

A MODEL OF THE TAPPING ZONE

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This article is intended to accompany the Tapping Zone Model available to download at the University of Vermont Proctor Maple Research Center (UVM-PMRC) website. It provides a general explanation of the model and how it can be used.

MODEL OVERVIEW AND BACKGROUND INFORMATION

The tapping zone of a maple tree is defined as the area around the circumference of the stem that can be utilized for sap collection. For sap collection with tubing, it can be thought of as a radial band of wood based at the point on a tree where the dropline meets the lateral tubing of the sap collection system. The physical boundaries of the tapping zone are defined by the depth of the taphole, the length of the sap dropline, and the circumference of the tree (Figure 1).

Each year, tapping for sap collection not only permanently removes a small amount of wood from the taphole itself, but, in addition, the tree's response to the taphole wound¹ generates a "stained" column of wood extending above and below the taphole that remains permanently nonconductive to sap (Figure 2). However, stem growth also adds new conductive wood to the outside of the tree each year. This outward growth functionally shifts the tapping zone outward over time so that some of the nonconductive wood generated by previous tapping is embedded deeper into the tree and is thus no longer within the tapping zone boundaries. Thus, the volume of the tapping zone of a particular tree, and the relative amounts of conductive and nonconductive wood within it over time, are dependent on the tree's size and growth rate, as well as tapping practices - tapping depth, spout size, dropline length, and the number of taps.² And, these volumes can be calculated for any given time using these input parameters (Figure 3). Based on these premises, we developed a model that calculates the proportions of conductive and nonconductive wood in the tapping zone of a tree over time given user-input values for tree diameter and tapping practices. (The model is described in greater detail on the following page.)

¹The response of trees to wounding is termed "compartmentalization", and is aimed primarily at reducing the ability of disease causing organisms to spread throughout the tree.

²It is worth noting that neither vacuum, nor the date of tapping or date of spout removal (assuming spouts are removed at some point in the late-spring or early-summer) affect the volume of nonconductive wood.

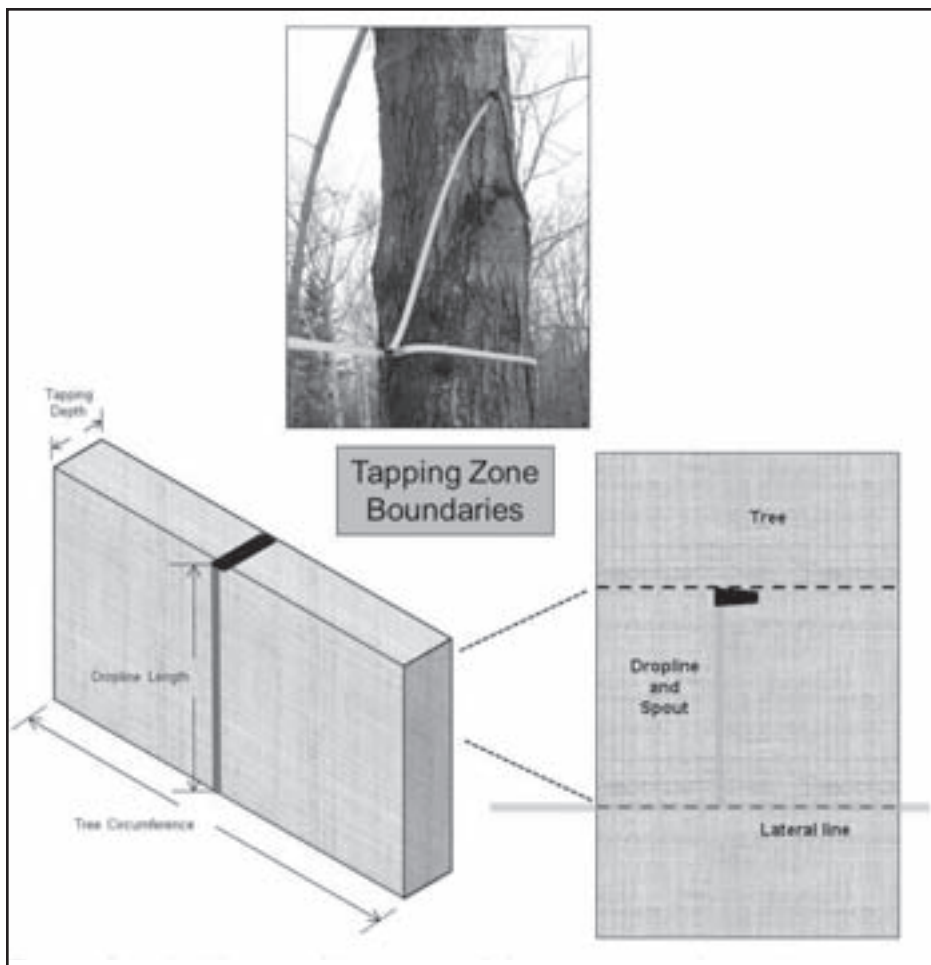


Figure 1. Generalized illustration of the "tapping zone" of a maple tree tapped for sap collection, the portion of each tree accessible for annual tapping to collect sap. The dimensions of the tapping zone are defined by the circumference of the tree, the length of the dropline, and the depth to which the spout is inserted.

Nonconductive wood ("NCW") is generally brownish in color, and can be observed in cross-sections (cookies) or lateral sections (boards) of cut trees (Figure 2), and detected as relatively dry, brown wood chips when a damaged area is inadvertently drilled into during tapping (Figure 4). Tapholes drilled into NCW will produce little or no sap, and an excessive buildup of NCW can affect the physiological functioning of water transport and negatively impact tree health. The total proportion of the tree's tapping zone that is comprised of this NCW will determine how frequently it is hit during tapping - if 20% of the wood in the tapping zone is nonconductive, there is a 20% chance of hitting NCW when tapping that tree. Thus, the aim is to maintain the proportion of NCW at

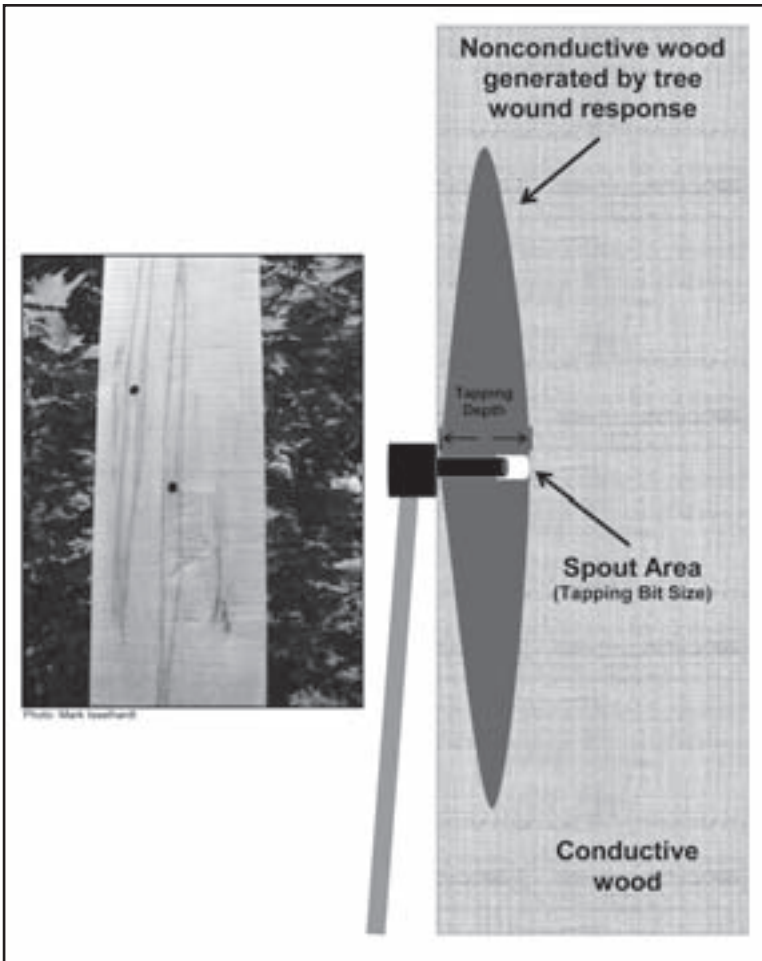


Figure 2. Photo (left) and generalized illustration of the volume of nonconductive wood generated by each taphole (right). The volume of wood removed by each taphole is defined by the depth and area of the hole drilled for tapping (the area is determined by the size of the drill bit and the spout used). As part of the wounding response of the tree, tapping also generates a column of nonconductive wood surrounding the hole such that the total volume of wood rendered nonconductive by each taphole is between 50 and 150 times greater than the amount removed by the taphole.

levels as low as possible (and, conversely, the proportion of conductive wood as high as possible). The relative frequency at which brown wood is encountered during tapping also provides an indication of the level of tapping intensity - hitting NCW frequently generally indicates that tapping intensity is too heavy, and that practices should be modified to reduce NCW generation and to allow more conductive wood to develop. The model estimates the proportions of conductive and nonconductive wood in the tapping zone; thus, the

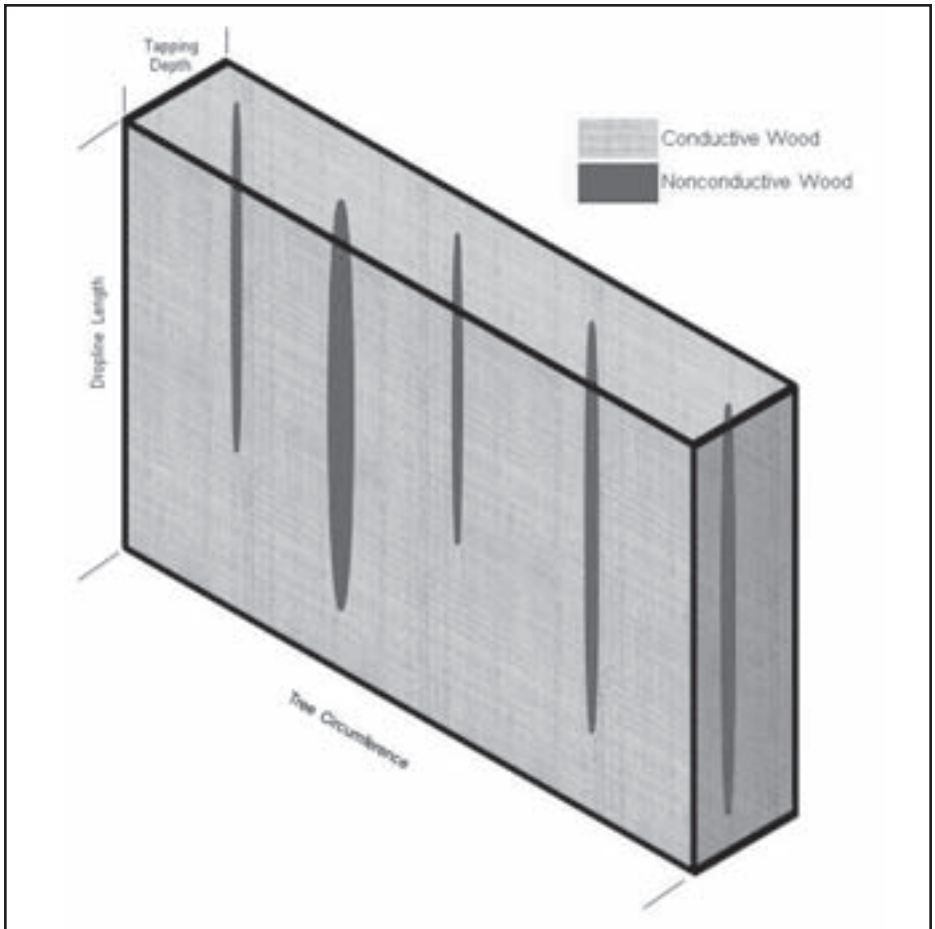


Figure 3. Illustration of the conductive (tan) and nonconductive wood (red) within the tapping zone of a tree. At any point in time, the total amount of nonconductive wood within the tapping zone is the total volume of nonconductive wood within the zone's boundaries from all previous tapholes. The remainder of wood in the zone is the portion of conductive wood available for tapping. The proportion of the tapping zone comprised of conductive wood is equivalent to the probability of tapping into conductive wood annually.

model can be used to estimate the chances of hitting conductive and nonconductive wood when tapping, and this can be used to assess the sustainability of current or planned tapping practices.

MODEL DETAILS

The model calculates the proportions of conductive and nonconductive wood in the tapping zone of an individual tree each year for 100 years. Values for the following initial parameters must be entered: starting tree diameter, tap-

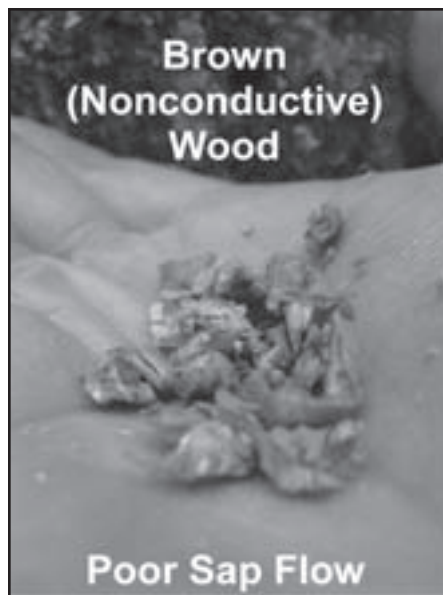


Figure 4. Wood chips from tapholes drilled into conductive wood (left) and nonconductive wood likely from an old taphole (right).

ping depth, spout size, number of taps per stem, and dropline length. If applicable, the number of years the tree has already been tapped with the given practices can be entered (up to 100 years).³

For each year, the model first calculates the total volume of wood in the tapping zone. For smaller trees, this value is equal to the tree's circumference multiplied by the length of the dropline and the tapping depth (Tree Circumference \times Dropline Length \times Taphole Depth) (Figure 1). For larger trees, where the dropline cannot reach fully around the tree, the boundaries of the tapping zone are constrained to a smaller area of the tree's trunk. In these cases the tapping zone is limited to the half-circle made by the dropline, and its volume is calculated as: $(\pi \times \text{Dropline Length}^2)/2 \times \text{Tapping Depth}$.⁴

The model also calculates the volume of nonconductive wood generated by each annual taphole. This volume is equal to the volume of the taphole itself (which is equal to the area of the hole drilled for the spout multiplied by the tapping depth) plus the volume of the column of nonconductive wood that forms as a result of the taphole. The volume of the taphole is multiplied by a "Staining Multiplier" to account for the size of the column. Previous studies

³The model does not currently allow changes in tapping practices to be made during the 100-year period.

⁴This is also why the graph of the model output sometimes shows a discontinuous line over time - the break indicates the point when the tree reaches a size at which the dropline is no longer able to reach around the tree, and the tapping zone is limited to the arc made by the dropline.

conducted at UVM-PMRC indicate the size of this column can range from 50 to 150 times the size of the taphole (and can actually extend beyond the area of visible discoloration). The model uses 75 as a conservative estimate. The formula used to calculate the total volume of nonconductive wood generated by each taphole is thus: Spout Area × Tapping Depth × "Staining Multiplier".

The volume of the tapping zone depends in part on the circumference of the tree, which will increase each year due to new radial (diameter) growth. The model uses average growth rates to calculate the volume of new wood added to the tree each year, and the tree's new circumference.⁵ These growth rates are also used to calculate the amount of NCW from each old taphole that is "removed" from the tapping zone as the new diameter growth shifts the zone outward.

The default values of the model parameters are set to match those of the Conservative Tapping Guidelines from the 2006 North American Maple Syrup Producers Manual (Chapeskie et al. 2006). These guidelines specify a minimum tree diameter of 12", a tapping depth between 1-2", a minimum dropline length of 30", and a maximum spout size of 5/16" (19/64").

MODEL OUTPUTS

Probability of Tapping Conductive Wood

The model calculates the total volume of NCW in the tapping zone each year by summing the individual volumes of NCW from all tapholes present at that time (Figure 3). Likewise, the total volume of conductive, clear wood is calculated by subtracting the amount of NCW from the total volume of the tapping zone. Finally, for each year, the model calculates the proportion of the tapping zone that is comprised of conductive wood by dividing the total volume of conductive wood by the total volume of the tapping zone. The result represents the probability of tapping clear, conductive wood in that tree each year. The model performs this calculation for every year over a 100-year period (as the tree grows), and assumes tapping practices remain the same during that period. The graph illustrates how this value changes over time.

Lowest Proportion of Conductive Wood

⁵The average growth rates the model uses for these calculations are derived from data collected from approximately 500 healthy sugar maple trees with dominant or codominant canopy position, ranging from 8 to 20" in diameter. They had been tapped for at least 5 years with current sap collection practices and a single tap, and were from 18 stands in VT with good site quality for maple growth. The average 5-year (2006-2009) growth rates were determined for six DBH classes (8-10, 10-12, 12-14, 14-16, 16-18, and 18-20"), and were used to generate a best-fit regression equation to estimate the relationship between tree dbh and growth rate ($y = -0.0024x^2 + 0.6435x - 4.2231$, $r^2=0.99$). Because tree growth rate varies with tree size, the model uses this equation to adjust the growth rate of the tree over time as it increases in size. Growth rates and compartmentalization of other maple species and for sugar maple trees growing in conditions different than those of the trees studied here can vary considerably.

The model also calculates the lowest proportion of conductive wood likely to be present in that tree tapped with those practices over the 100-year period. As discussed previously, this proportion should remain as high as possible in order to support both tree health and sap yields. Based on consultation with producers and maple researchers, we recommend this level remain at or above 90%. This would be equivalent to a likelihood of hitting conductive wood in 9 out of every 10 trees when tapping (assuming all trees were the same size and tapped with same practices input into the model). Depending on your preferences, you might choose to aim for practices that result in an even higher level, e.g. >95%.

USING THE MODEL

The model estimates the proportion of conductive wood in the tapping zone of a tree with the specified size and tapping practices for each year while the tree grows, the volume of the tapping zone increases, new wood is added to the tapping zone, brown wood from old tapholes grows out of the tapping zone, and new NCW is generated by annual tapping.

You can use the model to examine the effects of tree size and of altering tapping practices on the amount of conductive wood in the tapping zone over time, and thus to evaluate the potential sustainability of various tapping practices. In general, for model scenarios in which the "Probability of Tapping Conductive Wood" remains above 90%, the practice can be considered "sustainable". If the probability drops below 90%, especially if it stabilizes below that level for a considerable time, then sustainability may be compromised.⁶

The model also provides some insight into practices that have particularly strong impacts on the buildup of NCW in the tapping zone. For example, the model can be used to illustrate how the length of droplines influences the accumulation of NCW. This is because the dropline is a factor that determines the total size of the tapping zone - the longer the dropline, the greater the tapping zone volume, and the smaller the resulting proportion of the zone taken up by each old taphole. Figure 5A shows the model output for a 12" tree tapped following current Conservative Tapping Guidelines - using a 30" dropline and 5/16" spouts at a depth of 1.5" (Chapeskie et al. 2006). Reducing the length of the dropline to just 20" results in the proportion of conductive wood dropping below 90% after just 15 years of tapping (Figure 5B). Similarly, the model demonstrates that using 7/16" spouts or tapping small trees, even while following all other conservative tapping practices, can also quickly result in an accumulation of NCW above sustainable levels after just a few years (Figures 6 and 7).

⁶Probabilities remaining below 90% for sustained periods are particularly problematic due to the fact that merging NCW columns typically result in higher NCW volumes than isolated columns alone. That is to say that the nonfunctional volume of merged columns is greater than the sum of its individual parts. The model does not account for this fact.

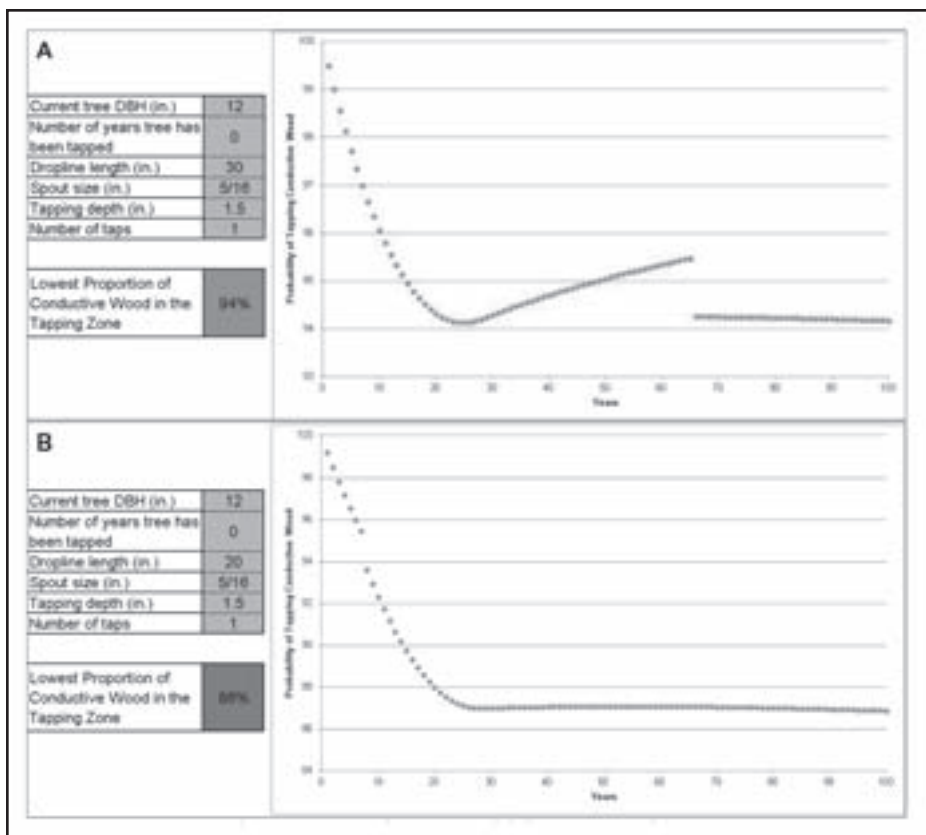


Figure 5. A) Example output from the tapping zone model showing the probability of tapping conductive wood and the lowest proportion of conductive wood in the tapping zone over 100 years for a 12" diameter tree tapped following current Conservative Tapping Guidelines (5/16" spouts, 1.5" tapping depth, 30" droplines). **B)** Example output for the same tree using shorter, 20", droplines.

The model was developed as part of a larger effort underway at UVM-PMRC to evaluate and revise existing tapping guidelines to incorporate the results of recent research, and particularly to ensure they are appropriate for current sap collection practices that facilitate much higher sap yields than those achievable using past collection methods. The new guidelines will aim to incorporate the results from research on the effects of tapping practices on both sap yields and tree health, as well as to reflect a balance between costs and benefits of various practices. The new guidelines will be included in the upcoming 3rd Edition of the North American Maple Syrup Producers Manual, which is expected to be published in 2016.

If you have any questions about the model or interpreting its output, please contact Dr. Abby van den Berg (Abby.vandenBerg@uvm.edu)

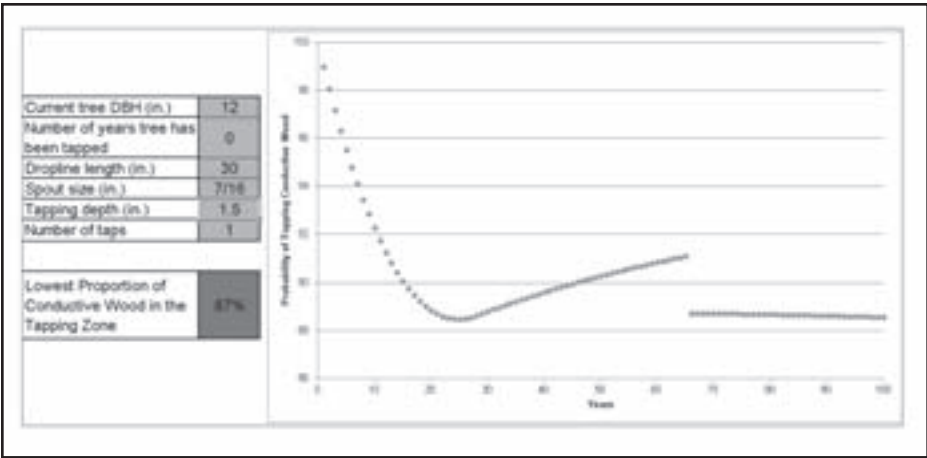


Figure 6. Example output from the tapping zone model for a 12" diameter tree tapped following current Conservative Tapping Guidelines (1.5" tapping depth, 30" droplines), but using 7/16" spouts. Note that the proportion of conductive wood falls below the 90% threshold in less than 20 years.

SOME IMPORTANT NOTES:

This model is a work-in-progress, and will be updated over time as refinements are made. Check the UVM-PMRC website frequently for updated versions and information.

This model provides only estimated values. It should be used only as a general tool to help evaluate current or potential practices. It is not a substitute for a thorough evaluation of tree health or growth rates.

The model makes several assumptions and has some limitations that should be noted. It does not account for decreases in growth rates that might occur as the result of tree ageing, changes in site conditions or management practices, or events such as drought or disease. It also assumes that all other best practices are being followed (Chapeskie et al. 2006). The model calculations are based on the growth rates of healthy trees with dominant or codominant canopy position growing on good quality sites that were between only 8 and 20 inches in diameter and had been tapped with only a single tap. The model estimations are thus less reliable for trees tapped with 2 taps or trees that are larger or smaller than 8-20" dbh. The model should not be used to estimate values for trees that are growing on sites with poor or below average site quality, have suppressed or intermediate canopy position, or those that are stressed or unhealthy or have below average or poor growth rates.

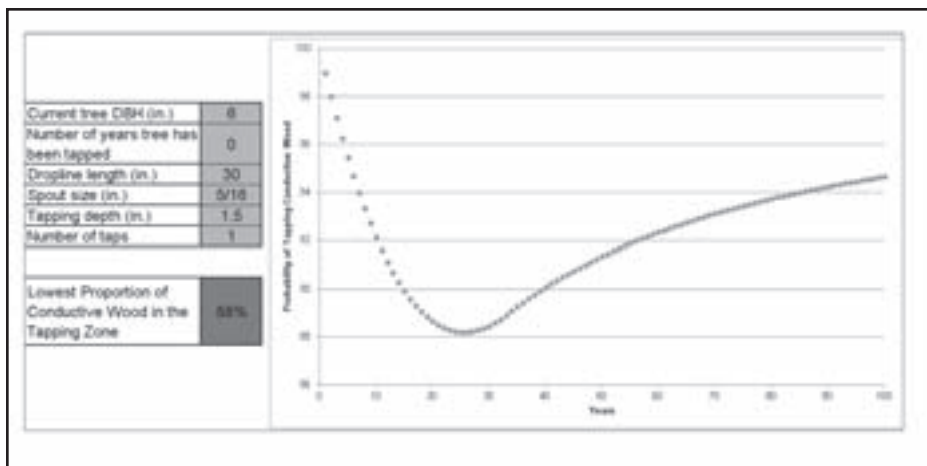


Figure 7. Example output from the tapping zone model for a 6" diameter tree tapped following current Conservative Tapping Guidelines (5/16" spouts, 1.5" tapping depth, 30" droplines). Note that the proportion of conductive wood falls below the 90% threshold in less than 20 years.

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