WHITE PAPER

USDA Forest Service | Pacific Northwest Region | Umatilla National Forest

WHITE PAPER F14-SO-WP-SILV-26

Is This Stand Overstocked?
An Environmental Education Activity[1]

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Initial Version: **MAY 1990**[2]
Most Recent Revision: **OCTOBER 2011**

INTRODUCTION

This activity was prepared by a type of forester called a silviculturist. What is a silviculturist? Originating, growing, and tending stands of trees is called silviculture (silva is the Latin word for forest). Silviculture is a cornerstone of forestry. Someone who is trained and experienced in silviculture is called a silviculturist.

Forestry is a profession that exists to help people get benefits they want from forests, but forests have limits. Like all living things, trees are restricted in what they can do. A tree species needing well-drained soils cannot survive in a marsh. If seeds require bare soil for germination, no amount of urging will get them to establish on a thick layer of tree needles.

A silviculturist helps people understand what trees need, why only certain tree species grow in an area, and how stands of trees could be managed to supply people with the forest benefits they want (to meet people's objectives).

Sometimes, what society wants from a forest is for trees to be left alone to pursue their own destiny. But more often, a forester is asked to get involved, particularly when a forest has problems – stands that have been damaged by insects or diseases, stands that don't provide good wildlife habitat, or stands that need to produce more feed for cattle or sheep.

[1] White papers are internal reports; they receive only limited review. Viewpoints expressed in this paper are those of the author – they may not represent positions of USDA Forest Service.
[2] This paper was prepared in 1990 for Mr. Kevin Steinmetz's sixth grade class at Humbolt Elementary School in John Day, Oregon. It has been used several times since then with other school groups.

To grow well, a tree needs a place in the sun and some soil to call its own. When trees are crowded and standing too close together, they lack enough sun or water to thrive. Trees without sufficient sun, water, and food (nutrients) become weak – and weak trees are more likely to be attacked by bark beetles or root diseases.

One thing foresters need to know is how many trees are present in a stand. This concept is called stocking. Foresters take measurements to determine how many trees are present now, which is then compared with how many trees there should be (stocking recommendations).

Your task is to take measurements in a forest stand, and then use the information to figure out if the stand is overstocked (does it have too many trees?).

You can accomplish this task in five steps:

- ✓ First, the whole group will be split up into small inventory teams, and each team will have a helper provided by the Forest Service.
- ✓ Second, each team will move into a portion of the stand and set up a circular plot, by using instructions provided below.
- ✓ Third, each team will use equipment provided by the Forest Service to measure trees occurring on a plot, and record your data on plot sheets provided in this handout.
- ✓ Fourth, you will summarize your data to come up with an average for the whole plot.
- ✓ Fifth, you will compare your plot information with stocking charts to figure out if the stand is overstocked or not.

My experience is that most folks do not enjoy mathematics. But many jobs require mathematics knowledge, and forestry is no exception. Exercises in this handout will show you some ways that foresters use mathematics in their work.

Foresters often deal with large land areas. They need to know what kind of trees grow on the area, how many of them there are, and how big they are. Trying to measure every tree on a national forest covering one and half million acres and containing more than 500 million trees would not only be time consuming and expensive, but impossible!

For these and other reasons, foresters only measure a portion of a forest, a process called sampling. They assume that a measured (sampled) portion represents the whole area, and the whole area is referred to as their population. Data collected from a sample portion is expanded to provide information for the unsampled portion.

Suppose we need to know tree stocking levels for a 54-acre tree stand on Heppner Ranger District. The entire stand (all 54 acres) is our population, but we can't measure every tree because it would take too much time. So, the best way to determine the stand's stocking level is to sample it, which is accomplished by establishing plots.

How can we figure out a plot size? By using some mathematical formulas, of course! Previous sampling experience shows that circular plots are easier to use than square plots, so we'll use circular plots to sample our forest stand.

To lay out a plot in the shape of a circle, we must know its radius, which we'll figure out by using this formula:

$$\text{Area} = \text{Pi} \times \text{Radius}^2$$

> Note: if you don't know what pi is, here is a short description. Pi does not refer to a dessert pastry (my favorite is cherry pie) – it is the number you get when you divide the distance around a circle (its circumference) by the distance through its middle (its diameter). Distance around the outside of every circle is about three times the distance across it. But, it's the 'about' part that creates the puzzle of pi! Mathematicians call pi an irrational number because when you divide a circle's circumference by its diameter, the answer comes out in decimals that go on forever without any apparent pattern. Pi begins as 3.14159265, ***but it never ends***. In 1999, a Japanese scientist used a supercomputer to calculate pi to about 206 billion digits, and it still goes on from there. All those digits aren't necessary to use pi, of course – by using only the first ten decimals, you can measure earth's circumference to within a fraction of an inch. Pi is often shown in textbooks or in formulas by using this Greek symbol: π.

Let's say that we decide to use a plot covering ¼ of an acre. The total area of an acre is 43,560 square feet. Since we want to use a ¼-acre plot, its area is 43,560 ÷ 4 or 10,890 square feet. We now have enough information to use the formula at the top of this page to figure out our plot radius.

$$\begin{aligned}
\text{Area} &= \text{Pi} \times \text{Radius}^2 \\
10{,}890 \text{ square feet} &= 3.1416 \times \text{Radius}^2 \\
10{,}890 \text{ square feet} \div 3.1416 &= \text{Radius}^2 \\
3{,}466.39 \text{ square feet} &= \text{Radius}^2 \\
\sqrt{3{,}466.39} \text{ square feet} &= \text{Radius} \\
58.9 \text{ feet} &= \text{Radius}
\end{aligned}$$

So, this means that each ¼-acre plot would be installed as a circle with a radius of 58.9 feet.

For your exercise today, each group will use the same plot size (and it might not be ¼ acre); a plot size will be selected by your group leader during the field exercise.

Each team will use a wooden or wire stake to mark a plot center, and you will then use a measuring tape to mark plot boundaries by measuring out a radius in several directions from the stake.

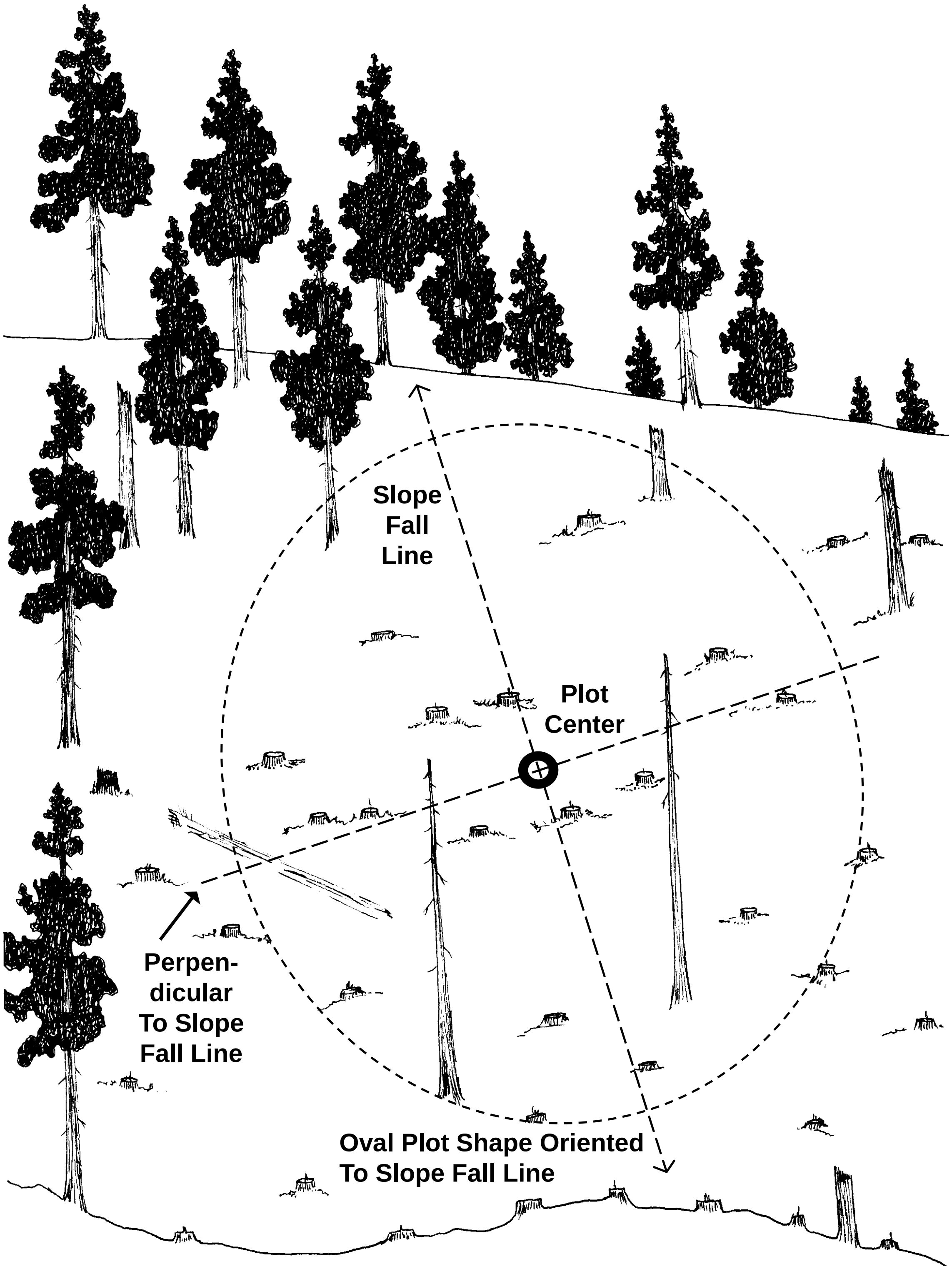
Rather than have each group figure out the size of your plot radius by using calculators and the formula for a circle (like the example above), I have done these calculations for you, and plot areas and plot radiuses are provided in table 1 on the next page.

Table 1: Plot size, plot area, and plot radius

Plot Size (Acres)	Plot Area (Square Feet)	Plot Radius (Feet)
1/4	10,890	58.9
1/5	8,712	52.7
1/10	4,356	37.2
1/20	2,178	26.3
1/50	871	16.7
1/100	436	11.8
1/250	174	7.5
1/300	145	6.8
1/500	87	5.3
1/1000	44	3.7

If the ground (called ‘terrain’) near your plot center is flat, then a plot will be a perfect circle with a radius as shown in table 1 above. But, problems start when you are working on a hill because a plot’s radius then varies, depending on steepness of a hill.

By projecting a plot’s radius onto a steep hillside, we see that it becomes oval in shape, not circular, as is shown in a diagram on the next page.



On sloping ground, plots have an oval shape with their long axis parallel to the slope (called a 'slope fall line'). Note that a line perpendicular to the slope forms a right angle with the slope fall line. Plots on sloping ground need to have their radius adjusted by using a factor that converts slope distance to what is called horizontal distance (horizontal distance removes the effect of slope, as though a plot area is flat instead of sloping).

How do we adjust the radius of a plot that occurs on sloping ground? Well, you could figure out an adjusted radius by using trigonometry (secants), but most foresters just carry around something called a slope correction table.

Below is part of a slope correction table for slopes ranging up to 61 percent, provided here as table 2:

Table 2: Slope correction factors

Slope Percent	Correction Factor
0 – 9	1.00
10 – 17	1.01
18 – 22	1.02
23 – 26	1.03
27 – 30	1.04
31 – 33	1.05
34 – 36	1.06
37 – 39	1.07
40 – 42	1.08
43 – 44	1.09
45 – 47	1.10
48 – 49	1.11
50 – 51	1.12
52 – 53	1.13
54 – 55	1.14
56 – 57	1.15
58 – 59	1.16
60 – 61	1.17

Now, let's use table 2's slope correction factors to figure out if some trees near our plot edge are 'in or out' (inside or outside of a plot's radius). Trees near a plot edge are referred to as borderline trees. Here is a way to measure borderline trees:

1. Use an instrument called a clinometer to measure slope percent from the center (side) of a borderline tree to the plot center (let's say that it is 30 percent).
2. Find a slope correction factor in table 2 for the slope percent you just measured (correction factor is 1.04 for 30 percent).
3. Multiply the correction factor by the plot's radius. This is called a corrected radius. For a ¼-acre plot, the result is: 58.9 feet × 1.04 = 61.3 feet.
4. Measure slope distance from the center (side) of the tree to the plot center. If measured distance is less than the corrected radius (61.3 feet for this example), then a tree is in; if measured distance is more than the corrected radius, the tree is out.

MEASURING TREE DIAMETER

Now that we know how to figure out which trees are in or out of a plot, we need to learn how to measure the size of trees that are in on the plot. Tree size has two dimensions – how big around (tree circumference), and how tall (tree height).[3] For this field exercise, we need to find out how big around each tree is.

There are two main ways we can describe the size of round objects like tree stems:

- We can measure circumference, the distance around the outside of their trunk, or
- We can measure circumference and convert it to diameter, which is the distance through the middle of a tree's trunk.

Foresters use special measuring tapes that show a tree's circumference on one side, and its equivalent diameter on the other side. How is this done? Actually, this is easy to do because circumference and diameter are closely related:

$$\text{Circumference} = \text{Pi} \times \text{Diameter}$$

$$\text{Diameter} = \text{Circumference} \div \text{Pi}$$

One final thought about measuring tree diameter. By historical convention, diameter is measured at 'breast height,' which is defined as 4½ feet above ground surface on the uphill side of a tree. It will hereafter be referred to as DBH (diameter at breast height) – and I extend a hearty welcome to the world of forestry jargon! [DBH is used because measuring diameter at 4½ feet is easier than bending down to measure it at ground line.]

CALCULATING BASAL AREA

Tree count tells us how many trees are present in an area, but a tree count does not account for differences in tree size. If a count shows 500 trees per acre, do they occur as 1-foot-tall seedlings or as 40-foot-tall trees? It makes a huge difference because 500 1-foot-tall seedlings per acre might be okay, but 500 large trees per acre almost always presents a problem.

To deal with this size issue, foresters use a measurement called basal area, which gets at the 'bulk' of a tree. Basal area is a hard concept to understand. It is the cross-sectional area of a tree at breast height (DBH), in square feet, as though we cut the tree off at DBH and then wanted to calculate the surface area of the stump's top (its flat part).

Here is the formula for calculating the basal area (BA) of a single tree, in square feet:

$$\text{BA} = \text{Pi} \times (\text{DBH}/24)^2$$

[Have you noticed yet that most mathematical formulas pertaining to circles, including round objects like tree stems, use pi?]

[3] Many tasks require foresters to measure tree height. To evaluate stocking, tree height is not needed, so the process for measuring tree height is not described in this white paper. However, tree height is described in white paper #54 – *Using mathematics in forestry: an environmental education activity*.

Rather than ask you to use a formula to calculate basal area for each tree on a plot, I will provide basal area values in a look-up table, provided below as table 3:

Table 3: Basal area by DBH

DBH (Inches)	Basal Area (Square Feet)
1	0.01
2	0.02
3	0.05
4	0.09
5	0.14
6	0.20
7	0.27
8	0.35
9	0.44
10	0.55
11	0.66
12	0.79
13	0.92
14	1.07
15	1.23
16	1.40
17	1.58
18	1.77
19	1.97
20	2.18
21	2.41
22	2.64
23	2.89
24	3.14
25	3.41
26	3.69
27	3.98
28	4.28
29	4.59
30	4.91
32	5.59
34	6.31
36	7.07

So, here's your process for sampling a stand and determining if it is overstocked:

1. Locate a plot area, and pound in a stake to mark its center.
2. Decide which plot size will be used, and find the radius for that plot in table 1.
3. Is a tree in the plot? Stretch out a measuring tape from a plot center stake in a full 360° circle to determine which trees are in your plot. Trees in the plot are called sample trees. Each sample tree is numbered and recorded on a plot form.
   Note: If your plot occurs on sloping ground, and if there is limited time for this field exercise, don't worry about correcting for slope. However, accurate plot measurements will always convert slope distance to horizontal distance.
4. Determine tree species. For all sample trees, record tree species on a plot form.
5. Measure DBH. For all sample trees, measure their diameter with a diameter tape (round off to nearest whole inch), and record the value on a plot form.
6. Determine basal area for each sample tree. For all sample trees, record their basal area on a plot form (hint: look up basal area values, by DBH, in table 3).
7. Calculate a plot's total basal area. Use your calculator to add values in the form's basal area column, and then record an answer (total basal area) in the space provided.
8. How many trees per acre does the stand have? This is an easy step – here's how to do it: multiply a plot's total number of sample trees by the plot expansion factor.

> Note: when you sample a portion of an acre, and then want to expand sample data so it represents the whole acre, sample values must be multiplied by denominator of plot size. Examples: for a 1/10-acre plot, each sample tree represents 10 trees (denominator value for 1/10); for a 1/20-acre plot, each sample represents 20 trees, and so forth. The denominator value is referred to as a "plot expansion factor."

9. How much basal area does the stand have? This is also easy – here's how to do it: multiply a plot's total basal area (see item #7) by the plot expansion factor.
10. Calculate an average stand diameter. Here's how: take square root of stand basal area (BA; item #9) divided by stand trees per acre (TPA; item #8), and multiply the answer by 13.54 (each team should ask their leader to assist with this calculation).
    Equation: $\sqrt{\text{Stand BA/Stand TPA}} \times 13.54$ = Average stand diameter (QMD)
11. Now, you are ready to decide if the stand is overstocked or not! Take average stand diameter (item #10) and stand basal area (item #9), and use them with stocking charts (at end of this handout) to find where your stand falls on the charts.
12. Here's how to interpret chart position for your stand's data:
    - Between the blue and green lines: not overstocked; **trees are happy**.
    - Between the green and red lines: moderately overstocked; **stand is crowded and trees are cranky**.
    - Between the red and black lines: greatly overstocked; **stand is very dense and trees are definitely stressed out**.

EXAMPLE PLOT (Plot size = 1/10 acre; radius = 37.2 feet)

Sample Tree	Tree Species	Diameter (Inches)	Basal Area (Square Feet)
1	Ponderosa pine	22	2.6
2	Ponderosa pine	27	4.0
3	Western larch	18	1.8
4	Douglas-fir	29	4.6
5	Western larch	12	0.8
6	Douglas-fir	8	0.3
7	Western larch	14	1.1
8	Ponderosa pine	9	0.4
9	Ponderosa pine	15	1.2
10	Douglas-fir	16	1.4
	TOTAL		18.2

1. Trees per acre: 100 (number of Sample Trees × expansion factor) (10 × 10)
2. Basal area per acre: 182 (total Basal Area × expansion factor) (18.2 × 10)
3. Average stand diameter (QMD): 18 (use equation in item 10 on page 9)
4. Stocking status for ponderosa pine: **greatly overstocked**
5. Stocking status for western larch: **greatly overstocked**
5. Stocking status for Douglas-fir: **greatly overstocked**
6. Stocking status for grand fir: **not overstocked**

LET'S SUMMARIZE

What have you learned from this exercise?

- How forestry and silviculture serves society (pages 1-2).
- How to figure out the radius of a circular plot after being given its area (page 3).
- How to adjust a plot radius to account for sloping ground (pages 5-6).
- That many mathematical formulas involving circles use pi, a special never-ending constant that we round off to 3.1416 (pages 3 and 7).
- How to measure the diameter of trees (page 7).
- How to calculate basal area (pages 7-8).
- How to establish and measure a sample plot (page 9).
- How to use stocking charts to figure out if a stand is overstocked or not (page 9).

PLOT FORM

Plot number ____________

Plot size _________ Plot radius ___________ Expansion factor ___________

Sample Tree Number	Tree Species	Diameter (Inches)	Basal Area (Square Feet)
		Total	

1. Trees per acre: __________ (number of Sample Trees × expansion factor)
2. Basal area per acre: __________ (total Basal Area × expansion factor)
3. Average stand diameter (QMD): __________ (see item #10 on page 9)
4. Stocking status for ponderosa pine: ____________________
5. Stocking status for western larch: ____________________
6. Stocking status for Douglas-fir: ____________________
7. Stocking status for grand fir: ____________________

PLOT FORM

Plot number ____________

Plot size _________ Plot radius ___________ Expansion factor ___________

Sample Tree Number	Species	Diameter (Inches)	Basal Area (Square Feet)
________	________________	________	_________
________	________________	________	_________
________	________________	________	_________
________	________________	________	_________
________	________________	________	_________
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________	________________	________	_________
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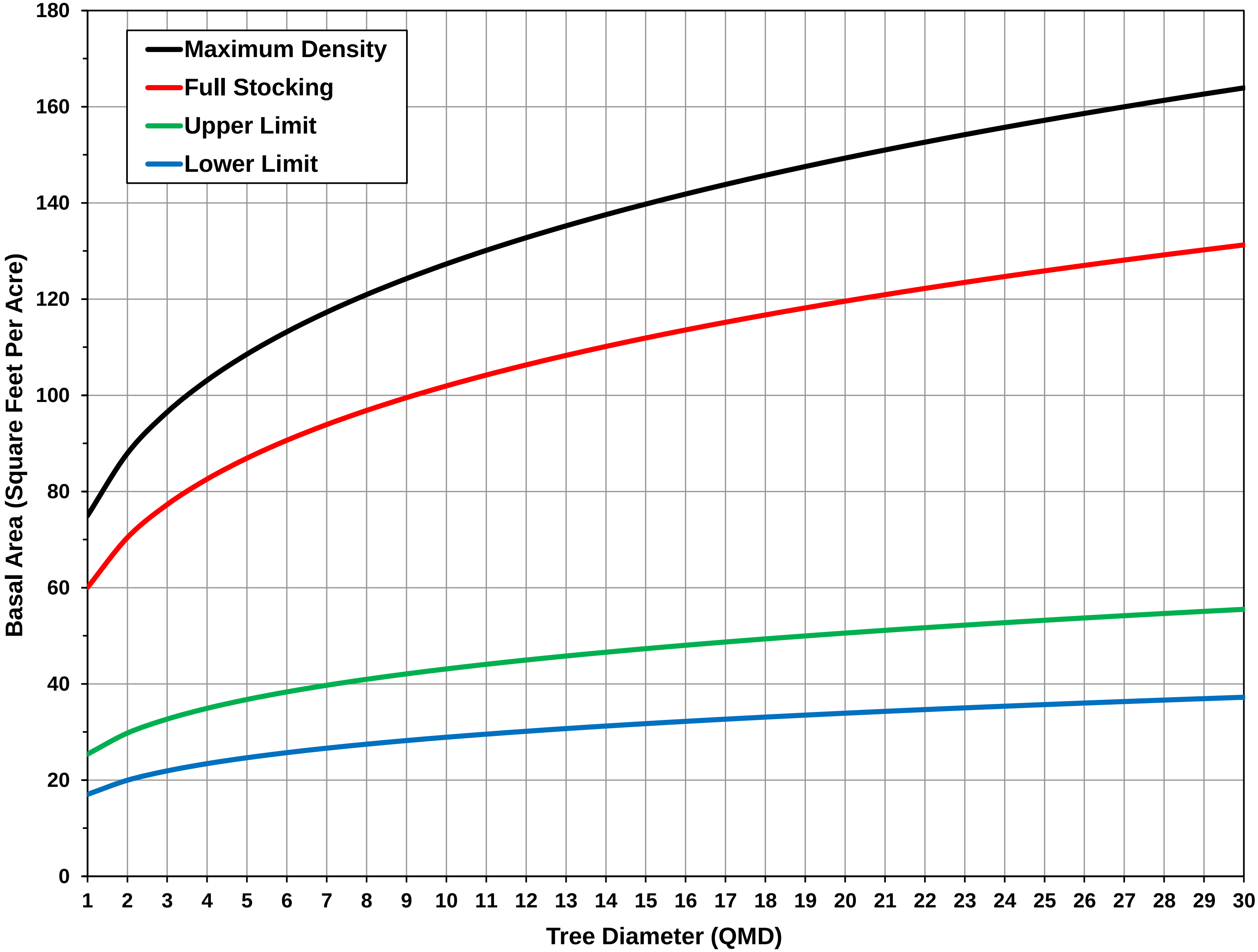
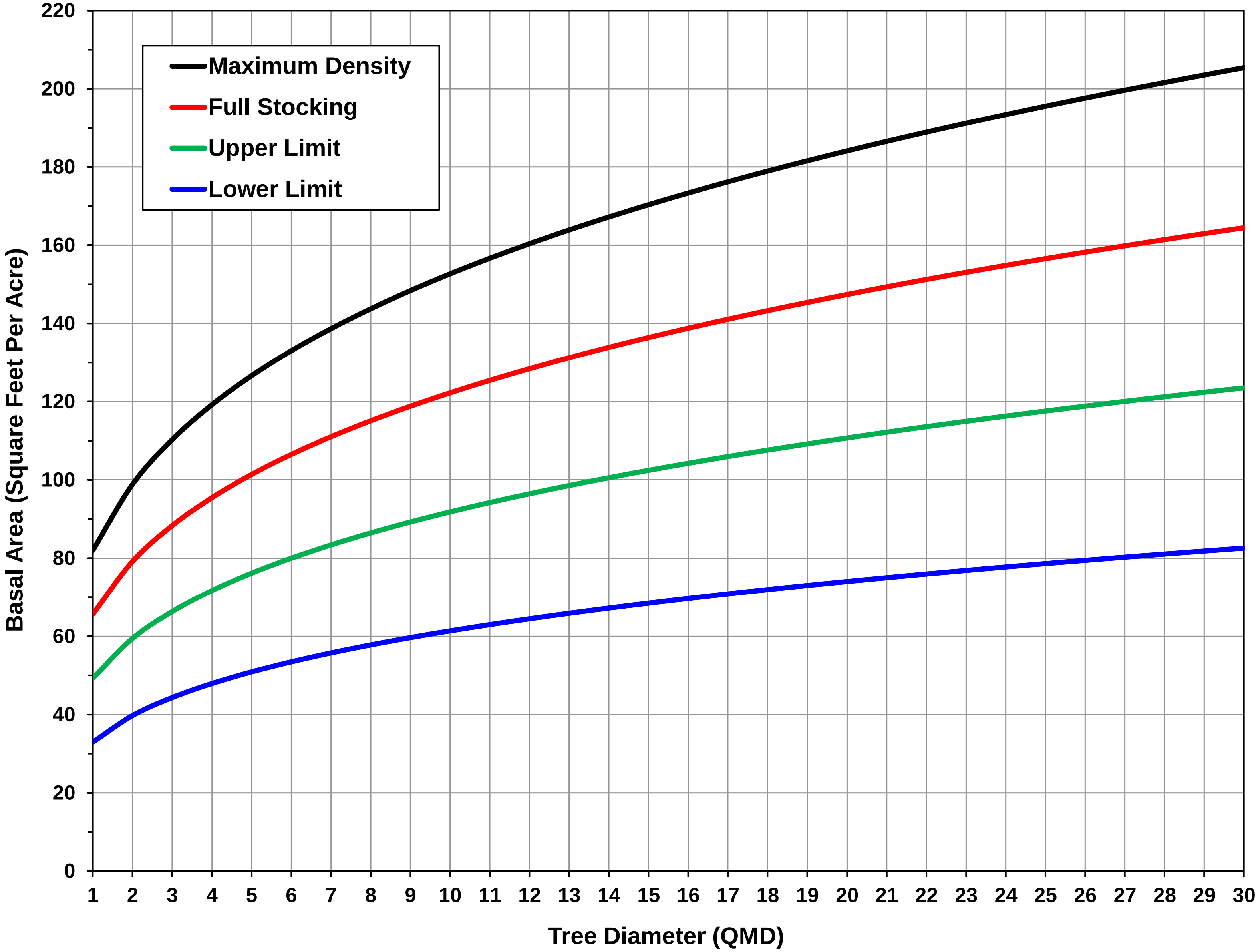
________	________________	________	_________
________	________________	________	_________
________	________________	________	_________
		Total	_________

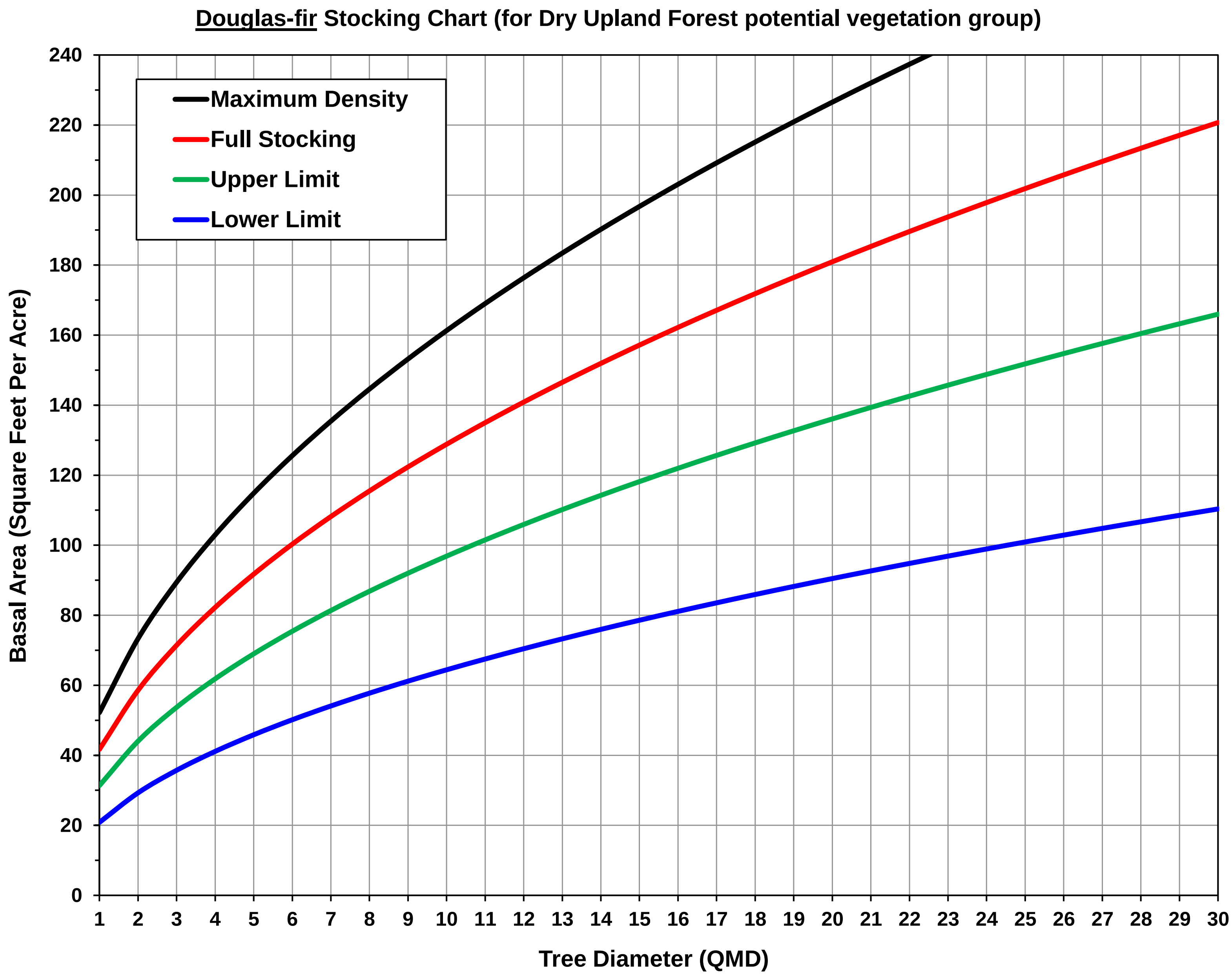
1. Trees per acre: __________ (number of Sample Trees × expansion factor)
2. Basal area per acre: __________ (total Basal Area × expansion factor)
3. Average stand diameter (QMD): __________ (see item #10 on page 9)
4. Stocking status for ponderosa pine: ____________________
5. Stocking status for western larch: ____________________
6. Stocking status for Douglas-fir: ____________________
7. Stocking status for grand fir: ____________________

<u>Ponderosa Pine</u> Stocking Chart (for Dry Upland Forest potential vegetation group)

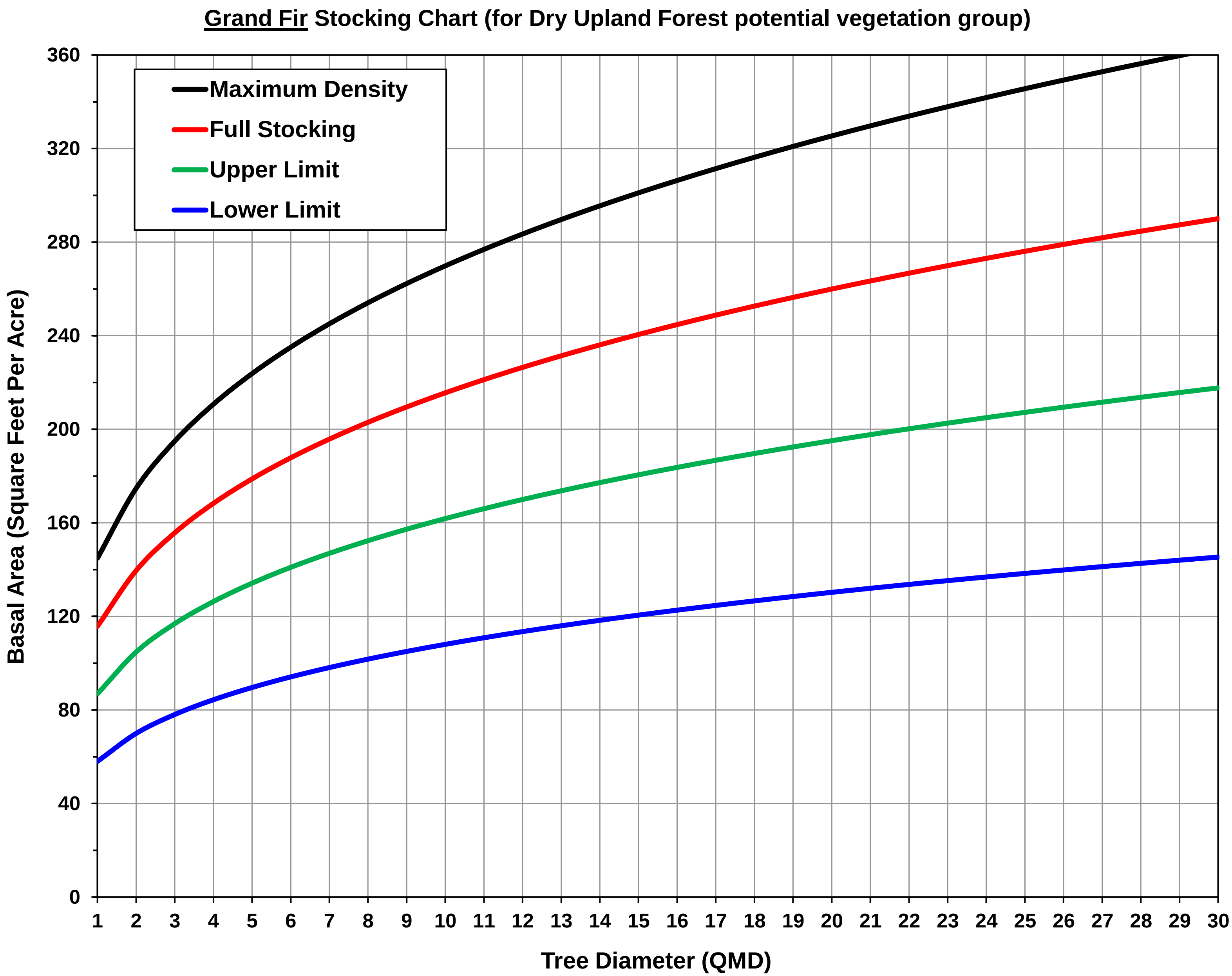


<u>Western Larch</u> Stocking Chart (for Dry Upland Forest potential vegetation group)





Douglas-fir Stocking Chart (for Dry Upland Forest potential vegetation group)
Maximum Density
Full Stocking
Upper Limit
Lower Limit
Basal Area (Square Feet Per Acre)
0
20
40
60
80
100
120
140
160
180
200
220
240
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Tree Diameter (QMD)


Grand Fir Stocking Chart (for Dry Upland Forest potential vegetation group)
Maximum Density
Full Stocking
Upper Limit
Lower Limit
Basal Area (Square Feet Per Acre)
0
40
80
120
160
200
240
280
320
360
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Tree Diameter (QMD)

APPENDIX: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper, specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new

product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of Blue Mountains dry forests: Silvicultural considerations
5	Site productivity estimates for upland forest plant associations of Blue and Ochoco Mountains
6	Blue Mountains fire regimes
7	Active management of Blue Mountains moist forests: Silvicultural considerations
8	Keys for identifying forest series and plant associations of Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created opening, minimum stocking level, and reforestation standards from Umatilla National Forest land and resource management plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: A process paper
16	Douglas-fir tussock moth: A briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of Blue and Wallowa Mountains
21	Historical fires in headwaters portion of Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important Blue Mountains insects and diseases
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: Some ecosystem management considerations
28	Common plants of south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of Umatilla National Forest
30	Potential vegetation mapping chronology

Paper #	Title
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – Forest vegetation
33	Silviculture facts
34	Silvicultural activities: Description and terminology
35	Site potential tree height estimates for Pomeroy and Walla Walla Ranger Districts
36	Stand density protocol for mid-scale assessments
37	Stand density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: Forestry direction
39	Updates of maximum stand density index and site index for Blue Mountains variant of Forest Vegetation Simulator
40	Competing vegetation analysis for southern portion of Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for Umatilla National Forest
42	Life history traits for common Blue Mountains conifer trees
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: Vegetation management considerations
46	Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in northern Blue Mountains: Regeneration ecology and silvicultural considerations
48	Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for Umatilla National Forest: A range of variation analysis
51	Restoration opportunities for upland forest environments of Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: An environmental education activity
55	Silviculture certification: Tips, tools, and trip-ups
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman National Forests
57	State of vegetation databases for Malheur, Umatilla, and Wallowa-Whitman National Forests
58	Seral status for tree species of Blue and Ochoco Mountains

REVISION HISTORY

April 1990: First version of this white paper was prepared to demonstrate how foresters use mathematics for Mr. Kevin Steinmetz's elementary school class in John Day, Oregon. It had minor revisions many times since 1990 as it was used for other environmental education activities, such as outdoor schools and a Fire and Fuels Camp hosted by Heppner Ranger District of Umatilla National Forest.

[Note: The original paper is available as white paper #54: *Using mathematics in forestry: An environmental education activity*.]

October 2011: For an October 2011 revision, the original 1990 subject matter was modified to be used as a stocking-level exercise rather than to demonstrate how mathematics is used in forestry. This revision also added an appendix describing a white-paper system, and a white-paper header and formatting was implemented.