City Well-field Final Report

30 December 2008

Greater Flagstaff Forests Partnership (GFFP)
Monitoring Effort 2007-2008
City Well-Field

Stand History: The entire 80 ac area known as the City Well-Field was "thinned from below" approximately 15 years ago. Thinning was followed by a broadcast burn of the entire site over 2005 and 2006. The objectives of these activities included ladder fuel reduction, increased forest health, retention of appropriate dead and down woody material and snags, preservation and enhancement of oak inclusions and the reintroduction of a periodic low intensity prescribed fire regime.

Purpose and Objective: The GFFP proposed to develop a prescription and provide a sample/demonstration "Partnership mark" on several stands totaling 80 acres within the City Well-Field project area located approximately one mile south of the Arboretum. This mark would be a reasonable starting point to bring the adaptive management process forward and a vehicle for encouraging communication on treatment implementation within and outside the GFFP. The prescription and mark would emphasize restoring natural ecosystem structure, function and composition while reducing forest fuel levels. The MRT collected data to verify that the resulting forest structure will simultaneously meet desired conditions for wildland fire severity and behavior while providing for greater overall ecological benefit. Flagstaff Fire Department (FFD) specifically planned to reduce canopy cover in the well-field by approximately 55%, create a tree group forest structure that interspersed treed areas with interlocking crowns and multiple stories with opened areas (openings and interspaces within tree groups) and establish natural regeneration in these openings to achieve structural heterogeneity.

Thinning Guidelines:

> ***Tree Groups and Clumps***: Spacing between groups will vary between 50± to 200 ± feet. Multiple *tree clumps* of 5-40± trees of varying size will be scattered within each individual tree group, and will range from 1/10 – 1.5 acres in size. Stocking of each group will vary between 40 to 140 ft_/ac, and most will have interlocking crowns. Irregular tree spacing and vertical diversity within-and-between the individual groups and clumps is desired.
>
> ***Interspace***: Trees outside of an identified clump but within an identified group will largely be removed, but some individual "link" trees *may* be retained in order to meet objectives.
>
> ***Openings***: All stems will be removed with the exceptions that *Yellow* pines (regardless of size), Gambel oak (regardless of size), pines greater than 24 inches DBH, and all large snags will be retained.
>
> ***Additional Directions***: Once selective tree removal and piling are complete, a few trees with a mid-point diameter of approx. 12" will be dropped in the clumps lopped and scattered to create downed logs for wildlife habitat.

Methods: The well-field was divided pre-treatment into three strata based on desired future and existing conditions: clumps of trees that would be left ("Clumps"), the space between these clumps in a group of clumps ("Interspace") and the space between groups where all trees were to be removed ("Opening"). We identified five randomly assigned permanent tenth acre plots in each stratum on which to collect data, pre- and post-treatment. We modified the USDA Forest Service, Southwestern Region Fuels Sampling Protocol data collection techniques by excluding the species specific floral inventory and the life form cover data and including estimates of five categories of ground cover and the percent of interspace in each plot (refer to Appendix A for a detailed protocol and sample data sheets). Pre-treatment data were collected in April 2007 while post-treatment data were collected after thinning, but before burning, in May 2008.. All data were entered into EXCEL© spreadsheets and analyzed using SAS© software to determine physical characteristics, habitat suitability and surface fuel loading. We calculated crown bulk density (cbd) for each stratum using the average crown base height for trees in the plots in that stratum. Cbd for the stand was based on the average canopy base height for the lowest quintile of trees sampled, thus, it exceeded what would be calculated using an average of the strata values and represents a very conservative estimate. We assessed habitat suitability with models developed by NAU, Forest ERA. NEXUS fire modeling software predicted fire behavior under 97% weather conditions in June using the results from stand structural analysis (refer to Table 1). We performed statistical tests of differences between pre- and post-treatment conditions on a selection of habitat suitability, physical characteristics, surface fuel loading and fire behavior data.

Table 1. Environmental Conditions that Define the 97 Percentile for the Month of June Pre-monsoon for NEXUS Analysis

Metric	Value
1 hour dead material moisture content	2.2%
10 hour dead material moisture content	3.0%
100 hour dead material moisture content	4.7%
Live herbaceous material moisture content	50%
Live woody material moisture content (range 30-300%)	100%
Wind speed	25 mph
Wind direction	225°

We compare pre- and post-treatment levels of measured characteristics via histograms, tables (refer to Appendices B-E), photos (refer to Appendix F) and paired-comparisons statistical tests. We compared plot-level values within each stratum for selected variables using Student's t-tests. The assumptions associated with this test, or any statistical test, precluded testing all measured or calculated variables as the level of significance of each test would be unknown. Therefore, we chose several metrics from each of the four categories, physical characteristics, habitat suitability, fire behavior and surface fuel loading. Tests were conducted on the torching and crowning indices, ba, canopy closure, cbd, Abert squirrel densities, exotic species richness, heat per unit area, percent of bare ground and total surface fuel load. We set the significance level at _ = 0.05.

Results:

Plot Locations: We expected to relocate plot centers using the directions encoded on two tree tags per plot. However, in one third of the plot, either one or both tags were absent due to disturbance or the removal of the tagged trees. In these cases we attempted to relocate the rebar marking the plot center with the information present on the remaining tag and/or with the GPS coordinates. Four plot centers were remarked with new rebar. We found no rebar and no trees for two plots in openings; we relocated plot centers by matching pre-treatment data to tree stumps and GPS coordinates. Thus, some relocated plot centers were approximate.

Physical Characteristics (refer to Appendix B): Structural characteristics were measured in 15 plots (refer to Table 2). The most obvious changes occurred in plots in openings where all trees had been removed during treatment, effectively driving all tree related variables to zero. Ponderosa pine (*Pinus ponderosa*) dominated the stand and, therefore, all forested plots. Several Gambel oak (*Quercus gambelii*) were found in the southern portion of the stand. Average dbh, canopy depth, tree height, crown base height, basal area, tree density, canopy closure, cbd and crown biomass progressively decreased from clumps to interspace to openings which was expected based on the treatment applied to each stratum. Plots in clumps and interspace contained 13% and 82% interspace, respectively. Existing and potential vegetation remained invariant across all plots and strata. Litter dominated ground cover in plots in clumps and interspace in percentages comparable to pre-treatment conditions. However we found less litter in plots situated in openings where bare ground was predominant due to disturbance from thinning operations. Both clump and interspace plots classified as VSS 4 (refer to Table 2).

Table 2. UTM Coordinates of Plot Centers
Post-Treatment

Strata	Point	UTME	UTMN
Opening	O23	432845	3889099
	O117	432937	3889200
	O118	432960	3889213
	O137	432988	3889233
	O467	433127	3889648
Clump	G3/C5	433020	3889685
	G5/C3	433090	3889279
	G6/C8	433133	3889117
	G12/C12	432982	3889234
	G18/C5	433046	3889540
Interspace	G2	433138	3889781
	G4	433110	3889580
	G7	432925	3889095
	G8	432787	3889090
	G14	432899	3889673

Table 2. Vegetative Structural Stage (VSS) Definitions

Stage	Diameter Range (in)
1	1.0-4.9
2	5.0-8.9
3	9.0-11.9
4	12.0-17.9
5	18.0-23.9
6	24.0+

Habitat Suitability (refer to Appendix C): Pronghorn antelope (*Antilocapra Americana*) and Abert squirrel (*Sciurus aberti*) occupy quite different habitats. Openings rated highest for pronghorn suitability and lowest for squirrel density, while the reverse proved true for clump structure. Interspace structure fell in between. Avian richness decreased from clump to interspace and opening plots. No single species was found in all plots, however, we found cheat grass (*Bromus techtorum*), dandelion (*Taraxacum offiicinale*), lambsquarter (*Chenopodium album*) and clover (*Medicago sativa*) represented in all strata. Exotic species richness inversely reflected canopy cover; highest in open canopy (openings) and lowest in the closed-canopy clumps.

Fire Behavior (refer to Appendix D): NEXUS predicted that a fire in any strata would be a surface fire with no crown burned and a spread rate of 0.01 mi/hr. Spread rate (ft/hr), fireline intensity and flame length remained at lower levels for clumps and interspace than for openings while heat per unit area revealed the opposite trend. Effective mid-flame wind speed did not vary between strata. All flame lengths fell well below the break point for mechanical fire suppression (4 feet). Torching and crowning indices ranged from 2509 to 3636 mph and 53 to 112 mph, respectively, values well above the highest recorded wind gusts for June. The crowning index increased indirectly with strata crown biomass and crown base height while the torching index followed the reverse trend. Analyses of crowning and torching were not possible in openings. Crown base height exceeded the estimated critical flame length for crown fire initiation by more than quadruple in clumps and interspace.

Surface Fuel Loading (refer to Appendix E): As expected, surface fuel depth (litter + duff) was highest in clumps, under the highest tree density, and lowest in openings, however the inter-strata differences were small. We found more total available fuel (twigs and logs) in clumps and less in openings and interface plots post-treatment. Logs dominated surface fuel in clumps while surface fuel in the interspace and openings was comprised of mostly twigs.

Discussion/Pre- and Post-treatment Comparisons:

Physical Characteristics (refer to Appendix B). Diameter at breast height (dbh), canopy depth, tree height and crown base height increased in clumps post-treatment while decreasing in interspaces and openings. The average of the lowest quintile of lower canopy heights in the stand (plots in clumps and interspace combined) rose from 12.3 to 14.9 feet. We found lower post-treatment tree density, basal area, canopy closure, crown bulk density and crown biomass in all strata. The reductions in basal area, crown bulk density and canopy closure proved significant ($p \leq 0.05$) for plots in interspaces and openings. We attribute decreased values in clumps to the removal of trees in the interspace, which occupied a portion of the plots in clumps (an average of 13.4%). Differences in the proportion of interspace in plots pre- and post-treatment can be attributed to method of measurement, visual estimation. Thinning resulted in reduced basal area in VSS 3 but increased basal area in VSS 4 and VSS for clumps and interspace. Prior to treatment all three strata were categorized as VSS 3 and lacked VSS 1. Post-treatment VSS 4 dominated the basal area in clump and interspace plots, where trees were included in interspace plots due to plot location. Percentages of VSS 1 and VSS 2 remained low. The percent of basal area attributed to large trees (VSS 6) decreased for interspace plots while increasing for plots in clumps due to the redistribution of tree diameter classes following tree removals.

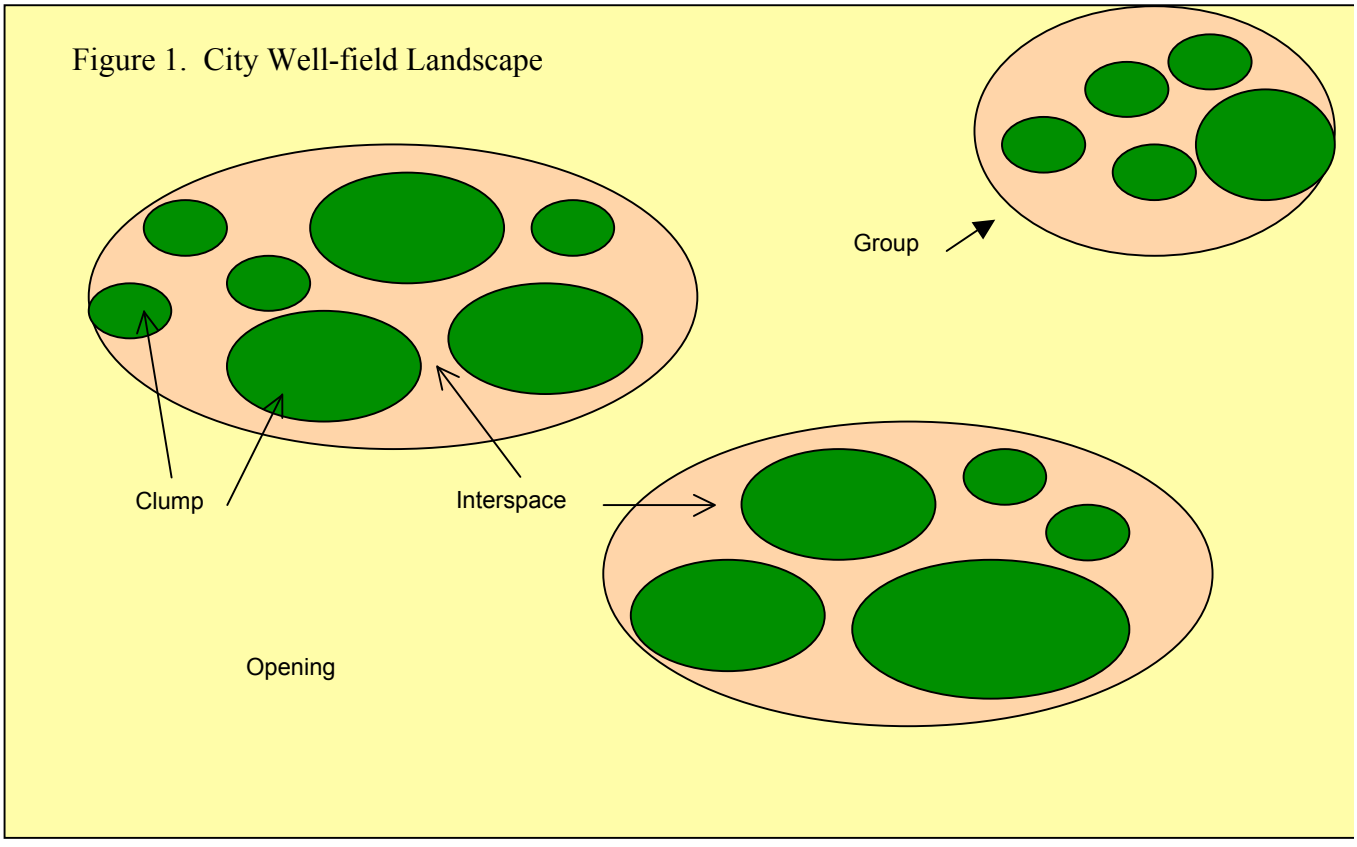
Habitat Suitability (refer to Appendix C): Overall pronghorn suitability increased post-treatment directly reflecting changes in canopy closure. Squirrel density estimates also decreased from pre-treatment values for all strata, significantly so for interspace and openings ($p \leq 0.05$). The extent of the decrease was comparable to the extent of basal area reduction; the model is based on basal area. The avian species richness model also was based primarily on basal area. However, we found it relatively insensitive to changes in that variable; it could assume one of only two values, 8.5 or 11.5, for the range of basal areas found in the well-field (0 – 260 ft_/ac). The number of exotic plant species decreased in openings and clumps. Sufficient time may not have elapsed for recovery from the disturbance during treatment, however, plots in interspace showed no changes despite disturbance. Future monitoring will be needed to establish any relationship between canopy closure and exotic species richness post-treatment.

Fire Behavior (refer to Appendix D): Treatment rendered clumps and interspaces more resistant to fire. Spread rate, heat per unit area and flame length decreased post-treatment while the crowning index increased. Both the wind speed at which some crowning is possible and the critical flame length for crown fire initiation dropped in the interspaces while rising slightly in clumps. However, none of the differences tested proved significant. Post-treatment values did differ significantly from pre-treatment values for the torching and crowning indices in openings. We used a different fuel model post-treatment for interspace and openings due to treatment effects.

Surface Fuel Loading (refer to Appendix E): Surface fuel size distribution reflected the treatment activities that occurred in the various strata. Disturbance may have contributed to the decrease in surface fuel depth in clumps and openings while the higher depths post-treatment in openings may reflect treatment debris. Logs dominated surface fuel in all strata pre-treatment. Although the quantity doubled post-treatment in clumps, it was halved in the interspace and disappeared in openings, presumably due to thinning and slash treatment. The changes proved statistically insignificant.

Conclusions: Strata structural characteristics supported Flagstaff Fire Department personnel's vision of post-treatment conditions to a great extent. At present the City Well-field can be described as shown in Figure 1. Areas of dense, closed-canopy ponderosa pine trees (canopy closure = 54%, tpa = 98, ba = 160) surrounded by more open areas (canopy = 23%, tpa = 44, ba = 36) were interspersed in a matrix of very open structure (canopy = 0, tpa = 0, ba = 1). These structural differences proved significant for changes in ba and canopy closure for plots in both interspace and openings. Treatment objectives were met; canopy closure decreased in all strata with the existing cover found primarily in tree groups and a "clumpy-groupy" structure remains (refer also to Appendix F for representative photo comparisons).

Figure 1. City Well-field Landscape



Fire behavior metrics reflected the structural components: the average crown base height for the lowest quartile rose several feet; cbd, spread rate, heat per unit area, and flame lengths decreased in all strata while the crowning index increased. Openings, the strata that received the most intense thinning, also showed significant differences in torching and crowning indices. Tree clumps in forested groups showed no significant changes in structure or fire behavior, as would be expected from treatment. Our analyses did reveal intermediate responses to treatment in the interspace; cbd was reduced significantly, however, the differences in other fire behavior metrics did not prove significant.

At present the area has not achieved a multi-storied canopy due to the dominance of one particular size class and the absence of younger, smaller trees. The previous thinning from below removed the lower canopies while reducing the ladder fuels. The opened canopy and site disturbance enhance the potential for ponderosa pine regeneration on site under favorable weather conditions and cone crops while maintenance of natural fire regimes ensures control of ladder fuels and natural structural development.

APPENDIX A

Protocols

Information common to all data forms:

1. Project Name:
2. Treatment: GFFP abbreviation for treatment (ex. Thin BA)
3. Block #: FS cutting unit (*for any partnership marking, this will be the strata designation (ex. Group)).*
4. Date: Date data collected, however data may be collected over several days.
5. Region: Forest Service Region (Two digits: 03).
6. Proc. Forest: Forest data collected on (Two digits: 07).
7. District. District data collected on (Two digits: 01=Mormon Lake RD, 02=Peaks RD).
8. Location: USFS compartment number (Three digits, ex. 106).
9. Stand number: USFS stand number (Six digits, ex. 000110).

Plot Data Form

1. Strata/Plot: Plot number and strata type (I = Interspace, O = Opening, C = Clump)

2 & 3. UTM East & North: Recorded at plot center in Map Datum NAD 27 CONNUS

4. Capable grow area: Visual estimate of percent of plot capable of growing trees (0=cannot support a tree, 100=can support trees) If there is a significant unusual feature like a road or rock face estimate percent and subtract from 100.
5. Aspect: Record the bearing that the plot faces in degrees.
6. Slope: Percent slope as recorded with clinometer for entire 1/10 acre plot.
7. Elevation: In feet, derived from GPS unit.
8. Existing vegetation code: Code derived from *Common Stand Exam Field Guide v. 1.7*, APPENDIX E: Existing Vegetation Codes (*always = SRM110 here)*.
9. Potential Vegetation: *Plant Associations of Arizona and New Mexico, Forest and Woodlands Series* of 2 Volumes, third edition. Be prepared to enter in database as numeric code that is recorded in Plant Associations books (Ex: 001150 not ABCO/QUGA)
10. Fuel Model (Anderson): *Aid to Determining Fuels Models for Estimating Fire Behavior*, GTR INT-122, 1982. Models are numbered 1-13, ranging from grass, shrub, timber, and slash fuel loadings.
11. Plot Remarks: Pertinent comments to plot area.
12. Plot number: to avoid any confusion.

13 – 16. C1-C4: Canopy cover estimate from spherical densitometer reading taken at each of the four cardinal points.

17. Average of columns 13-16 – calculated in EXCEL in the office.
18. BA (Basal area): Quick estimate of basal area taken with a BAF=20 prism at plot center.
19. TPA (Trees per acre): Number of live trees measured in the plot, taken from the tree data form(s).
20. Fuel Model (S & B): *Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model*, GTR RMRS-GTR-153.
21. Exotic Richness: Number of exotic species found in the plot, taken from the exotic species data form.

22 – 26. Ground cover: Percent of plot covered by bare ground, litter, grasses, forbs and shrubs as a percentage, recorded from a 3' X 3' quadrat placed with the bottom aligned with the 20 ft mark on the east side of the Brown's transect tape.

27. Percent interspace: Visual estimate of percent of 0.1 ac plot occupied by interspace.

Downed Woody Material Form: A Brown's transect in a set direction (North) starting at plot center. Transect is 50' in length in conditions of natural fuels, but may be reduced to 35' in slash fuels. If the transect length of is changed, it needs to be changed in the sample design.

1. Strata/Plot#: Corresponds to plot number and strata type on Plot Data Form.
2. Duff measurements: Called Duff 1 and Duff 2, taken at 6' and 10' along transect.
3. Fuel (Litter) Depth: Three litter measurements, taken at 15', 30' and 45'along transect. Measurement is to highest point of litter, even if suspended aboveground. The average of these measurements is calculated by EXCEL. Both litter and duff are recorded to the nearest 0.1 inch.
4. Twig 1: 0-.24'' (1-hour fuel): Tally all woody material this diameter that intersects the transect between the 0-6 foot marks.
5. Twig 2: 0.25-.99" (10-hour fuel): Tally all woody material this diameter that intersects the transect between the 0-6 foot marks.
6. Twig 3: 1.0-2.99'' (100-hour fuel): Tally all woody material this diameter that intersects the transect between the 0-10 foot marks.

Twig 1, 2 and 3: DO NOT INCLUDE PINE NEEDLES OR PINE CONES. COUNT ONLY PIECES ON THE SURFACE of the forest floor, or what is visible from the surface; do not disturb litter or duff. If a stick is curved and intersects a transect twice, count it twice.

7. Log/Piece Count: Individually record every log over 3'' in diameter that intersects the plane of the transect over the entire 50 foot transect. The following data is recorded for each log:
8. Decay class: A numeric ranking, class 1-5. Descriptions of those decay classes are found in CSE Field Guide, pg. 3-5-15.
9. Diameter: Estimated diameter of log where it crosses the transect.
10. Length: Estimated entire length of log.

Tree Data Form:

Use for three concentric fixed radius plots: snag plot (1/10 acre), live tree plot (1/10 acre), and regeneration plot (1/100 acre).

The following is recorded for a live tree, regeneration, or a snag:

1. Strata/Plot#: Corresponds to plot number and strata type on Plot Data Form.
2. Tag ID: Number each tree on every plot starting with 1.
3. Tree Status: Record as Live (L) or Dead (D).
4. Species: Record species of every sampled tree (Examples: PIPO= Ponderosa Pine: QUGA=Gambel oak, JUDE2=Alligator juniper: JUSC2=Rocky Mountain juniper)

Live Trees: All live trees ≥5 inches DBH (diameter at breast height) or DRC (diameter at root collar) within a 1/10th acre plot (37.2' radius) are recorded and measured individually.

5. Tree Count: The number of individuals being represented by these measurements.
6. DRC # Stems: Required for non-timber species. Number of stems per woodland species individual (Examples: Oaks, Junipers, Pinyons).
7. DBH/DRC: Record diameter at breast height (4.5' from ground level, uphill side of tree) for tree species. Record diameter at root crown for woodland species (measured at root collar, see Appendix M, CSE Field Guide). Record to the nearest 0.1'' using diameter tape.
8. Height: Record height from ground to top of tree to the nearest foot using clinometer.
9. Height to crown (Live Low): Measure height from ground level to lowest live branch. Record to nearest foot using clinometer.
10. Crown Ratio: Estimated percent of the total tree height that is occupied by live crown. Visually estimate by compressing live crown if crown appears sparse. Record to nearest 5%.
11. Crown Class: A tree's relative position in the canopy. Recorded as a two-letter code. Use DO=Dominant, CO=Co-dominant, IN=Intermediate, and OV=overtopped. Refer to CSE Field Guide.
12. Yellow Bark: Check if tree being measured has yellow-orange bark, a flattening top and 50% of the circumference at breast height is occupied by platey bark.
13. Tree Damage Category. If any damage exists. Appendix L of CSE Field Guide or App.R of CSE User Guide.
14. Damage Agent. If any damage exists. Appendix L of CSE Field Guide or App.R of CSE User Guide.
15. Damage Severity. If any damage exits. Appendix L of CSE Field Guide or App.R of CSE User Guide.
16. Tree Remarks. Comments relevant to the tree (ex. squirrel nest).

Snags: All dead trees ≥5 inches DBH or DRC within a 1/10th acre plot (37.2' radius) are recorded and measured individually.

5. Tree Count: Tree Count: The number of individuals being represented by these measurements.
6. DRC # Stems: Required for non-timber species. Number of stems per woodland species individual (Examples: Oaks, Junipers, Pinyons).
7. DBH/DRC: Record diameter at breast height (4.5' from ground level, uphill side of tree) for tree species. Record diameter at root crown for woodland species (measured at root collar, see Appendix M, CSE Field Guide). Record to the nearest 0.1" using diameter tape.
8. Height: Record height from ground to top of tree to the nearest foot using clinometer.
9. Snag Class: Record class number 1 - 5. CSE Field Guide page 3-5-15.

Regeneration plot:

Tally by species all live or dead trees with a DBH or DRC between 0.1" and 4.9" dbh, or <4.5' tall. Collected on 1/100th acre, (11.8' radius). Use a separate row for each species and major size division within that species.

5. Tree Count: Total number of individuals of a species represented by these measurements.
6. DRC # Stems: Average number of stems of individuals tallied. Woodland species only.
7. DBH/DRC: Average estimated DBH/DRC.
8. Height: Average estimated height of regeneration.
9. Canopy Class: Record as UN; understory.

Exotic Species Form:

1. Rate the percent of ground within the 0.1 ac plot covered by each exotic species present using the Daubenmire scale where species is present:
    a. T = < 1%
    b. 1 = 1-5%
    c. 2 = 5-25%
    d. 3 = 25-50%
    e. 4 = 50-75%
    f. 5 = 75-95%
    g. 6 = > 95%

MISCELLANEOUS:

Permanent plot photos: Digital photos are taken from plot center in the four cardinal directions. A laminated sign is placed within each photograph with identifying information (Project Name, Location, Stand, Plot#, Direction of photo). The photos encompass the general landscape and not just the plot boundaries.

Literature Cited:

Anderson, H. E. 1982. Aids to Determining Fuel Models for Estimating Fire Behavior. USDA Forest Service General Technical Report INT-122, 22p. Intermountain Forest and Range Experiment Station, Ogden, UT.

Scott, J. H. and R. E. Burgan. 2005. Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model. USDA Forest Service General Technical Report RMRS-GTR-153. 72 pp. Rocky Mountain Research Station, Fort Collins, CO.

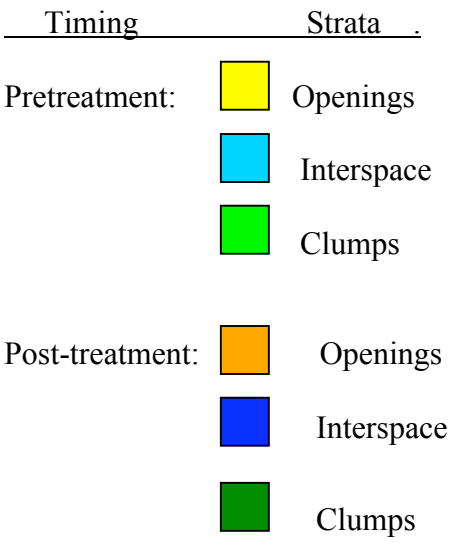
USFS. 1997. Plant Associations of Arizona and New Mexico, Edition 3, Vol. 1: Forests. USDA Forest Service Southwestern Region Habitat Typing Guides, 291 pp.

USFS. 2005. Common Field Exam Field Guide Region 3, Version 1.7. USDA Forest Service Natural Resource Information System: Field Sampled Vegetation. 166 pp.

APPENDIX B

Physical Characteristics

Legend for all histograms in Appendices B-E:



* Variable tested for statistical significance

Statistically significant difference between pre- and post-treatment conditions (_ ≤ 0.05)

Greater Flagstaff Forests Partnership

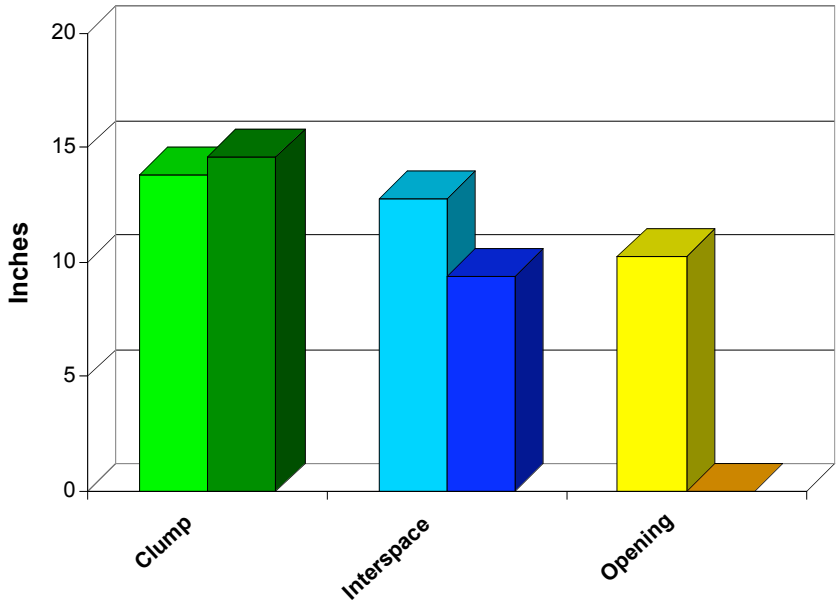
Flagstaff Fire - City Well-field - Post-treatment 2008

Stand Physical Characteristics

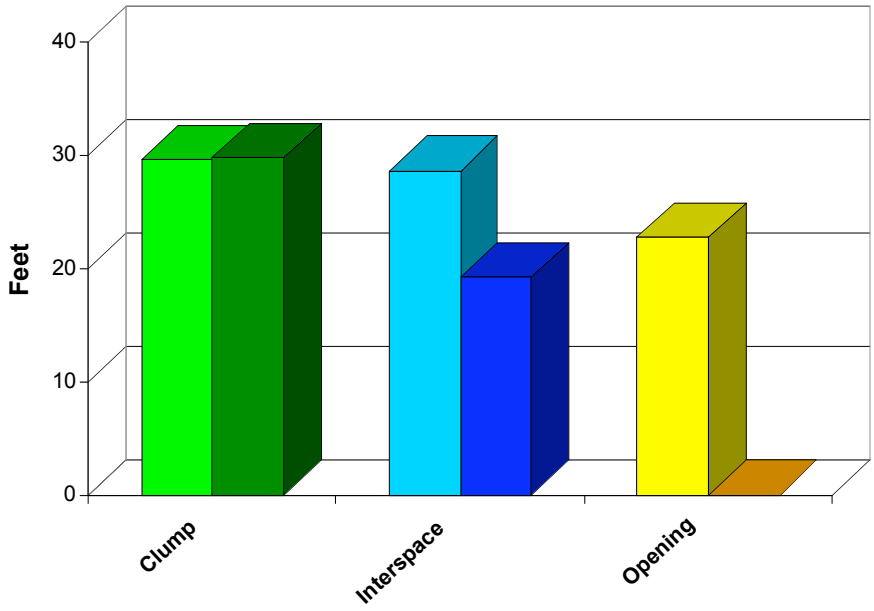
		Trees									Crown				
Strata	Species	DBH (in)	Height (ft)	Crown base ht (ft)	depth (ft)	Canopy ratio (%)	crown posit	density (trees/ac)	Basal area (ft2/ac)	Snag density (snags/ac)	bulk density (kg/m3)	biomass (tons/ac)	Aspect (degrees)	Slope (%)	Canopy closure (%)
Clump	PIPO	14.62	57.8	28.2	29.7	44.5	CO	98	160	0	0.0342	3.04	51	4.2	54.3
Interspace	PIPO	9.40	39.1	19.9	19.2	32.4	CO	44	36	2	0.0118	0.67	85	5	22.8
Opening								0	1	0	0	0	43	3.8	0.3
				14.9 Lowest 20%											

Vegetation		Fuel Model		VSS	Distribution						Ground Cover					Interspace
potential	existing	Anderson	S&B	Class	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	bare (%)	litter (%)	grass (%)	forb (%)	shrub (%)	in Plot (%)
SRM110	11090	9	TL1	4	0	4	10	36	34	16	6.4	76.0	1.4	0.2	0.0	13.4
SRM110	11090	3	GR1	4	1	11	15	52	21	0	38.2	57.2	3.6	0.8	0.2	82.4
SRM110	11090	0	SB1	0	0	0	0	0	0	0	62.0	35.4	2.2	0.4	0.0	0.0

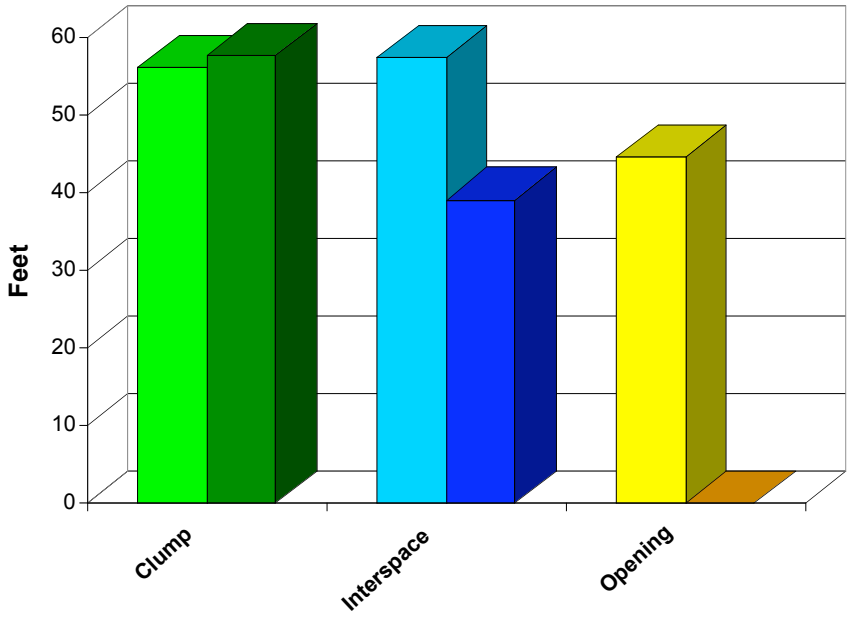
Diameter at Breast Height (DBH)



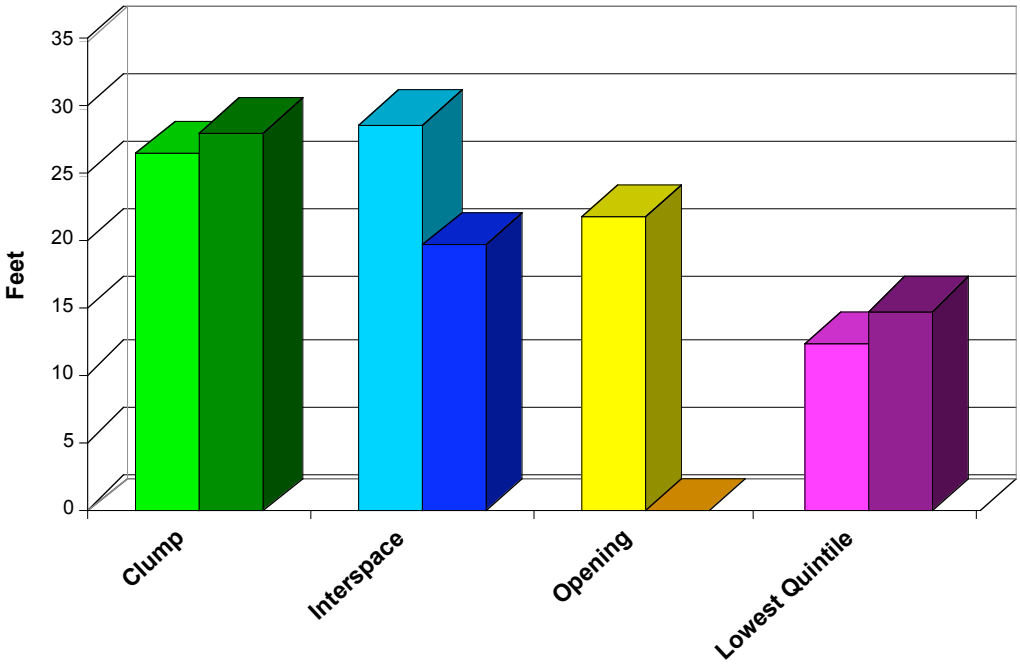
Canopy Depth



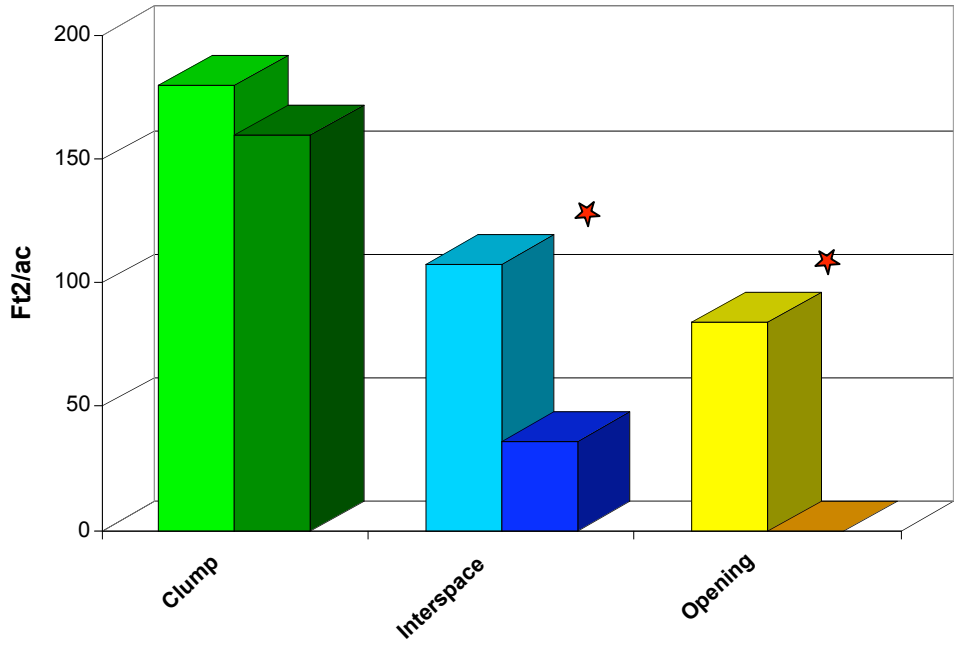
Tree Height



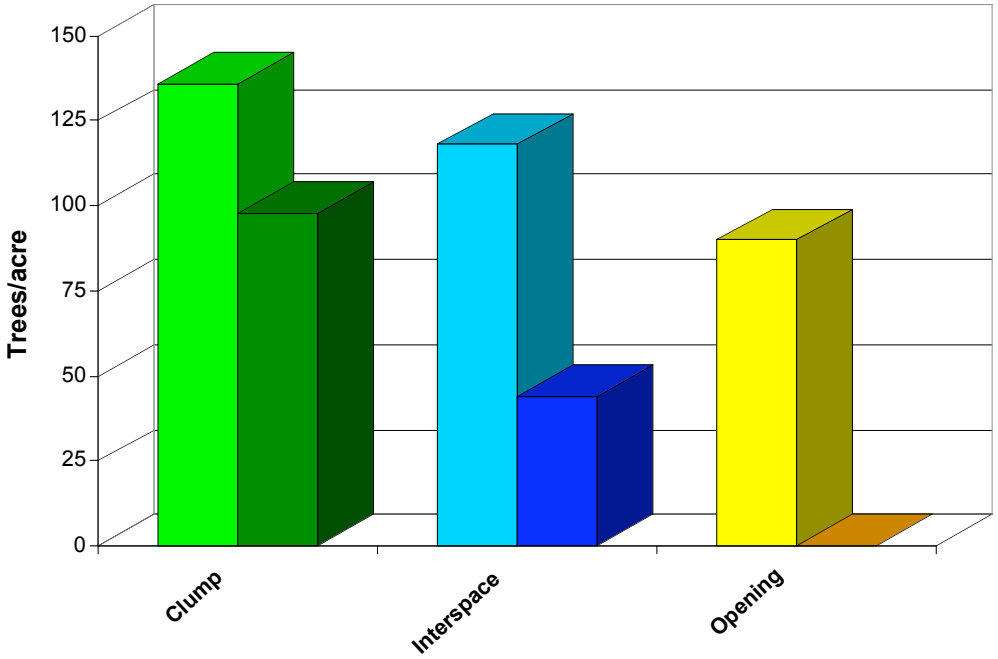
Crown Base Height



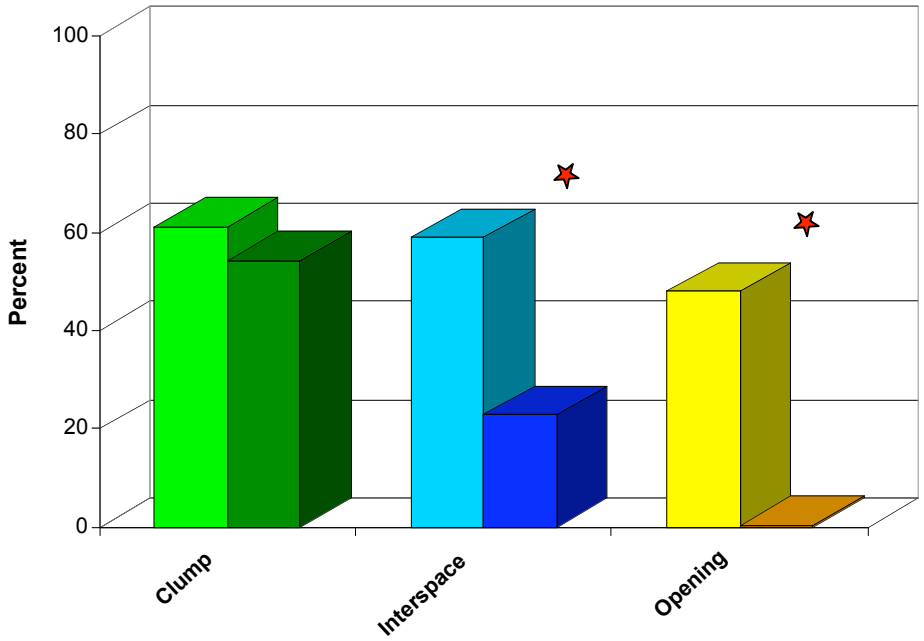
Basal Area *



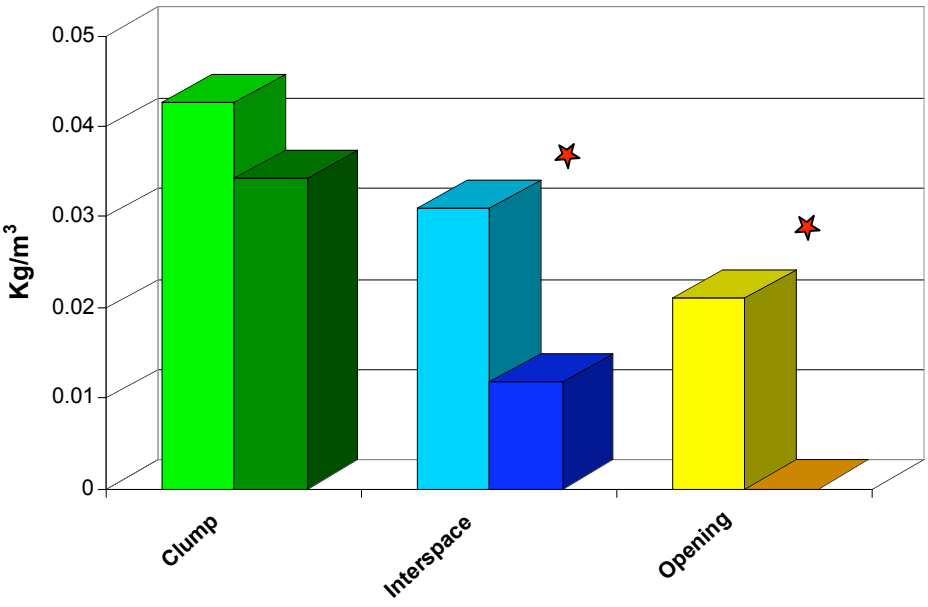
Tree Density



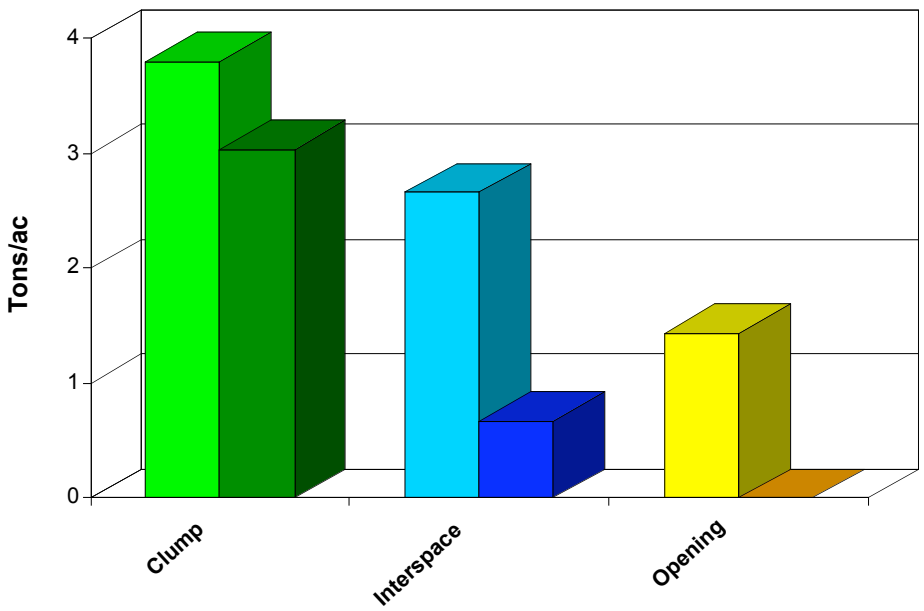
Canopy Closure *



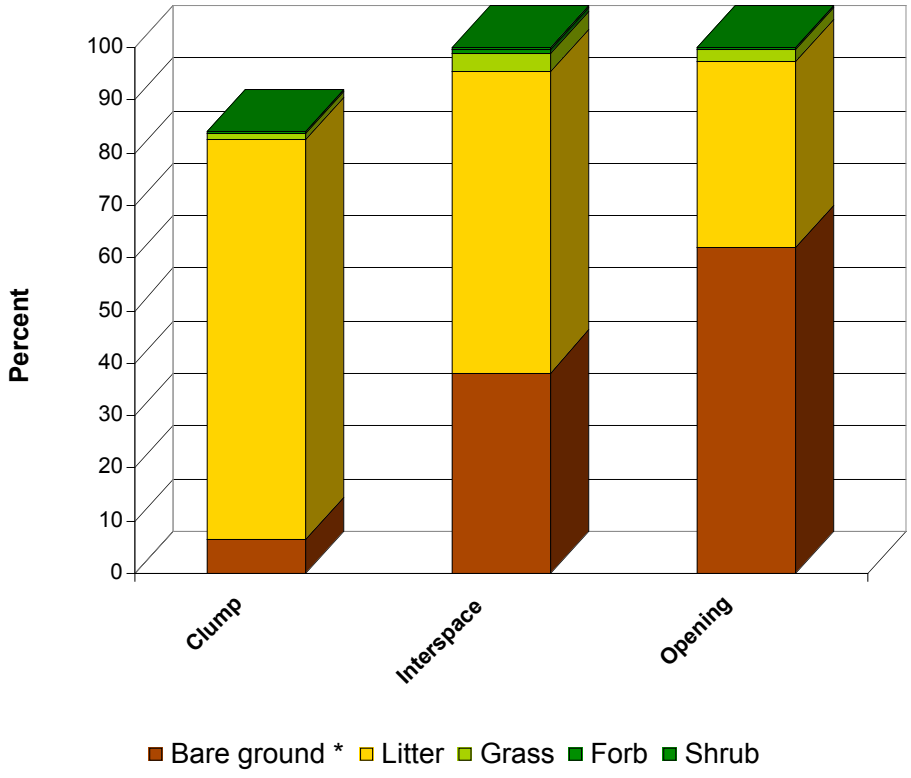
Crown Bulk Density *



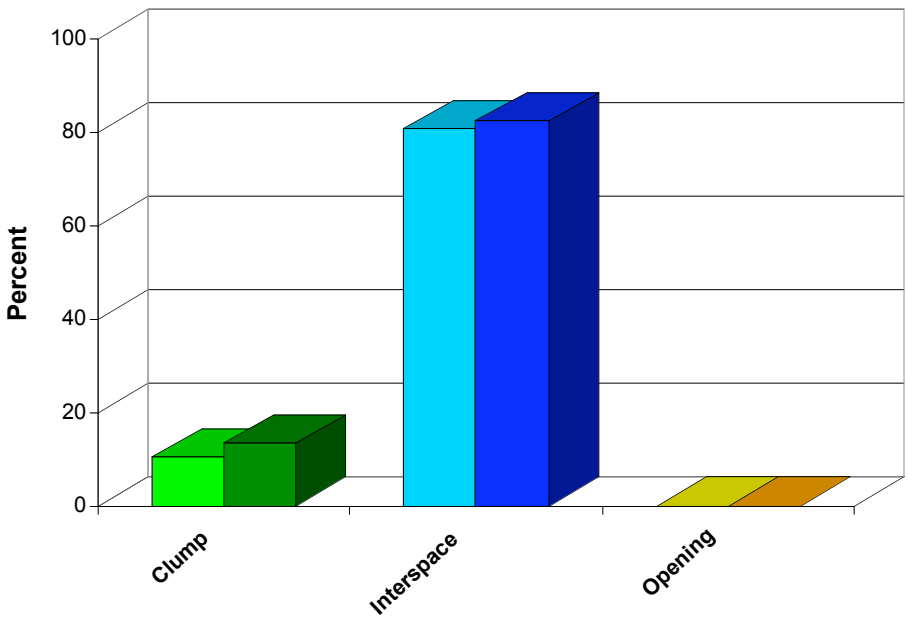
Crown Biomass



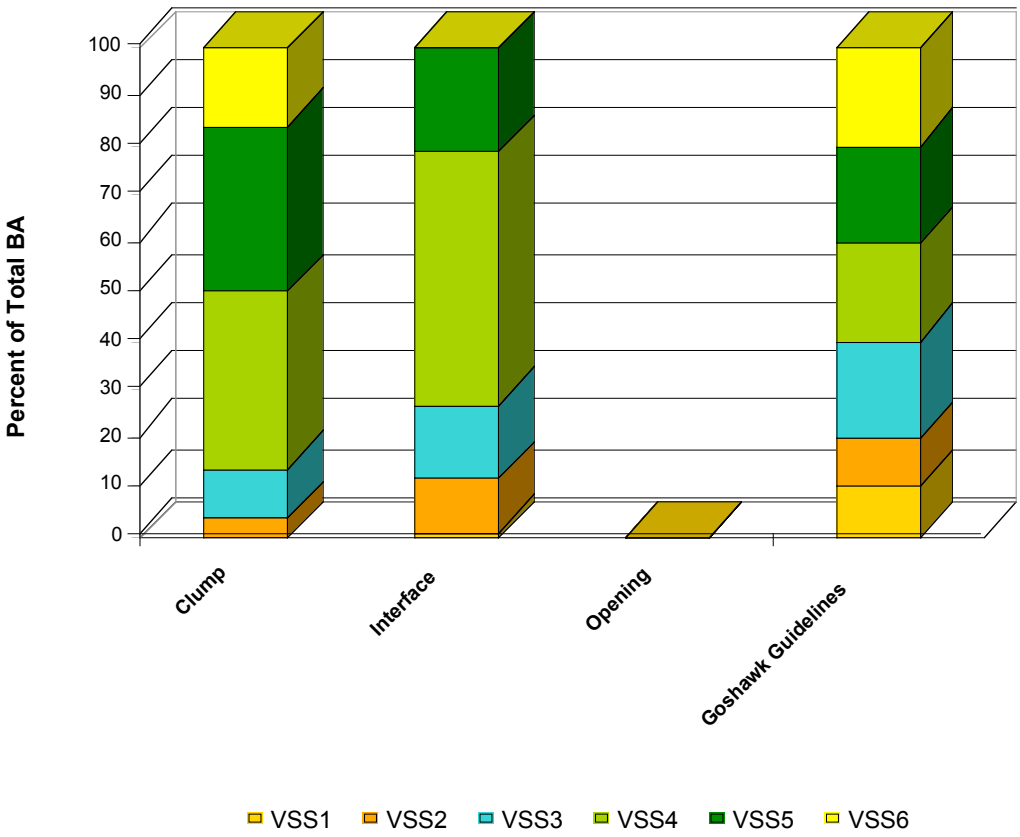
Ground Cover *



Interspace in Plot



Strata Basal Area Distribution by VSS Class



APPENDIX C

Habitat Suitability

Greater Flagstaff Forests Partnership
Flagstaff Fire – City Well-field – Post-treatment 2008
Habitat Suitability

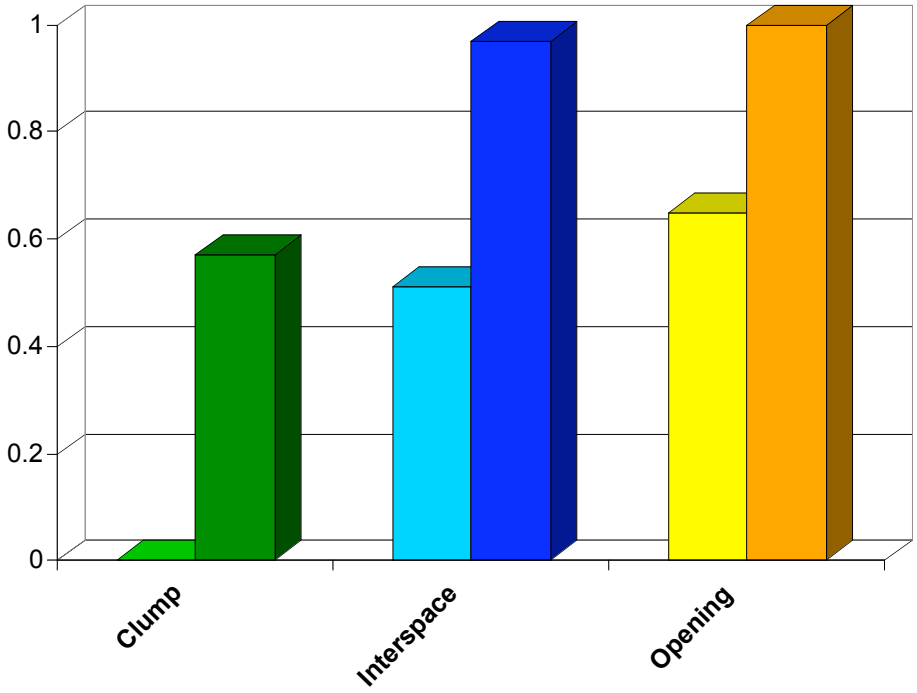
Strata	Index			
	Pronghorn Antelope (suitability)	Avian Species Richness (# species)	Abert Squirrel Density (# squirrels/ac)	Exotic Species Richness (# species)
Clump	0.57	11.5	7.39	1.60
Interspace	0.97	8.5	1.53	4.20
Opening	1.00	8.5	0.00	3.80

Greater Flagstaff Forests Partnership
Flagstaff Fire – City Well-field – Post-treatment 2008
Exotic Species Occurrence

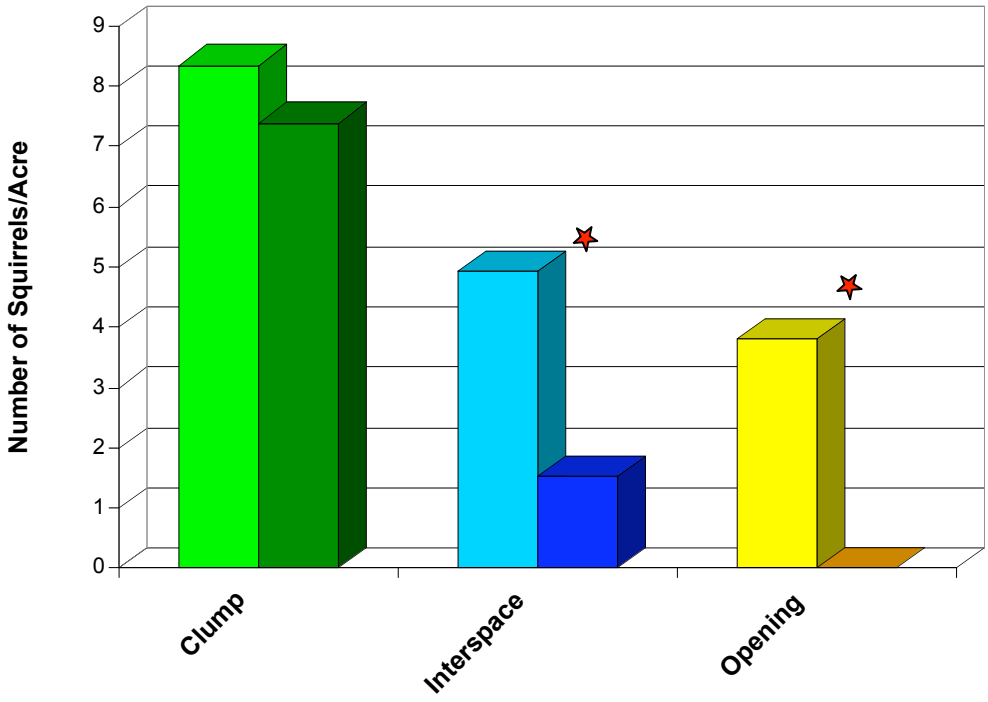
Strata	Species NRCS Code									
	AMBRO	BRTE	CHAL7	CIVU	COAR4	DAGL	ERCI6	LASE	LIDAD	MAVU
Clump	0	40	20	20	0	0	0	0	0	0
Interspace	0	80	60	0	20	0	20	0	20	0
Opening	0	60	80	20	20	0	0	0	0	0

Strata	Species NRCS Code									
	MEAL2	MEOF	MESAS	ONAC	POPR	TAOF	TRDU	TRRE9	UNK1	VETH
Clump	0	0	40	0	0	40	0	0	0	0
Interspace	0	0	40	0	0	60	0	0	0	60
Opening	0	0	40	0	0	80	0	20	80	20

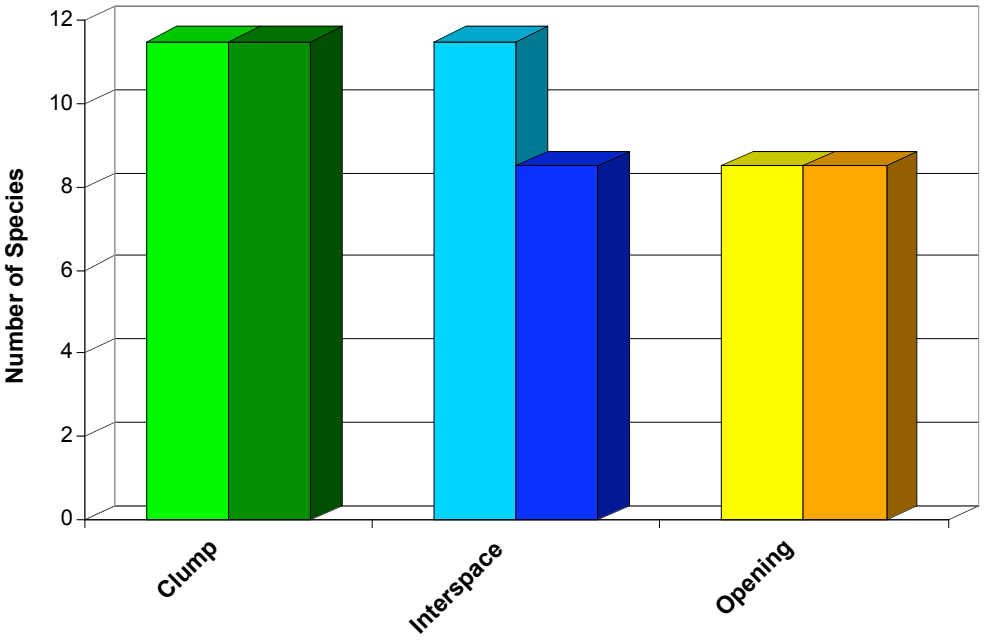
Pronghorn Antelope Suitability



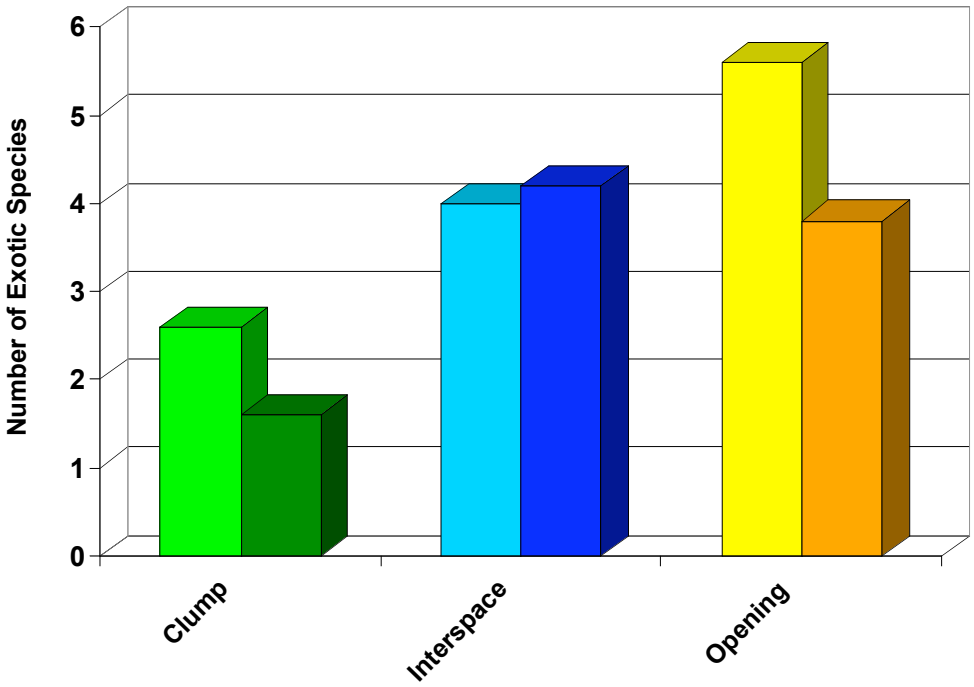
Abert Squirrel Density*



Avian Species Richness



Exotic Species Richness *



APPENDIX D

Fire Behavior

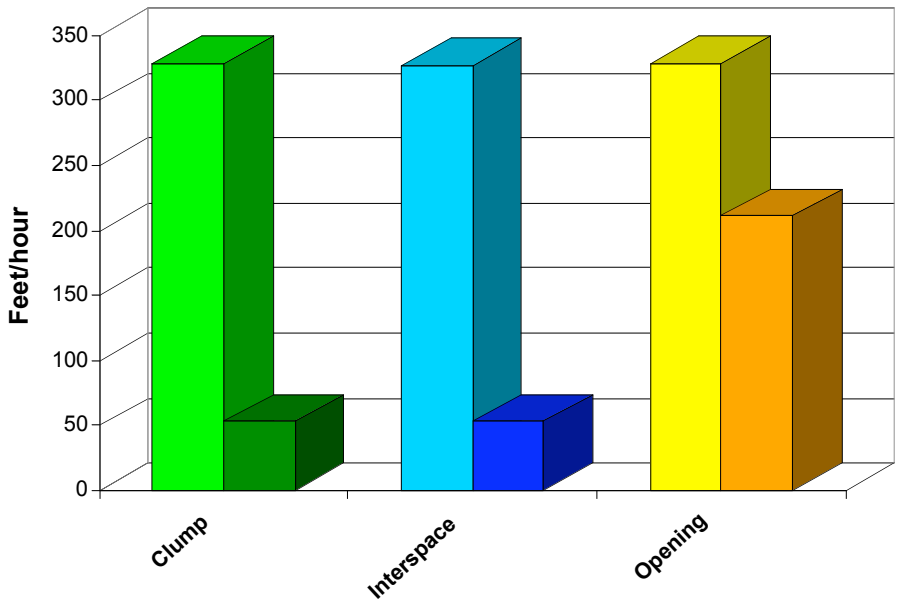
Greater Flagstaff Forests Partnership
Flagstaff Fire - City Well-field - Post-treatment 2008
NEXUS Output
June 97% Weather Conditions

	Scenario								Crown Fire Index		
	FTYP	CRFB	SPRT		HPUA	FLIN	FLML	EMFW	TORI	CRNI	SURI
Strata		(%)	(mi/hr)	(ft/hr)	(BTU/ft2)	(BTU/ft)	(ft)	(mi/hr)	(mi/hr)	(mi/hr)	(mi/hr)
Clump	Surface	0.0	0.01	53	134	2	0.5	2.5	3636	53.1	53.1
Interspace	Surface	0.0	0.01	53	134	2	0.5	2.5	2509	112.3	112.3
Opening	Surface	0.0	0.01	211	83	5	0.9	2.5			0.0

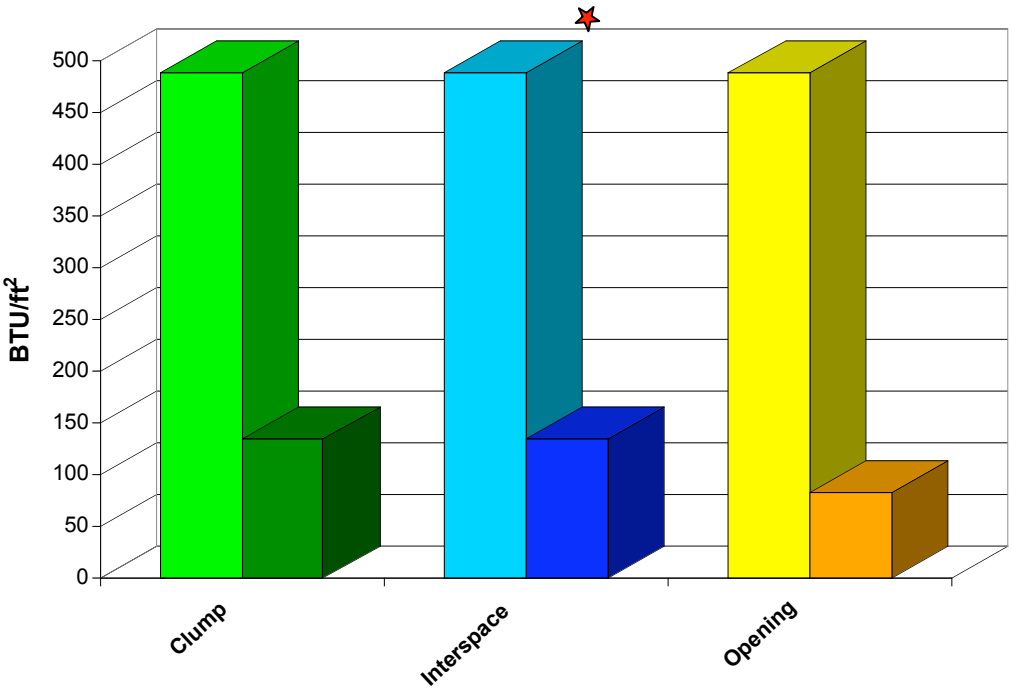
	Critical Initiation				Critical Active			Cessation
	FLIN	FLML	SPRT		ACBD	SPRT		OWND
Strata	(BTU/ft)	(ft)	(mi/hr)	(ft/hr)	(kg/m3)	(mi/hr)	(ft/hr)	(mi/hr)
Clump	1227	11.9	6.3	33264	0.1	3.3	17266	6.3
Interspace	727	9.3	3.7	19536	0.1	9.5	50054	3.8
Opening	0	0.0	0	0	0.0	0	0	0.0

Abbreviation	Name	Definition
Scenario:		
FTYP	Fire type	Type of fire that would occur under stated weather conditions: surface, conditional, passive, active
CRFB	Crown fraction burned	The fraction of the crown that would burn in the above fire
SPRT	Spread rate	The rate at which the above fire would spread
HPUA	Heat per unit area	The amount of heat generated by the above fire
FLIN	Fireline intensity	The heat generated at the fireline
FLML	Flame length	The length of the flame generated by the fire
EMFW	Effective mid-flame windspeed	
Crown Fire Index:		
TORI	Torching index	The 20-ft windspeed at which some kind of crowning is possible
CRNI	Crowning index	The 20-ft windspeed at which active crown fire is possible
SURI	Surfacing index	The 20-ft windspeed at which an active crown fire would drop to the surface
Critical Initiation:		
FLIN	Fireline intensity	The critical fireline intensity for crown fire initiation
FLML	Flame length	The critical flame length for crown fire initiation
SPRT	Spread rate	The critical spread rate for crown fire initiation
Critical Active:		
ACBD	Available crown bulk density	The critical available bulk density for a sustained active crown fire
SPRT	Spread rate	The critical spread rate for a sustained active crown fire
Cessation		
OWND	Open wind speed	The critical open windspeed to cause active fire cessation due to too-high canopy base height

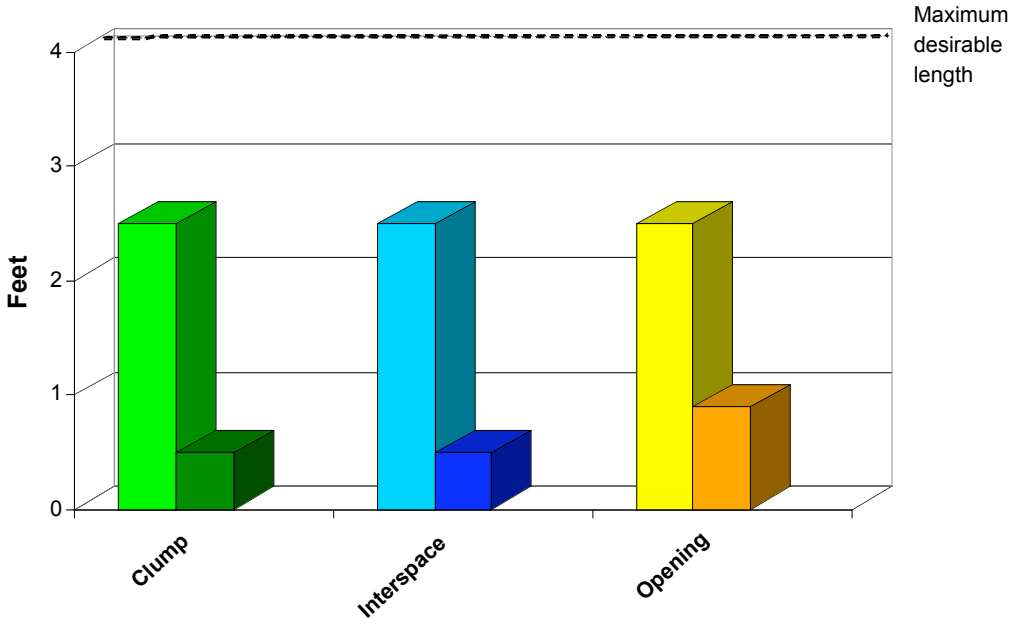
Spread Rate



Heat per Unit Area *

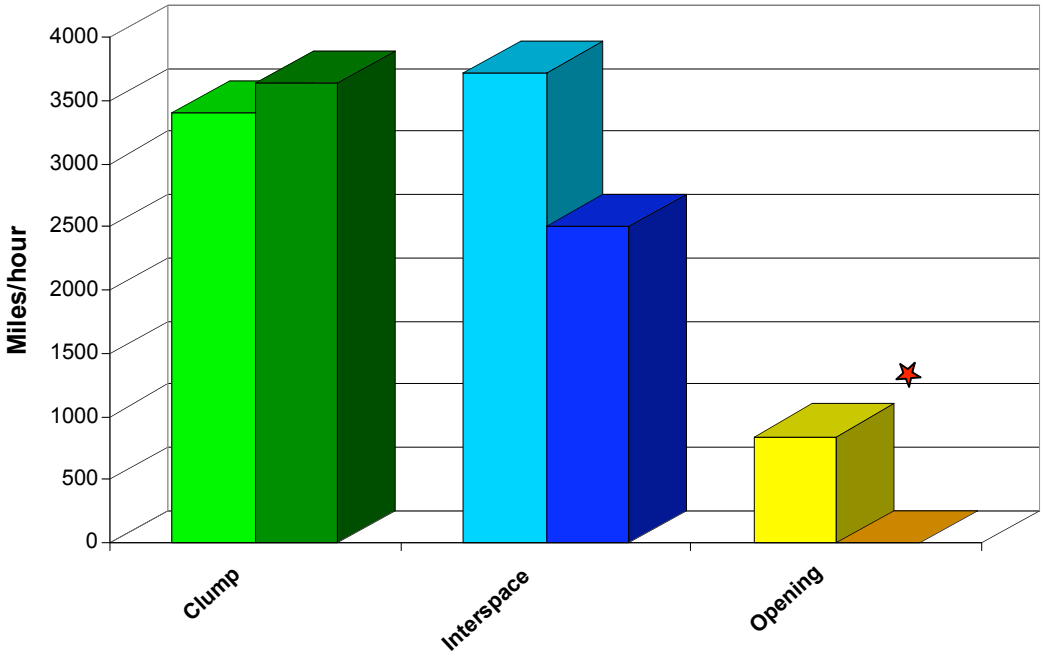


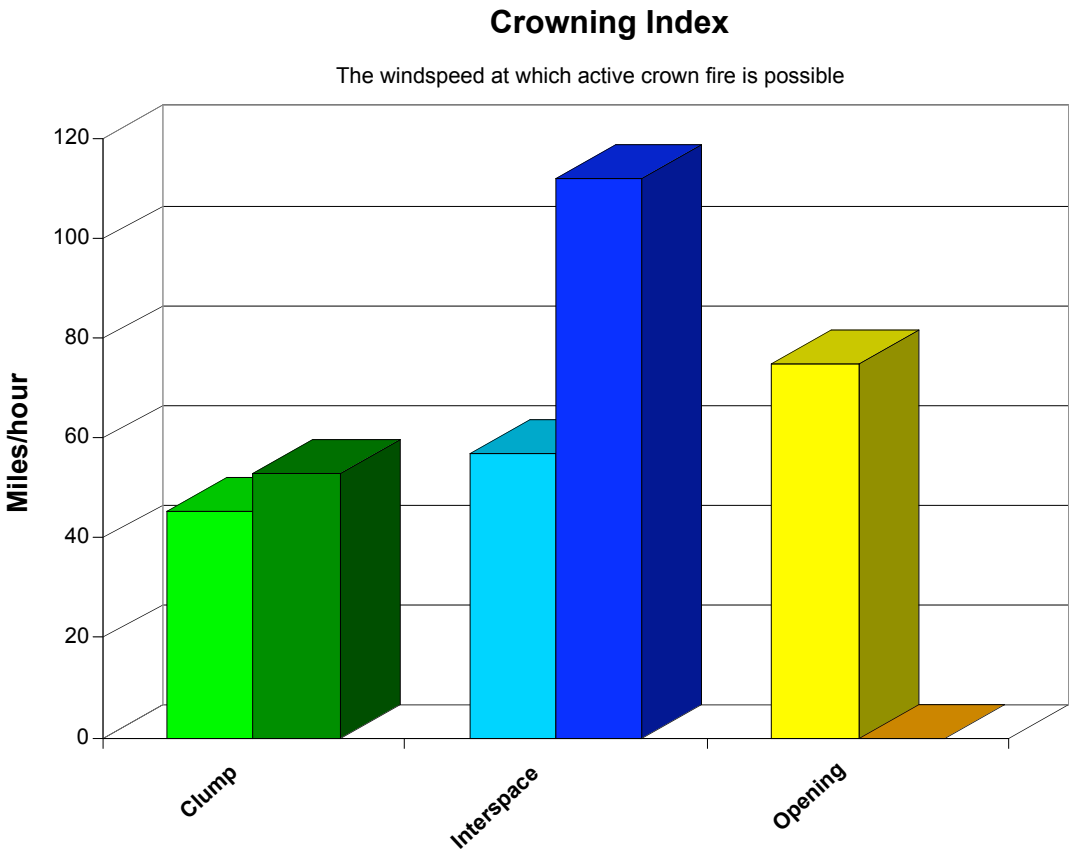
Flame Length

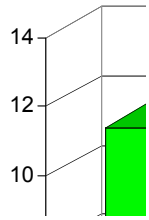


Torching Index *

The windspeed at which some crowning is possible





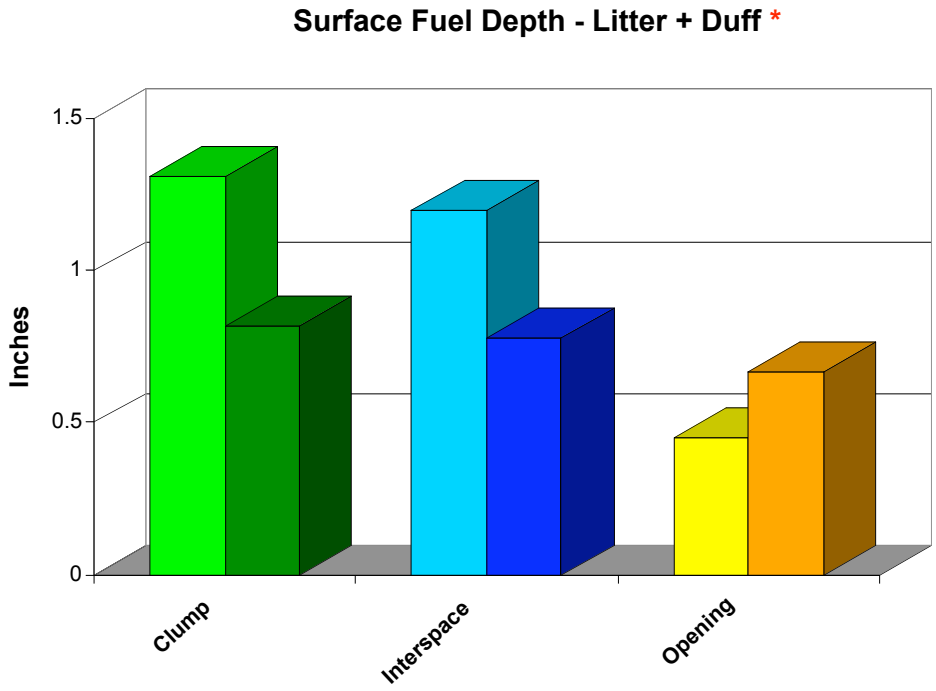


APPENDIX E

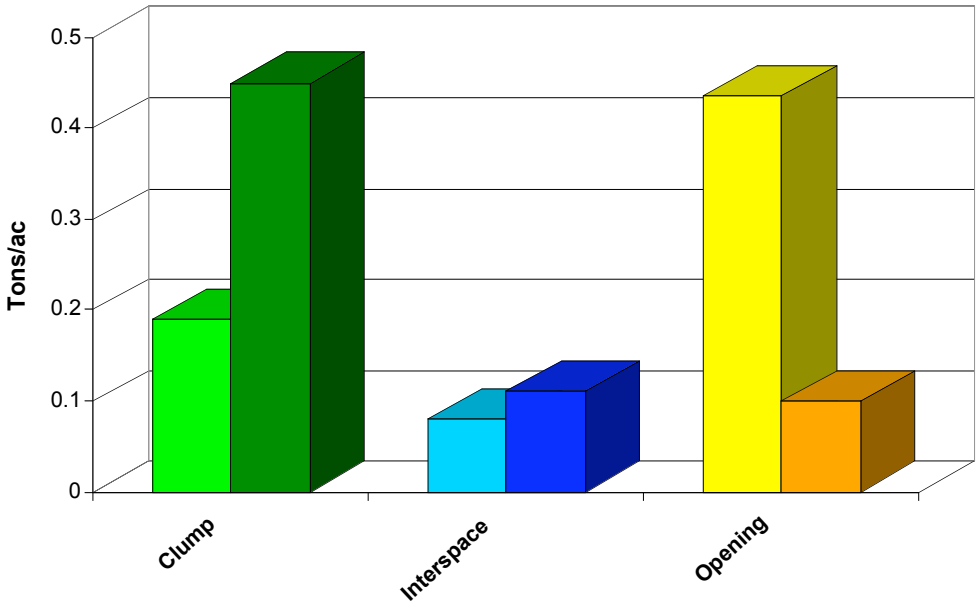
Surface Fuel Loading

Greater Flagstaff Forests Partnership
Flagstaff Fire - City Well-field – Post-treatment 2008
Surface Fuel Loading

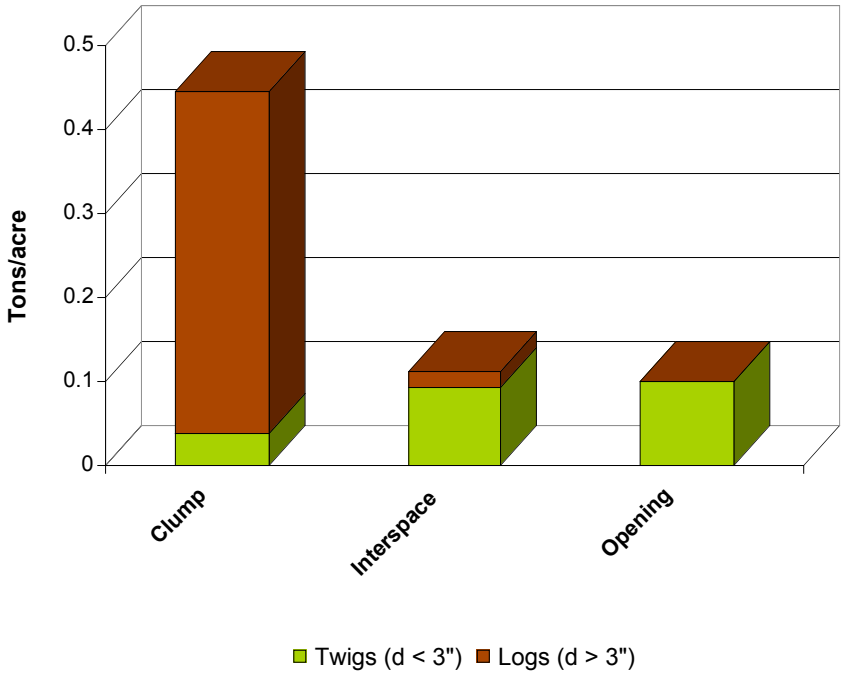
Strata	Surface fuel depth (in)	Available Fuel Small d < 3" (tons/ac)	Large d ≥ 3 in (tons/ac)	Total (tons/ac)
Clump	0.820	0.038	0.408	0.446
Interspace	0.780	0.093	0.019	0.111
Opening	0.670	0.099	0.000	0.099



Total Available Surface Fuel*



Available Surface Fuel



APPENDIX F

Representative Comparison Photographs

Pre-treatment

CLUMP

Post-treatment

Pre-treatment

INTERSPACE

Post-treatment

Pre-Treatment

OPENING

Post-treatment