

**Forest Service Handbook
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Forest Service Handbook 2409.17 – Silvicultural Practices Handbook

Chapter 9 - Timber Stocking Guides and Growth Predictions

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9.02 - Objective

This Stocking Level Chapter specifies standards and procedures for the development of stocking level guides within the National Forest System for even-aged stands. It displays the approved format to illustrate the three principal stand parameters used to determine relative density; basal area per unit area, number of trees per unit area, and quadratic mean diameter to be included in all stocking level curves. It describes the use of stocking charts to determine the adequacy of stocking to meet the timber management objective.

9.04 - Responsibility

9.04a - Director, Timber Management, Washington Office

The Director, Timber Management, Washington Office through the TM Mensuration Unit in Fort Collins shall:

- a. Evaluate stocking data and management zone information for completeness and consistency.
- b. Plot curves from satisfactory regional stocking data.
- c. Return plotted curves to Regions for review and verification.
- d. Resolve differences in stocking level curves between Regions for the same timber types.
- e. Maximize the area of application for stocking level guides without loss of accuracy.
- f. Discuss with Regions data problems and needs.

9.04b - Director of Timber Management, Regional Office

The Director of Timber Management in a Regional Office shall submit stocking data and management zone information to TM Unit in Fort Collins. Each Region shall issue a supplement to this handbook to include all stocking level guides appropriate for Regional use, source of data used to develop the guide, and the NFS and Research Staff Units responsible for development of the curves. Stocking level guides which overlap and apply to more than one adjacent Region must appear in each of the affected Region's handbooks.

9.04c - Director of Experiment Station

The Director of an Experiment Station should work with Regions to achieve the short-term goal of converting existing stocking level guides to the standard format. Stations should also assist Regions in identifying data collection needs where required information for specific species or types is inadequate or missing. Continued cooperation between Research and the National Forest System is required in the development of reference levels and the establishment of management zones for a range of objectives.

9.04d - Forest Silviculturists

Forest Silviculturists shall train field personnel in proper use of stocking level guides for stand management, ensure collection and storage of relative stand density in the unit's stand record system of Timber Management Information System (TMIS), pinpoint problems with application of guides, and convey problems to Regional Office.

9.05 - Definitions

1. Basal Area. The area of the cross-section of a tree inclusive of bark at breast height (4.5 feet or 1.37 meters above the ground) most commonly expressed as square feet per acre or square meters per hectare.

2. Forest Cover Type. A category of forest defined by its vegetation (particularly its composition) and/or locality factors.

3. Habitat Type. The aggregate of all areas that support or can support the same primary vegetation at climax.

4. Management Zone. The area on stocking charts defined by the upper and lower bounds of relative densities in managed stands. The bounds may be defined as:

(a) Upper bound -- the stocking level above which growth is reduced and the stand tends toward stagnation due to excessive mortality or pathologic damage.

(b) Lower bound -- the recommended minimum stocking level needed to achieve a management objective.

5. Quadratic Mean Diameter (QMD). The diameter of the tree of average basal area. For fixed area plots this is the same as the quadratic mean of the sampled tree diameters, $QMD = d^2/n$. The QMD for variable radius plots is determined using procedure described in chapter 9.2.

6. Reference Level. The absolute stand density that would normally be expected under some standard site condition for a specific forest cover type and stand size. May be either:

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(a) Average maximum competition--the average maximum density (AMD) that occurs in natural, undisturbed stands of a given quadratic mean diameter.

(b) No competition--the density in a hypothetical stand of open grown trees with their crowns almost touching, constructed mathematically from the observed relationship between crown area and stem size of open-grown trees.

7. Stand. A community of naturally or artificially established trees of any age sufficiently uniform in composition, constitution, age, site productivity, spatial arrangement, or condition to be distinguishable from adjacent communities thereby forming a silvicultural or management entity.

8. Stand Density. A quantitative measure of some feature of the stand which can be expressed either absolutely as a quantity per unit area such as trees, basal area or volume per acre, or relatively as the ratio of the measured absolute stand density of a given stand to some reference level specific to the forest cover type.

Relative density can be expressed relative to:

(a) The average maximum competition that occurs in natural undisturbed stands of a given quadratic mean diameter.

(b) No competition which is developed from a hypothetical stand of open grown trees when the crowns begin to touch.

9. Stocking Guides. Graphic displays of forest stand relationships used to determine relative stand density. Relative stand density is compared to the stocking levels appropriate to a given management objective.

10. Stocking Level. The relative stand density (RSD) that may guide some management objective, such as maximum volume yield.

9.06 - Theory and Concepts

Stocking guides have been developed for most of the major forest cover types and species in North America. Virtually all of these guides use number of trees or basal area per unit area as expressions of stand density. Another parameter used as an index of stand development is the diameter of the tree of average basal area, that is, the quadratic mean diameter. Standardization of the definitions associated with development of these guides and the format in which they are presented provides for a common understanding and interpretation of displayed relationships regardless of species or forest cover type.

The format described by Gingrich in 1967 (For. Sci. 13: 38-53) and recently discussed by Ernst and Knapp (Gen. Tech. Rep. WO-In Press. Washington, DC: U.S. Department of Agriculture,

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Forest Service) shall be used as a background chart for the preparation of National Forest stocking level guides. This format graphically defines the relationships among basal area per unit area, number of trees per unit area, and the quadratic mean diameter (QMD) and their relation to density. The parameters needed to use this format are easily developed from stand examination data (basal area and number of trees per unit area) and can be used for all species and forest cover types. The quadratic mean diameter is calculated directly from the former two parameters. The mathematical relationships among the three parameters are shown in Exhibit 1. The mathematical relationship is $BA = TPA(QMD^2 / x 0.005454)$ where BA = basal area, TPA = trees per acre and $QMD^2 / =$ quadratic mean diameter.

The reference level referred to as the average maximum density and the stocking levels fitted to the background chart will vary by species, plant community, forest cover type, habitat type, and site productivity.

SEE PAPER COPY FOR EXHIBIT 1

9.1 - Stocking Guide Development

9.11 - Existing Regional Stocking Guides

9.11a - Procedure

Regions shall send current stocking guide information; trees per acre (TPA), quadratic mean diameter (QMD), or basal area per acre (BA) to TM Mensuration Unit in Fort Collins. The TM Mensuration Unit in Fort Collins shall:

1. Review the information and either accept it or contact the Region for clarification or additional information.
2. Plot stocking level curves.
3. Send the resulting charts to the Region for review.

Regions shall review draft stocking charts and approve or request changes. After regional acceptance of the charts, the TM Mensuration Unit in Fort Collins shall distribute them for Regional issuance as supplements to this handbook.

9.11b - Format

The standardized format for stocking charts is shown in Exhibit 1.

1. Format requirements for the charts are:

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- a. Quadratic mean diameter (QMD) shall begin at 2 inches if data is available and range to the diameter anticipated at final harvest.
 - b. For most long rotation forest cover types diameter intervals shown will be 1 inch for QMD's less than or equal to 14 inches and 2 inches for a QMD's above 14 inches.
 - c. Two charts will be needed for most forest cover types managed for sawtimber, a small tree chart and a large tree chart.
2. Information requirements:
- a. Identify the site index range and/or habitat type(s) applicable to the chart.
 - b. Reference the source of stocking information and identify the submittee.
 - c. The breakpoint between the small diameter and large diameter tree charts may vary by forest cover type within Regions and also may vary between Regions.
 - d. The average maximum density which should serve as the reference level for all forest cover types.
 - e. The upper and lower level management zone lines are highly desirable for forest planning and field use.

Research will assist in the development of reference curves where information is lacking or inadequate. The relative stand density curves are optional.

SEE PAPER COPY FOR EXHIBIT 1

9.12 - New Regional Stocking Guides

Regions shall send stocking level equation and data sources to WO TM Mensuration Unit in Fort Collins. An equation is preferred with basal area as the dependent variable and quadratic mean diameter as the independent variable. An alternative equation using trees per acre in place of basal area as the dependent variable is acceptable.

Equations should be provided for the average maximum density and management zone curves for each forest cover type important to the Region. The equations should apply to stands with QMD's of 2 inches to the diameter anticipated at final harvest. These equations should be based on growing stock level studies or reliable stand examination information.

Stocking level curves are plotted from the equations and sent to the Region for review and acceptance. Finalized charts are placed in this handbook.

9.2 - Use of Stocking Level Charts

Forests shall use the stocking level charts to evaluate the adequacy of stocking in existing stands and for planning intermediate treatments. An existing stand can be evaluated against the stocking charts by use of any two out of the three stand attributes; trees per acre, QMD, or BA.

To determine QMD:

1. Fixed Area Plots

- a. Sample the diameter of all trees 1 inch dbh (diameter breast height) and greater.
- b. Square and sum the diameters.
- c. Divide the sum by the total number of sample trees. The square root of this number is the QMD.

2. Variable Radius Plots

- a. Record number of sampled (in) trees 1 inch dbh and greater by diameter classes.
- b. Increase the number of sampled trees in each diameter class by the basal area factor for that class.
- c. Divide the expanded number of trees in each diameter class for all plots by the number of plots to obtain the average number of trees per acre for each diameter class.
- d. Square the diameter for each diameter class.
- e. Multiply the squared tree diameter by the number of trees per acre in each diameter class.
- f. Total all the squared tree diameters.
- g. Divide this number by total trees per acre. The square root of this number is the QMD.

QMD and mean stand diameter (D) for even-aged single species stands are nearly the same, but the QMD is slightly larger. In mixed species even-aged stands the difference between QMD and D is greater because of more variation in tree diameters.

Examples 1 and 2 illustrate the uses.

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Example 1: When the intersection of two attributes (BA = 81 square feet and QMD = 4.6 inches) occurs within the management zone (Exhibit 1, point A), the stand has the desired stocking provided the trees are evenly distributed within the stand. If the intersection of the two attributes (BA = 82 square feet and QMD = 3.6 inches) is above the upper level of the management zone (ULMZ) curve (Exhibit 1, point B), the stand is over stocked and should be thinned. If the stand attributes (BA = 67 square feet and QMD = 5.5 inches) intersect below the lower level of the management zone (LLMZ) curve (Exhibit 1, point C), the stocking is lower than required to meet the management objective and replacement or supplemental stocking of the existing stand is desirable or "no treatment" to allow stand to grow into desired stocking range.

Example 2: The intensity of thinning in an existing stand depends on the management objectives (see Exhibit 2). A heavy thinning can bring the stand down near or if not carefully prescribed below the LLMZ (B1 or B2). The latter result may not be desirable since the stocking is reduced below the LLMZ which will result in reduced timber production. The QMD of the stand can be raised or lowered depending on the size of trees targeted for thinning (B3 or B4).

SEE PAPER COPY FOR EXHIBITS 1 AND 2