

I will assess whether the regeneration goals are being met and if the timber sale process is optimizing the college's income. The regeneration aspect will be addressed by ground checking stands that have been harvested within 5-7 years ago. The plot locations will be based on clarity of the regeneration goals within the plan and access. Approximately 10 plots will be created based on time constraints. The prescription's regeneration goals will be compared to the ground check of each plot. Fixed radius plots (1/100th acre for intense harvests and 1/20th for extensive harvests) will be created to establish a post harvest assessments.I will collect data on basal area per acre, basal area per acre of acceptable growing stock, trees per acre, and species composition. The data will then be compared to the regeneration goals in the management plan.

The timber sale analysis is being done to distinguish whether the current process is optimizing PSC's revenue or if there needs to be a different approach. Microsoft Excel will be used to organize data. The first step will be to research the methods in which the timber sales on PSC lands takes place. Jim Burtis, Paul Smith's College's forester, will be interviewed about the timber sale process. The questions addressed to Jim will include how the field data is collected, what volume type is the sale based on (sawlogs, pulpwood, or both), what typically goes into the contract, and how the bidder is chosen. Once these steps are discovered, a hypothetical timber sale will be created. PSC's methods will be used as the control and alternatives will be developed to determine if a higher bid could be produced.

Timeline:

May 1, 2012: complete the visual depiction of the project

May 1- October 15: field data collection (AAC plots and regeneration

October 15- November 15: AAC analysis and regeneration analysis complete

November 15- December 15: completion of final capstone report

Literature Review:

Introduction:

Sustainable forest management practices are essential to successfully manage forests continuously. Research into sustainable forest practices has been ongoing for decades in order to find the optimum combination of regeneration goals and sustained yield. Forest management plans have been around for over 100 years and are the tool that foresters use to set goals and objectives. Generally, forest management plans not only include timber objectives, but the entire ecosystem including wildlife and wetlands. Forest management plans should include the most recent research so they can produce sustainable harvests while reaching regeneration goals and improving the quality of the ecosystem.

The Paul Smith's College forest management plan should incorporate up-to-date research in order to reach long term sustainability. PSC should use these tools to create even wood flow and sustained yield; two major laws of management principles of the US federal forests (McDill, 1999). Three of the primary objectives of a forest management plan include: establishing a regulation strategy, defining regeneration goals and deciding on a silviculture treatment that will obtain the regeneration goals. Establishing a regulation strategy includes defining the control type (ie. area vs. volume) and defining the Annual Allowable Cut (AAC) which can be based on acres or thousand board feet (mbf) depending on the control type. Defining regeneration goals is essential in a management plan because it is the future structure of the forest. Regeneration goals are generally based upon current stand structure and landowners' objectives. In order to achieve the regeneration goals, a silvicultural prescription must be made and applied via timber harvest. Due to the fact that these three topics are important parts of a forest management plan, they will be further discussed belowas they pertain to northern hardwood forests. Forest Stewardship Council (FSC) certifications and its ecologic and economic characteristics will also be addressed.

Forest Stewardship Council Certification:

The Forest Stewardship Council was the first international certification program for sustainable forest management (Foster, Wang & Keeton, 2008). The FSC involves soft laws that require certificate recipients to promote biodiversity, ensure Best Management Practices are in place, and protect wildlife and wetlands (Foster et al., 2008). Although only approximately 6% of the total forest land in North America is FSC certified, it has grown more than 15 times greater than it was in 1996 (Foster et al., 2008). PSC forests are currently FSC certified.

Foster, Wang and Keeton conducted a comparison in 2008 on the ecological and economic characteristics of FSC certified and uncertified northern hardwood forests in Vermont. Their goal was to discover if FSC certification actually increased the economic and ecological characteristics of a forest. After the post-harvest comparison it was found that above ground carbon storage, tree structure and productivity were similar in certified and uncertified forests. Net present value of sugar maple (*Acer saccharum*) with a 10 year projection was lower on certified forests but this was not statistically significant (Foster et al., 2008). The only difference found in the research was the "certified stands contained higher coarse woody debris volume that will likely offer ecological benefits" (Foster et al., 2008, p. 187). Some of these ecological benefits may include increased habitat for snag and log dependent wildlife species and increased carbon storage (Foster et al., 2008). The certified forests were also the only forests that had pre- and post-harvest data for coarse woody debris (Foster et al., 2008). Overall, anFSC certified forest can potentially increase ecological value and promote sustainable forest practices.

Annual Allowable Cut (Regulation Types):

The primary objective of regulating a forest is to achieve an even, sustained wood flow (McDill, 1999). The definition of regulated forest is an even distribution of each age class (McDill, 1999). When combined with proper silviculture prescriptions, regulated forests can create ecological improvements and still be economically feasible. “The flow of products from a regulated forest will be sustainable as long as the basic structure of the regulated forest is maintained and the productivity of the soil itself is not degraded.” (McDill, 1999, p. 169). Regulated forests are not only practical on commercial forestland, but can be used on government and private properties (Barber, 1994). Due to their even distribution of age classes, regulated forests create various wildlife habitats for all succession stages (McDill, 1999).

The two basic regulation types are area control and volume control. Area control is the simplest system for regulating a forest (Barber, 1994; McDill, 1999). Area control involves dividing the total acres by the number of age classes; this will give you the acres needed in each age class (McDill, 1999). The age class distribution is calculated by dividing the optimal rotation age by the number of years desired in each age class (ie. 40 year rotation/ 10 years within each age class = 4 age classes) (McDill, 1999). The goal of area control is to have an equal number of acres in each age class so that an even wood flow can be obtained throughout the rotation. The downfall of area control is that the volume output may vary greatly each cycle depending on site productivity (McDill, 1999). One way to mitigate variable volume flow is the further break down each stand by productivity class (McDill, 1999). The PSC management plan states that they use area control but they do not use age class distribution; therefore it cannot be considered a regulated forest.

Volume control is the second basic regulation type. Similar to area control, volume control involves finding an optimal rotation age and using a volume control formula, such as Hundeshagen's formula, to find annual/period volume flow (McDill, 1999). The Hundeshagen formula adjusts the volume output so if the inventory volume is greater than the target regulated volume, a greater volume will be harvests and vice versa (McDill, 1999). The downside to volume control is that the acres harvested per year may vary depending on site productivity. Also, inventory volume has a large percent error due to unforeseen degradation in the wood such as rot, knots and other characteristics that reduce timber quality.

Regeneration:

Regeneration is usually one of the primary objectives of a forest management plan. Regeneration can be thought of as the future assets of a stand, therefore the management plan is created to ensure the future assets will be reached. Regeneration can also be used as a biodiversity tool and to encourage wildlife. Even though a harvest has to happen before regeneration occurs, regeneration is usually the objective and the harvest prescription is create to meet the regeneration goals. The species that will be addressed are the desired regeneration in the PSC management plan; these species include: Eastern Hemlock (*Tsugacanadensis*), Eastern White Pine (*Pinusstrobus*), Balsam Fir (*Abiesbalsamea*), Yellow Birch (*Betulaalleghaniensis*), and Sugar Maple (*Acer saccharum*).

Eastern hemlock and eastern white pine often occur together in northeastern North America (Cook & Williams, 2011) due to their shade tolerance and similar soil preferences (Wendel& Smith, 1990; Godman and Lancaster, 1990). Both species prefer well drained, moist, sandy soils which are why they are commonly seen along riparian zones (Wendel& Smith, 1990; Godman and Lancaster, 1990). Hemlock has a higher preference to loam while white pine can survive on the sandiest soils (Wendel& Smith, 1990; Godman and Lancaster, 1990). According to Godman and Lancaster, because of its high shade tolerance, a shelterwood method is the best method for hemlock regeneration as long as the soil is scarified and hardwood understory competition is completely removed (1990). The most vital issue at hand is the hemlock woolly adelgid(*Adelgestsugae*Annand) because currently, there is nothing that can be done to prevent the spread (Cook & Williams, 2011). White pine has intermediate shade tolerance and thrives with increased sunlight (Wendel& Smith, 1990). Even though hemlock and white pine grow together in riparian zones and it can successfully regenerate in several harvest types, white pine regeneration is most successful with a clear-cut after a heavy seed crop (Wendel& Smith, 1990).

Balsam fir/ red spruce (*Picearubens*) stands are common in lowland areas of PSC forests. Many prescriptions from the PSC forest management plan are “balsam fir salvage.” Balsam fir is very shade tolerant and can survive under dense overstory shade but because it does not thrive in competition, it is usually seen in lowlands and swamps (Frank, 1990). According to Pothier and Prevost (2008), the optimum balsam fir/red spruce regeneration occurred when 60% of the initial basal area is removed. This type of basal area removal can be done with a shelterwood method (Pothier& Prevost, 2008). “This treatment is an attractive alternative to clear-cutting in such lowland stands where watering-up is anticipated after final harvest.” (Pothier& Prevost, 2008, p. 31). Essentially, a shelterwood method harvest can be done in lowlands for fir/spruce regeneration where flooding is anticipated as long as scarification of soils occur (Pothier& Prevost, 2008).

Approximately 44% of the PSC certified forest land is Northern Hardwood with co-dominant species including sugar maple and yellow birch. Also, because of their high timber value, yellow birch and sugar maple are desired species. Sugar maple is relatively shade tolerant and yellow birch is moderately-tolerant (Gasser, Messier, Beaudet & Lechowicz, 2010). Yellow birch can grow on a variety of soils but similar to sugar maple, it prefers well drained loams (Godman, Yawney& Tubbs, 1990; Erdmann, 1990). Gasser et al. conducted a study on sugar maple and yellow birch regeneration in 2010; during this study, it was found that liming had little to no effect on regeneration, therefore it is not economically justifiable. Also found in the study was that removal of understory competition had no effect on sugar maple and some positive effects on yellow birch regeneration (Gasser et al., 2010). A silviculture prescription that results in successful yellow birch regeneration is group selection with openings of 2000 ft2 or greater with scarification of soil (Gasser et al., 2010; Erdmann, 1990). Due to sugar maple's shade tolerance, a group selection of less than 1500 ft2 is preferred (Gasser et al., 2010).

Harvest Techniques:

The Paul Smith's College forest management plan's harvest techniques can be broken down into 3 general categories: single tree selection, group selection and shelterwood. Each of these harvest techniques has their pros and cons and each is suitable for a specific species regeneration goals. Selection systems, such as group and single tree, are believed to be more ecologically sensitive because they are less intensive treatment. The issue with selection systems is that they often require more entries, and it has been found that primary and secondary machinery tracts negatively affect fine root growth of sugar maple (Malo& Messier, 2011). "Fine root growth of maple was reduced fivefold in both primary (multiple trip) and secondary (only one trip) machinery tracts compared with the control." (Malo& Messier, 2011, p. 892). With selection systems, 15%-25% of the stand is covered with machinery tracks, thus potentially creating an issue with the survival of remaining maple trees (Malo& Messier, 2011).

Single tree selection has also been found to be the less preferable harvest type for regeneration of yellow birch and black cherry; both preferred species on PSC lands. Yellow birch and black cherry seedlings increase significantly with group selection versus single tree selection (Falk, Elliot, Burke & Nol, 2010). Bedard & Majcen (2003) found similar results; if single tree selection occurs, 21%-32% of the stand density must be removed to result in successful regeneration and growth of sugar maple and yellow birch.

Conclusion:

Sustainable forest practices are vital tools that need to be used to create a stable, healthy forest ecosystem. There are many considerations that are involved with making a forest management plan sustainable. Establishing the regulation type is one of the most important steps to create even flow and sustained yield (McDill, 1999). Area control and volume control are both viable regulation types as long as the age class distribution is established (McDill, 1999). Becoming FSC certified can increase ecological characteristics within a forest and will set up soft laws that call for sustainable management (Foster et al., 2008). Regeneration is typically the primary goal of a timber harvest and basic knowledge of a species can help determine the silviculture prescription needed for successful regeneration. Harvesting can achieve the regeneration goals set in a forest management plan but can also have detrimental effects on root hairs and the residual stand (Malo& Messier, 2011). Minimizing the amount of entries and reducing the machinery tracts can potential increase the health of the residual trees (Malo& Messier, 2011). All of these aspects of a forest management plan can work together to achieve common goals such as even wood flow, sustained yield and a stable long-lived forest.

<u>Project Participants:</u>

I am currently in my 4th year a Paul Smith's College where I am working on a Bachelor's Degree in Ecological Forest Management, an Associate's Degree in Arboriculture and Landscape Management, a Certificate in Geographic Information Systems and a Business Minor. I currently hold a 3.6 GPA and peer tutor several courses including Forest Management, Silviculture and Ethics. I received an A in Forest Management, all GIS related courses and Silviculture; topics which are an important aspect of my capstone. I am also an undergraduate teaching assistant for Geospatial Information Technology for Forestry. As for related work experience I have worked with the US Forest Service researching the invasive species Winter Moth (*Operophterabrumata*).

My mentor is Damon Hartman, a woodlot management forest for Prentiss and Carlisle. He has over 10 years of experience writing and implementing forest management plans and has worked in all three regions for forestry: private, commercial and government. Damon has strong skills in the timber sale aspect of forestry and has many resources for other aspects.

The Project Budget:

Due to the fact that the project is strictly analytical, the is no budget necessary. All of the analysis will be done on software supplied by PSC and myself.

Literature Cited

Barber, R.L. (1994). Sustained Yield Forestry: Regulation Strategies Based upon harvesting growth and a percentage of inventory volume. 1994 Symposium on Systems Analysisin Forest Resources

Bédard, S., &Majcen, Z. (2003).Growth following single-tree selection cutting in Québec northern hardwoods.*Forestry Chronicle*, 79(5), 898-905.

Cook, R. E., & Williams, C. E. (2011). Composition And Structure Of Riparian Forest Dominated By Tsuga Canadensis: Contrasts Between Old-Growth And Second-Growth Stands In Northwestern Pennsylvania.*Rhodora*, 113(953), 47-63.

Erdmann, G. G. (1990). Yellow Birch.*In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 2. Hardwoods.* Washington, D.C.: U.S. Department of Agriculture, Forest Service

Falk, K. J., Elliott, K. A., Burke, D. M., &Nol, E. (2010).Early seedling response to group selection harvesting in a northern hardwood forest. *Forestry Chronicle*, 86(1), 100-109.

Frank, R. M. (1990). Balsam Fir.*In R.M. Burns and B.H. Honkala (Eds.), Silvics of North America: Volume 1. Conifers.* Washington, D.C.: U.S. Department of Agriculture, Forest Service

Foster, B. C., Wang, D., & Keeton, W. S. (2008). An exploratory, post-harvest comparison of ecological and economic characteristics of forest stewardship council certified and uncertified northern hardwood stands.*Journal Of Sustainable Forestry*, *26*(3), 171-191.

Gasser, D., Messier, C., Beaudet, M., &Lechowicz, M. J. (2010). Sugar maple and yellow birch regeneration in response to canopy opening, liming and vegetation control in a temperate deciduous forest of Quebec. *Forest Ecology & Management*, *259*(10), 2006-2014.

Godman R. M., Yawney, H. W., &Tubbs, C.H. (1990).Sugar Maple.*In R.M. Burns and B.H. Honkala(Eds.), Silvics ofNorth America: Volume 2. Hardwoods.* Washington, D.C.: U.S. Department of Agriculture, Forest Service

Godman R. M. & K. Lancaster (1990). Eastern Hemlock.*In R.M. Burns and B.H. Honkala (Eds.), Silvics ofNorth America: Volume 1. Conifers.* Washington, D.C.: U.S. Department of Agriculture, Forest Service

Malo, C., & Messier, C. (2011). Impact of primary and secondary machinery tracks on fine root growth of sugar maple after selection cutting.Canadian Journal Of Forest Research, 41(4), 892-897.

McDill, M.E., (1999). *Forest Resource Management*- Ch10: Area and Volume Control

Pothier, D., & Prévost, M. (2008).Regeneration development under shelterwoods in a lowland red spruce – balsam fir stand. Canadian Journal Of Forest Research, 38(1), 31-39.

Wendel, G. W., & Smith, H. C.(1990).Eastern White Pine.*In R.M. Burns and B.H. Honkala(Eds.), Silvics ofNorth America: Volume 1. Conifers.* Washington, D.C.: U.S. Department of Agriculture, Forest Service