UNIVERSITY OF GEORGIA
Warnell School of Forestry & Natural Resources

Publication WSFNR-21-52C

June 2021

Assessing Tree Pruning Dose & Damage

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The act of pruning is a stressful and stunting process for a tree. Knowing how much (dose) to prune, as well as how much damage a tree has sustained, has been left to the experienced eye of a tree health care provider. Many trees are being over-pruned and damaged in each pruning cycle. More careful and quantitative pruning assessments are needed.

Pruning can also be a point of liability risk to practitioner and client. Wounds open trees to colonization by a myriad of organisms, to environmental problems, and to structural integrity losses from setting of defensive boundaries. Mechanical damage is one of the worst forms of damage with which a tree must biologically deal.

Pruning Wounds

Pruning, following standards and best management practices, and abusive cutting and trimming, all generate wounds of various sizes and depths. Potential risks to health and structure of a tree from any given wound are dependant upon individual genetics, species, site, season, wound history, sanitation, and residual character of the wound.

For example, a properly pruned branch with a tree-side wound area having tight, unmarred bark and having an intact stem flange (branch collar), would be a good wound situation for a pruned tree. By comparison, a similarly sized wound between branch connections (an internodal cut) made with a saw which tears periderm, and a sawyer nicking remaining periderm areas, would be a bad wound situation for a pruned tree.

Four Assessments

To better understand and minimize damage to trees during pruning, several assessment systems were developed. These assessments are trying to maximize tree health and sustainability. Assessments given here include:

1. Mmissed targets pruning;
2. Crown raising amount per tree and pruning cycle;
3. Heartwood exposure (deep wound) number per pruning cycle; and,
4. Sapwood area proportions pruned.

Assessment #1 -- Missed Targets Pruning

The easiest of pruning assessments is examining current and past pruning wounds for overgrowing or closing growth (i.e. compartment 4 containment). This is an estimate of the capability for living tissues remaining after a cut to defend a tree. A strong compartmentalization response is essential to prevent compounding and collateral injuries at the pruning wound site.

Key to understanding a tree's defensive response is visualizing the conical shaped defensive zone behind the pruning wound face comprised of interlaced stem and old branch tissues. This defensive zone minimizes loss of valuable electrons from within living tissues (i.e. environmental oxidation), minimizes water loss, and resists attack from other organisms seeking entry into a tree. Figure 1 shows where a defensive zone is developed behind a pruning wound for a small diameter branch. Remember these two-dimensional diagrams are representing three dimensional, conically shaped volumes.

Flange To Conserve

A stem flange is blended tissues of stem and branch growing together at a branch base. The stem flange helps stitch the branch onto a stem. Figure 2. The outside edge of a stem flange can be identified both on top and bottom of a branch just as the branch enters a stem. The area of a stem flange represents a defensive zone for a tree and should never be breached.

The bottom branch-side edge of a stem flange can be seen as a slight swelling of tissues on the branch underside just before it enters a stem. Never nick or cut into this area. The upper branch-side edge of a stem flange can be seen outside the periderm (bark) chine (ridge) just before a branch enters a stem. The stem flange begins at a point just before the upper side of a branch base starts to swell or curve up forming a periderm chine.

Targets To Miss

Figure 3 shows a diagram identifying pruning targets on a stem - branch confluence. Never cut on the stem side of a periderm chine, on the periderm chine, or on the branch side swelling which pushes up into the periderm chine. These areas are composed of both branch and stem tissues. Never nick from either side the periderm chine as it is well within the stem flange area. Pruning should only remove branch tissue, not expose and damage stem tissues. In addition, do not generate incidental injures to a stem with the back of a saw.

Once branch pruning targets are identified, they are used to set the boundary and saw kerf line of a final pruning cut. Figure 4 demonstrates target pruning. On branches which have well established stem flanges, and are 1/3 to ½ the diameter of a stem where they are attached, a traditional target pruning cut is essential. Depending upon the size and weight of a branch, either a one-cut (small branches only) or three-cut pruning process can be used. A three cut method, sometimes called the Davey, Shigo, or target pruning cut, identifies specific structural targets in the stem flange area. In a three cut pruning system, the final pruning cut is always immediately outside the stem flange.

The defensive zone at the stem flange outer edge must be left intact and undamaged after a branch is removed. Some pruning tools tend to damage defensive zones and should not be used. A clean, relatively smooth and intact wood and periderm surface should remain after pruning. Periderm surrounding a wound site should be firmly attached and not scrapped or loosened. Sharp bypass-pruners and saws in good repair should be used for pruning cuts, never dull tools and anvil-type pruners.

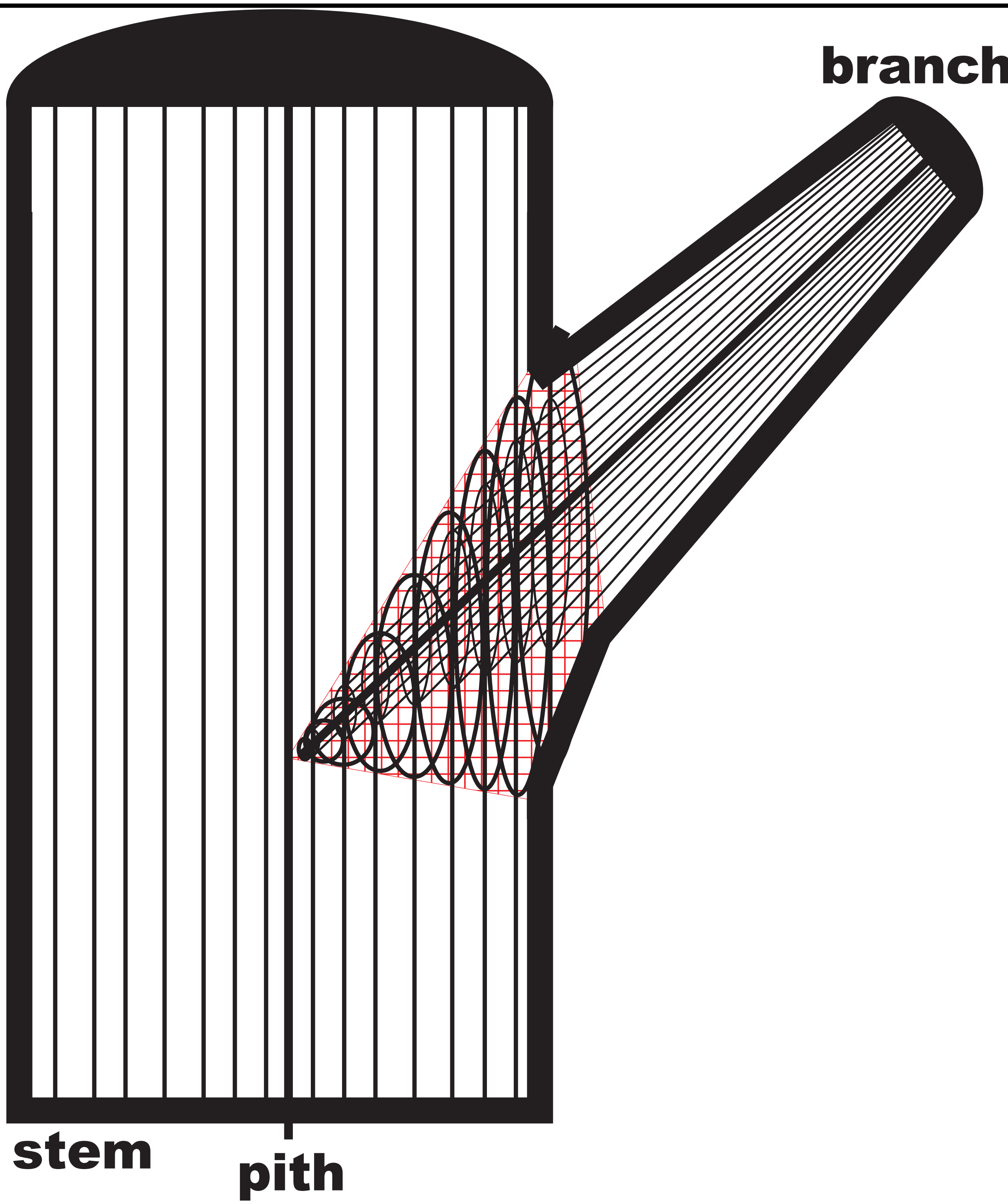


Figure 1: Diagram of stem - branch confluence area (stem flange) showing defensive zone (shaded), annual increments of tissues, and enveloping of branch tissues by stem tissues (ovals).

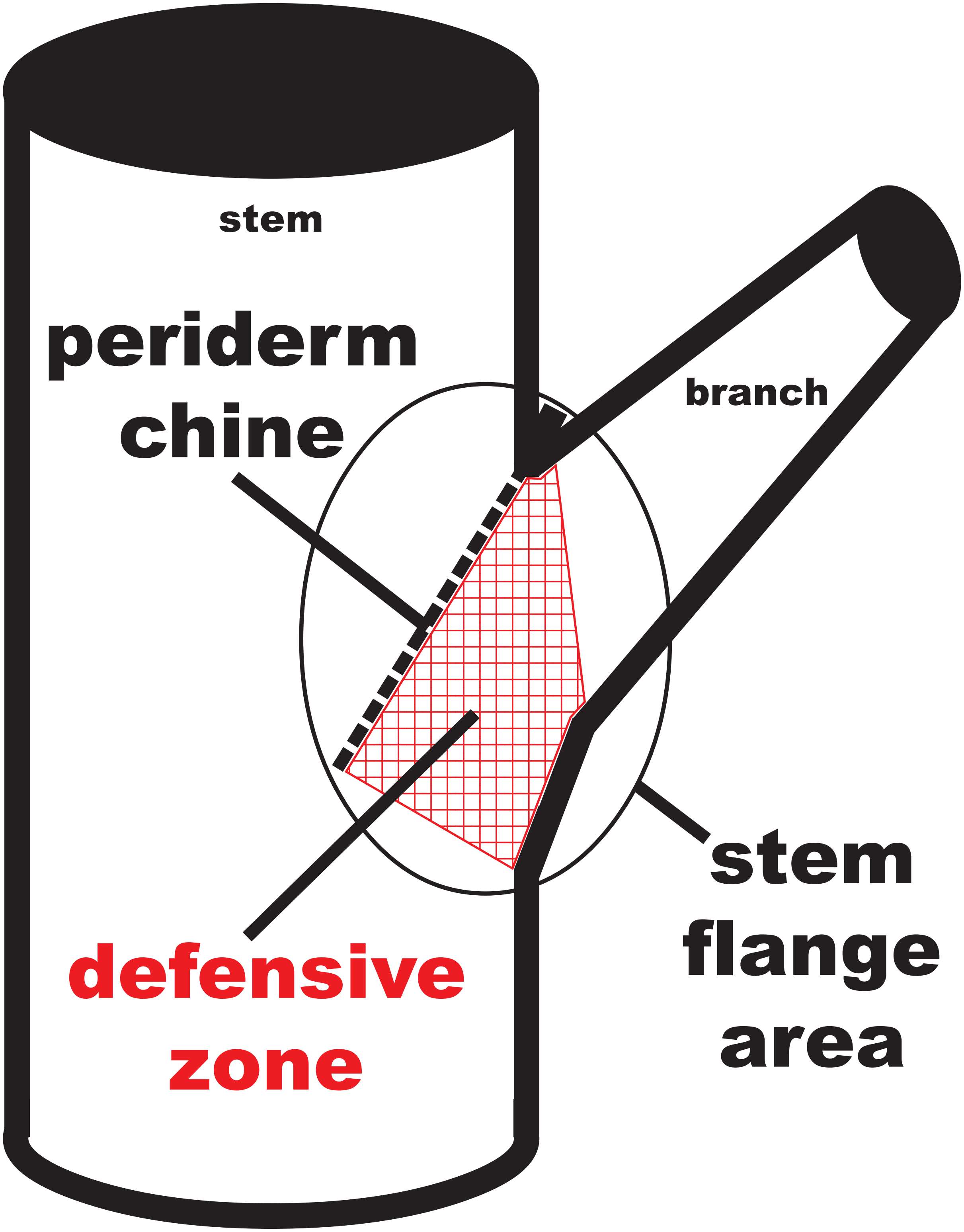


Figure 2: Stem flange or stem-branch confluence area showing periderm chine (bark ridge) and defensive zone (shaded) on a normally proportioned branch.

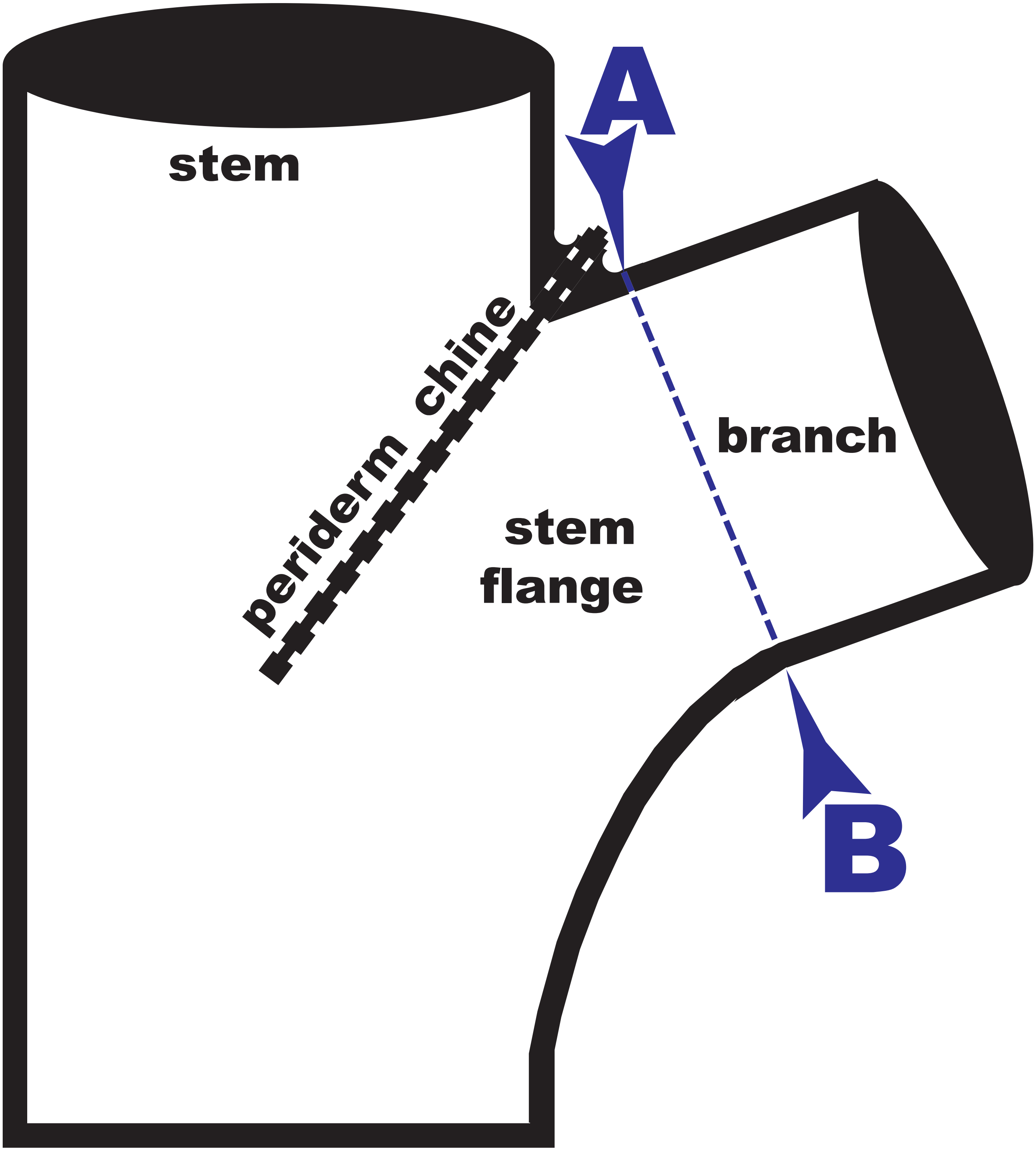


Figure 3: Stem flange area at stem - branch confluence.
A = branch side (outside) chine just before periderm curves up.
B = branch side (outside) of tissue swelling or gathering point on underside. Dotted line represents a branch removal edge just outside stem flange.

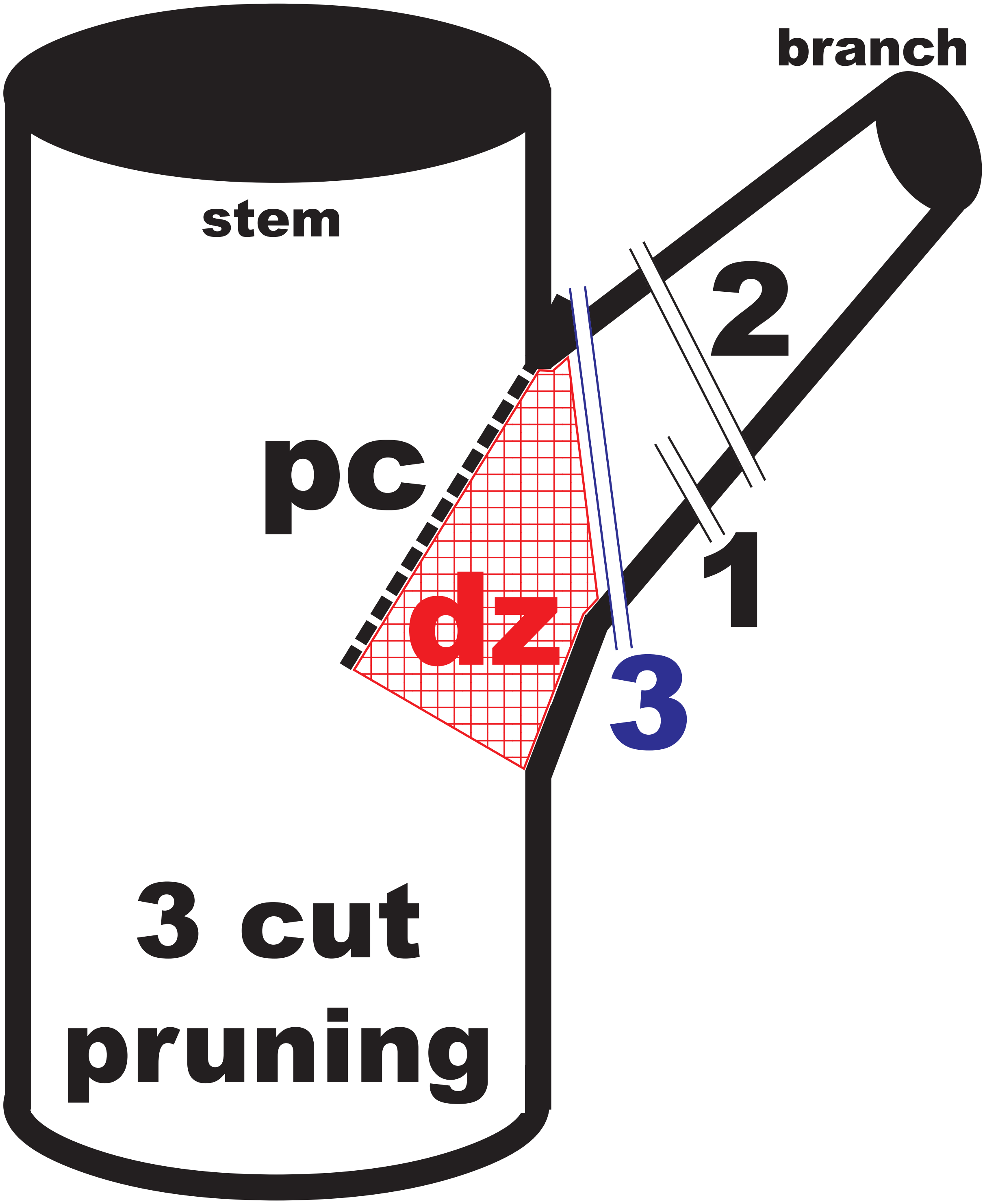


Figure 4: Diagram of stem - branch confluence area with a three-cut pruning prescription applied (in cut order) for a normally proportioned branch. Cut 3 is just outside the stem flange area. Defensive zone = dz. Periderm chine = pc.

Flush-n-Stub

Two abusive cutting techniques made by tree-illiterate people are flush cutting and stub cutting. Flush cutting removes branch tissue and the stem flange area vertically even (flush) with the stem surface. Figure 5. Flush cutting damages, at the very least, stem tissues above and below a pruning wound. Flush cut wound are significantly larger than needed for branch removal and are difficult for a stem to defend because defensive zone boundaries have been breached.

Stub cutting is topping (internodal cut) where a significant amount of branch tissue remains attached to a stem. Figure 6. As this branch stub dies, a large surface area and volume of dying tissue is exposed to the environment while physically interfering with a stem successfully growing over and sealing-off dead stub tissues.

Topping, or internode cutting is one of the most abusive biologically, damaging structurally, and disfiguring treatment applied to trees. Topping in all its many guises and fanciful names is an abomination on trees and people who care for trees. An internode cut is an untargetted and uneducated slice with a cutting tool. Figure 7. An internode cut is not made at a node where some defensive capabilities exist, but is made somewhere along an internode where damage can be severe and the wound poorly defended.
Figure 8 provides an example of a topping cut on a stem and a branch. Topping cuts are made with no care for survivability of the remaining tree, or for future health, structural integrity, or aesthetic value.

To summarize, a critical feature of proper pruning is to leave a defendable wound area. Flush cutting and leaving stubs of various lengths prevent effective defensive responses and leaves a tree open for other problems.

Wound Appearance

If the pruning targets presented at the stem-branch confluence site are recognized and conserved, a wound closure from all sides will develop. If the defensive zone is breached on any side, particularly top and bottom of the wound as occurs in flush cutting, wound closure will occur primarily from the sides pushing into the center. This wound closure pattern of tree-illiterate pruning will form a longitudinal line or crack. Figure 9. Compartment lines set around this abusive pruning wound can lead to a number of other aesthetic, structural and biological problems later on in the life of a tree, some life threatening. Proper wound closure is not a closed long crack, sometimes remaining perpetually open, but a single point soon grown over.

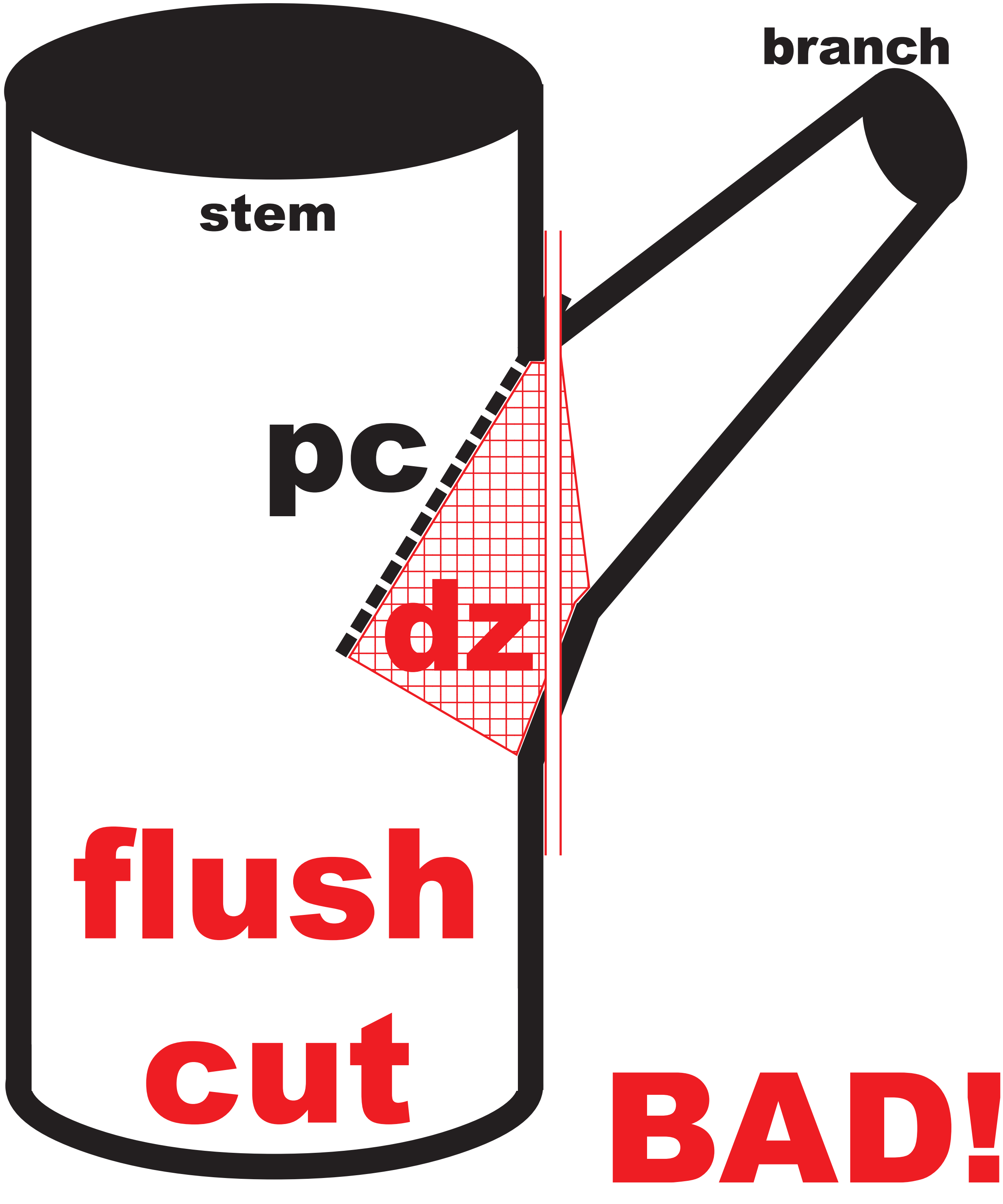


Figure 5: Diagram of stem - branch confluence area with an abusive, improper flush cut applied.
Defensive zone = dz. Periderm chine = pc.

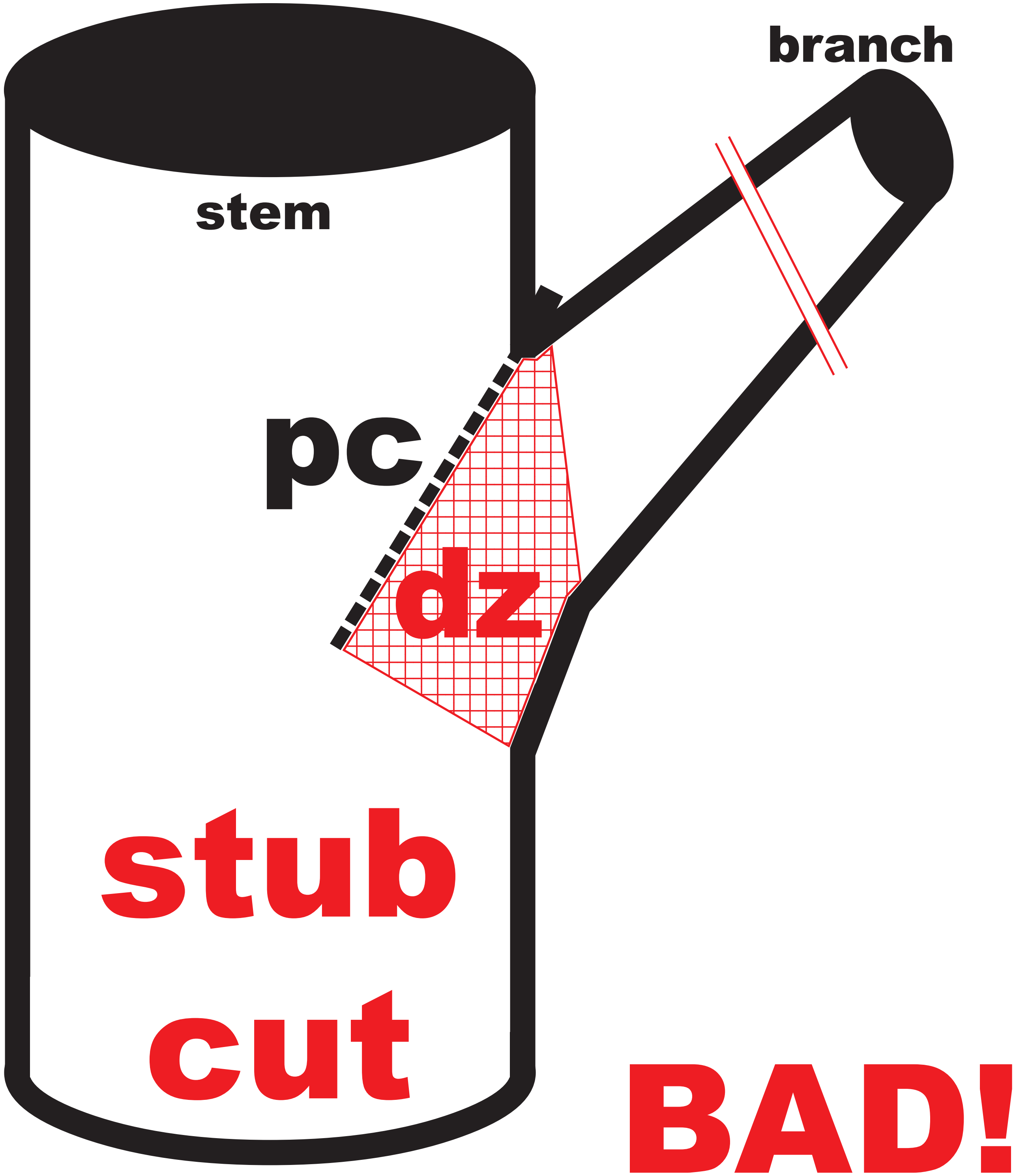


Figure 6: Diagram of stem - branch confluence area with an abusive, improper stub cut applied.
Defensive zone = dz. Periderm chine = pc.

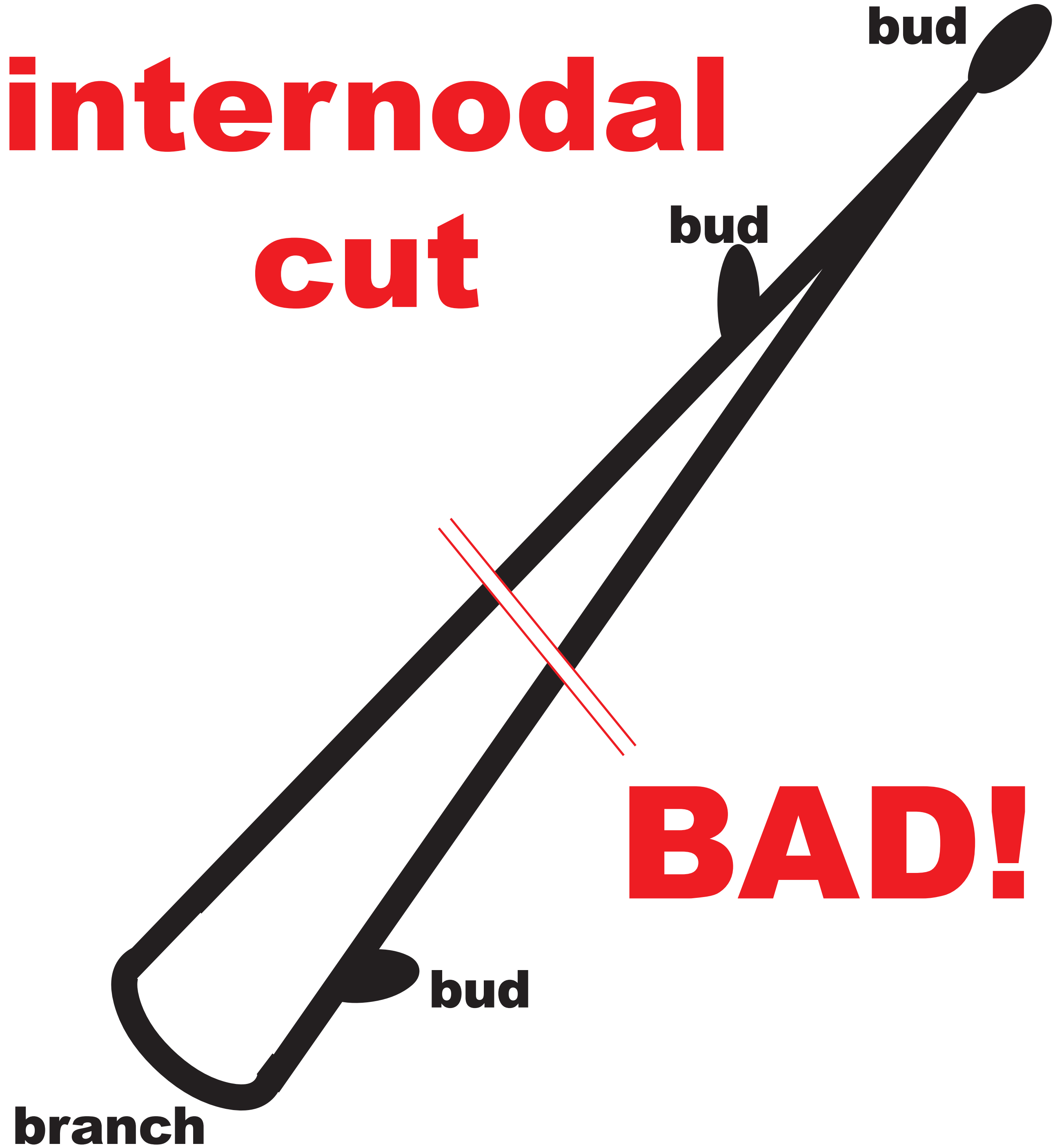


Figure 7: Diagram of abusive, improper, and damaging internode cut.

Figure 8: Diagram showing abusive and damaging topping (internodal) cuts on a stem and branch.

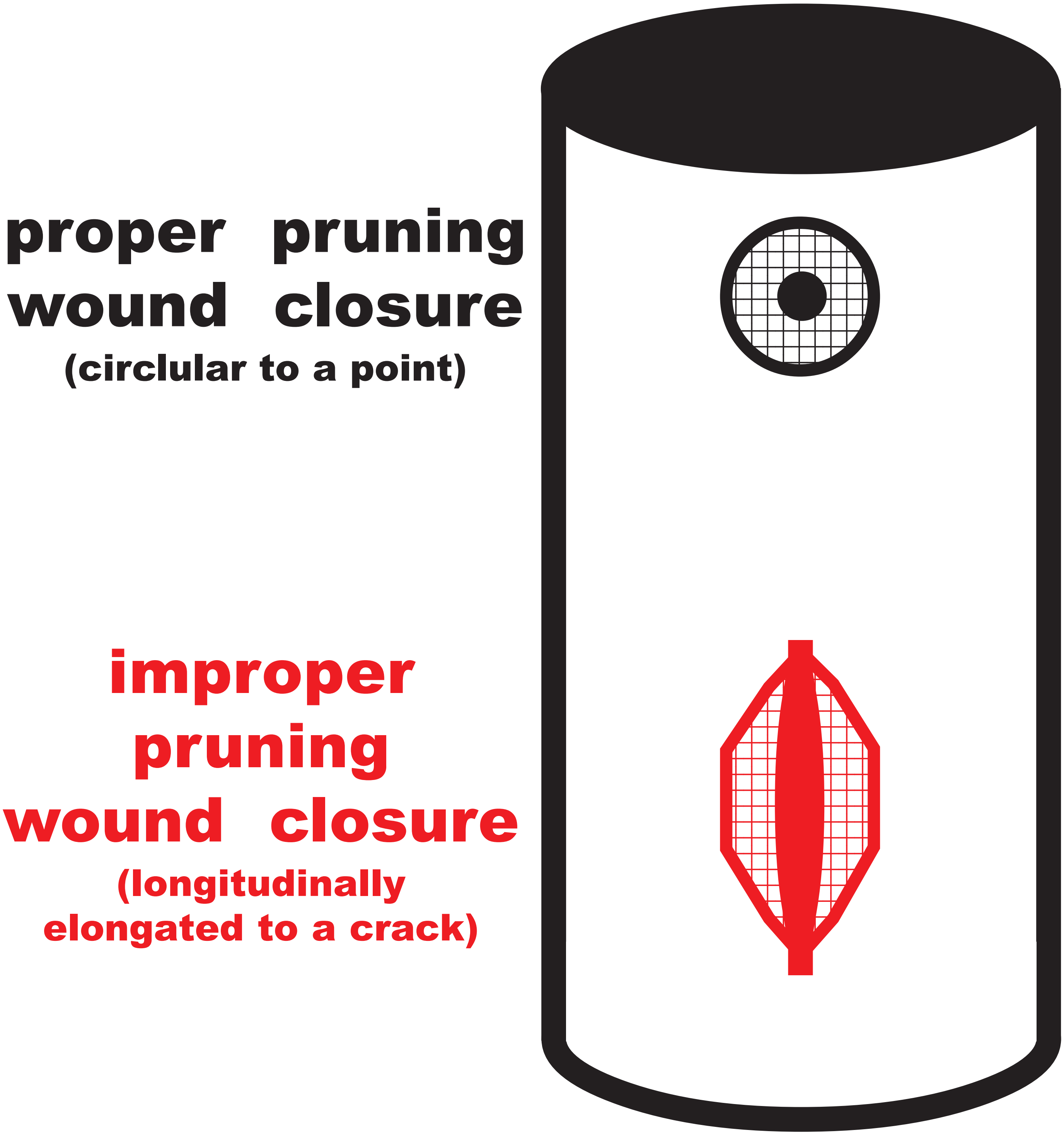


Figure 9: Diagram of pruning wound closure from a properly executed branch pruning cut (top), and an abusive, improper, to close to the stem flange flush cut (below), each made on a branch of the same diameter.

Assessment #2 -- Crown Raising Amount

For strong stems and branches, it is critical a living crown base is moved gradually up a stem over time. In some skirted tree species (live crown normally to ground level), a crown base never moves significantly. For trees with crowns raised to present a clear stem, a slow assent is needed to develop taper and resistance to bending and twist (torque). The position and movement of the live crown base is a key management marker in design of a strong and efficient tree. Changing or maintaining the live crown base is how tree health care specialists manipulate aesthetic values, structural integrity and biological efficiency in a tree.

Figure 10 provides the maximum crown raising for any given live crown ratio (i.e. Coder Crown Raising Dose Assessment). Note for trees with small live crown ratios, the maximum per pruning cycle raising which a tree can effectively adjust to is quite small on a height basis.

Small Changes

For example, a tree with 33% live crown should not be raised more than 1/16th (6%) of live crown per pruning cycle. The less crown, the less food and growth regulators generated, reducing the ability of a tree to react to change. Ideally, a healthy tree with a live crown ratio of 66% should be able to sustain up to 1/8 (~13%) of live crown removal in any pruning cycle. The larger the crown (and everything else being equal), the more accepting a tree is physiologically to productive crown loss. Healthy trees with 100% live crown ratios should be able to effectively react to crown raising up to 1/4 (25%) of living crown height in any pruning cycle.

The base of the living crown and its rapid diameter growth creates wood in positions to resist mechanical loads. Strong stem taper development is essential for allowing trees to withstand lateral wind loads and control sway. In addition, diameter of a tree must continue to grow at a much greater rate, in proportion to height growth, to maintain the same stem strength in resisting bending and twist. A key point is the live crown base must be allowed to develop a strong tree by building diameter and a well-tapered shape. Do not push crown raising too fast.

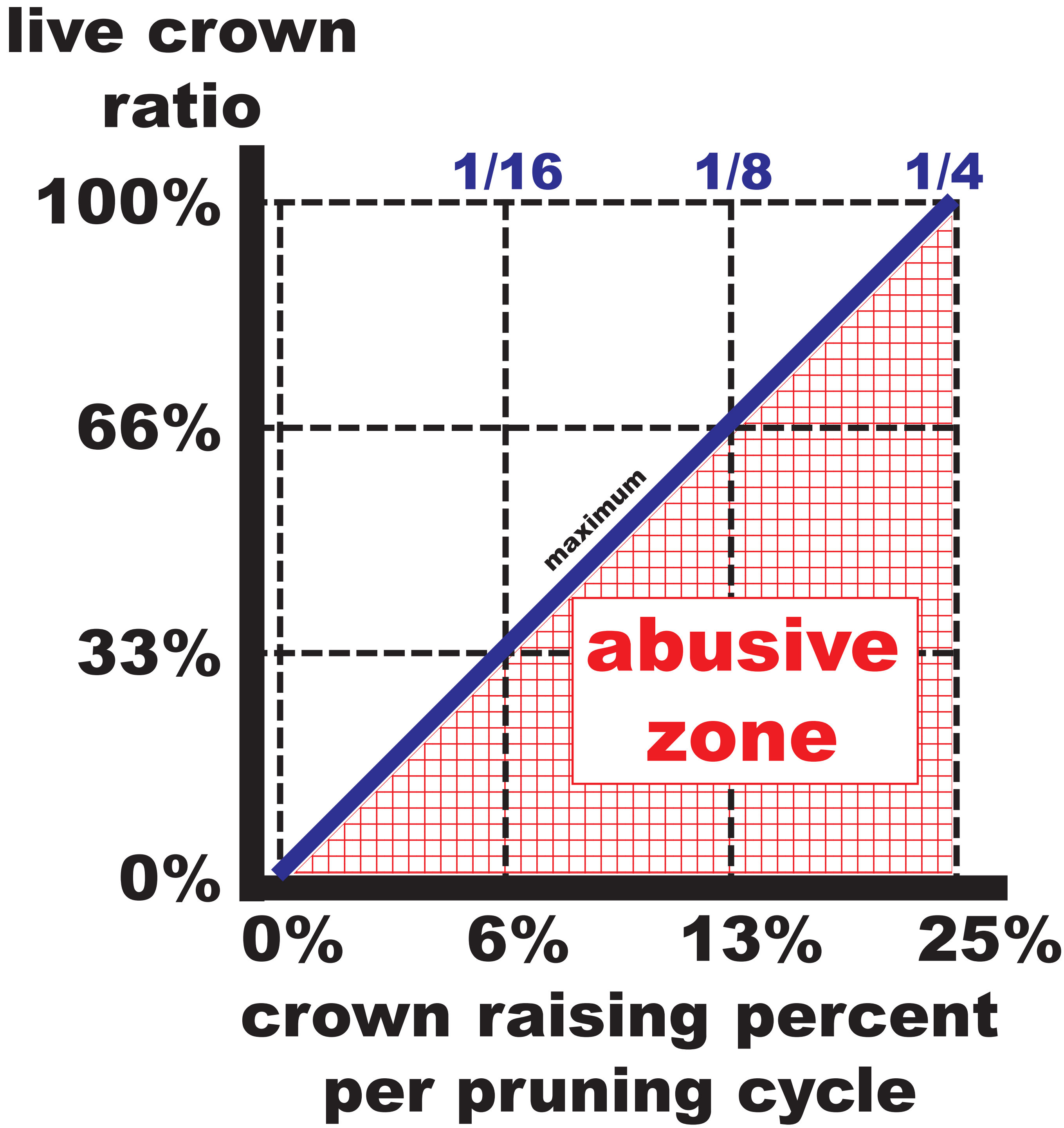


Figure 10: Coder Crown Raising Dose Assessment per pruning cycle demonstrating potential crown raising abuse. Graph shows percent of live crown (height basis) which can be removed, if warranted.

Assessment #3 -- Heartwood Exposure Values

Many examinations of pruning and mechanical injuries in trees have shown small, shallow wounds are much easier for trees to effectively react to than wounds small in area but deep. Many tree health care specialists have at times misinterpreted this research. Depth of injury is not about the number of inches into a tree which damage extends.

A deep wound is one that reaches into heartwood, whether the stem is three inches in diameter or thirty inches. Depth of injury in a tree concerns the number of annual growth increments breached and ability of surrounding cells to react to injury. Shallow wounds remain entirely surrounded by sapwood containing reactive living cells.

100% Sapwood

One of the most important issues in pruning is to always make cuts which cross 100% sapwood. (Note: Do not confuse a large pith with heartwood on smaller diameter branches.) Figure 11. Do not make cuts into or across heartwood, as this is a deep injury and difficult for a tree to react to effectively. Accumulation of repeated heartwood exposures on pruning wounds can be devastating over time.

It is not just large diameter branches, but all heartwood containing branches regardless of size which can present defensive problems for a tree. Even small, slow growing branches may have heartwood at their core, and exposing heartwood can signify long term structural and biological problems. Figure 12 provides a graphical definition of deep versus shallow – sapwood versus heartwood exposing -- pruning cuts.

Exposure of Heartwood

The Coder Heartwood Exposure on Pruning Wounds Assessment uses depth of pruning wounds, as shown on the tree side face of a pruning wound. In this assessment system, it is assumed proper standard pruning practices will be followed. Within standard pruning practices, heartwood and decay column exposure on the pruning wound face will be used to estimate potential damage to the health and structure of a tree now and into the future. It is critical assessors differentiate between heartwood and chemically altered wood areas (decay, discoloration, and defensive responses), and sapwood.

Basic tenets of this assessment system are: ("better" means potentially less damaging to a tree)

1) fewer wounds are better;
2) shallower wounds (fewer annual rings crossed) are better;
3) smaller wounds are better;
4) less heartwood exposed, which has limited defensive reactions and no living cells for sense or supply, is better; and,
5) fewer previous tree-set defensive boundaries crossed / exposed are better.

Wound Classes

Wound damage class is the amount of heartwood / discolored wood versus sapwood exposure on any pruning wound face. A key differentiation among wounds with heartwood exposure is the size of the heartwood column and whether other previously damaged or compartmentalized wood is present. A massive wound (Figure 13) is a pruning which cuts across decay columns, internally compartmentalized chemically altered wood, or cavities.

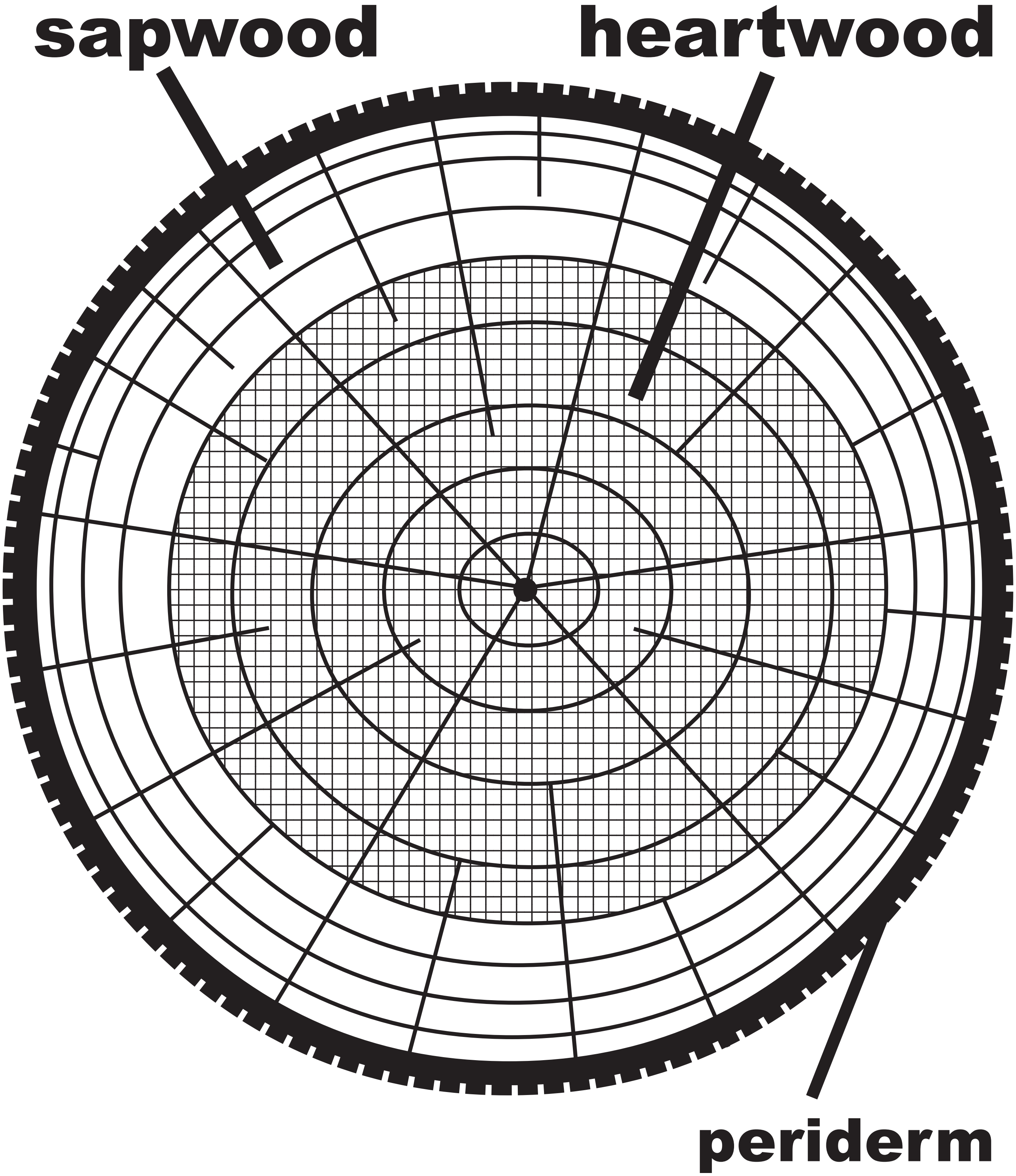


Figure 11: Diagram of a tree stem cross-section showing sapwood and heartwood (shaded).

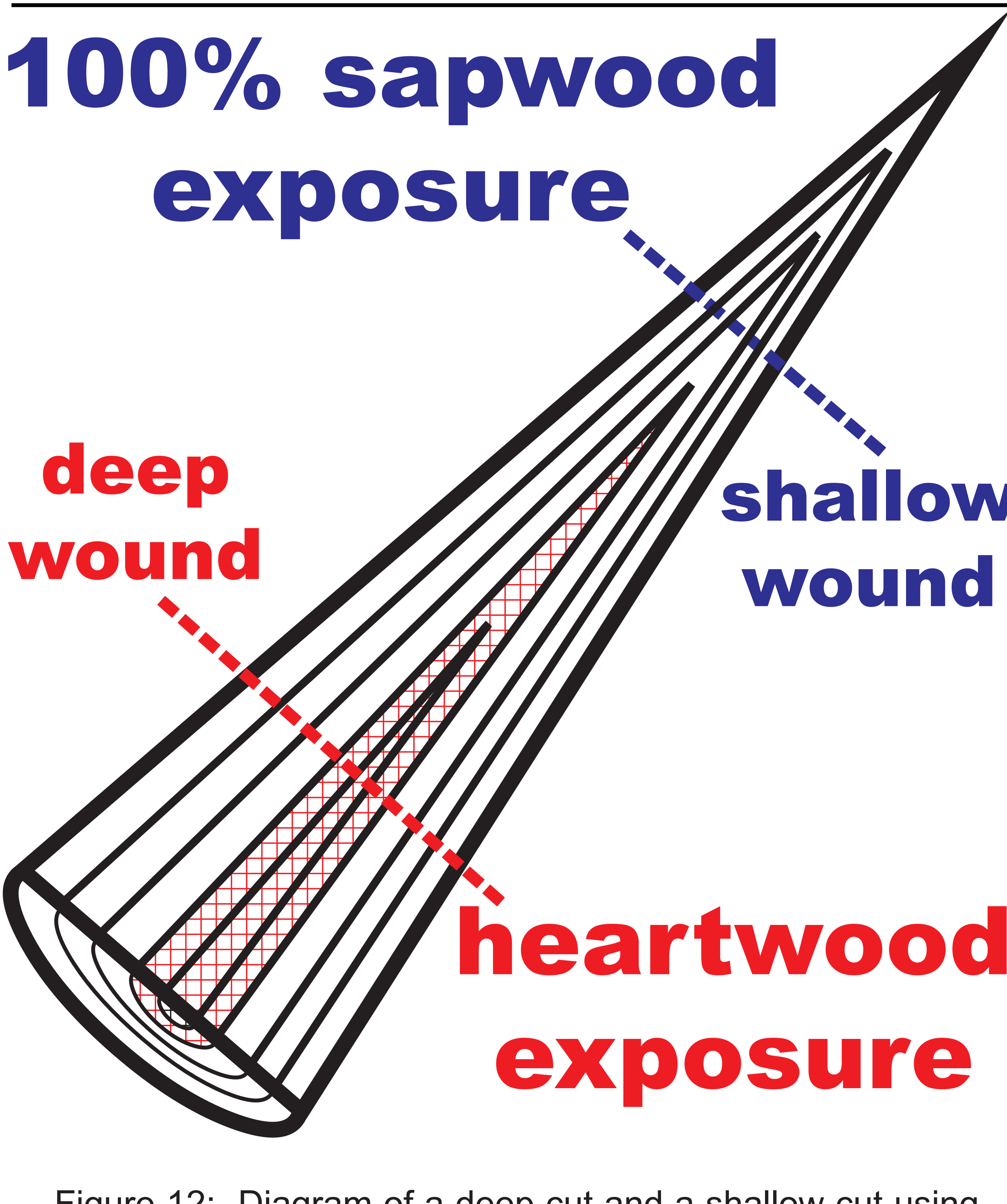


Figure 12: Diagram of a deep cut and a shallow cut using heartwood exposure to gauge relative wound depth.
Note it is assumed a proper nodal pruning cut will be made.

MASSIVE WOUND

crossing already developed decay & discolored boundaries

Figure 13: Coder Heartwood Exposure on Pruning Wounds Assessment for massive wounds.

The next two classes of heartwood exposure on pruning wounds requires an estimate be made whether heartwood column diameter takes up more or less than 25% of the diameter of a pruning wound face. Figure 14. A major wound (Figure 15) holds heartwood comprising more than 25% of the branch diameter. A large wound (Figure 16) holds heartwood comprising 25% or less of branch diameter.

The final two classes of heartwood exposure and wound type both contain 100% sapwood (no heartwood). The first is a standard pruning cut (Figure 17) leaving a wound on branches older than two years old clear of any heartwood exposure. The second is a minor pruning cut wound (Figure 18) on a 1-2 year old sprout with no heartwood exposure.

Wound Depth

Heartwood exposures, or functional depth of pruning wounds, in order of greatest potential damage to a tree to least are: massive, major, large, standard, and minor. Figure 19 provides a summary review of pruning wound damage classes. For each pruning wound class, this assessment provides a user with the maximum number of pruning cuts per wound damage class which should be made. Figure 20. One massive pruning cut has the same (if not more), damge potential to sustainability in a tree as 7 large pruning cuts. This system also provides a means of assessing pruning wounds already present in a tree.

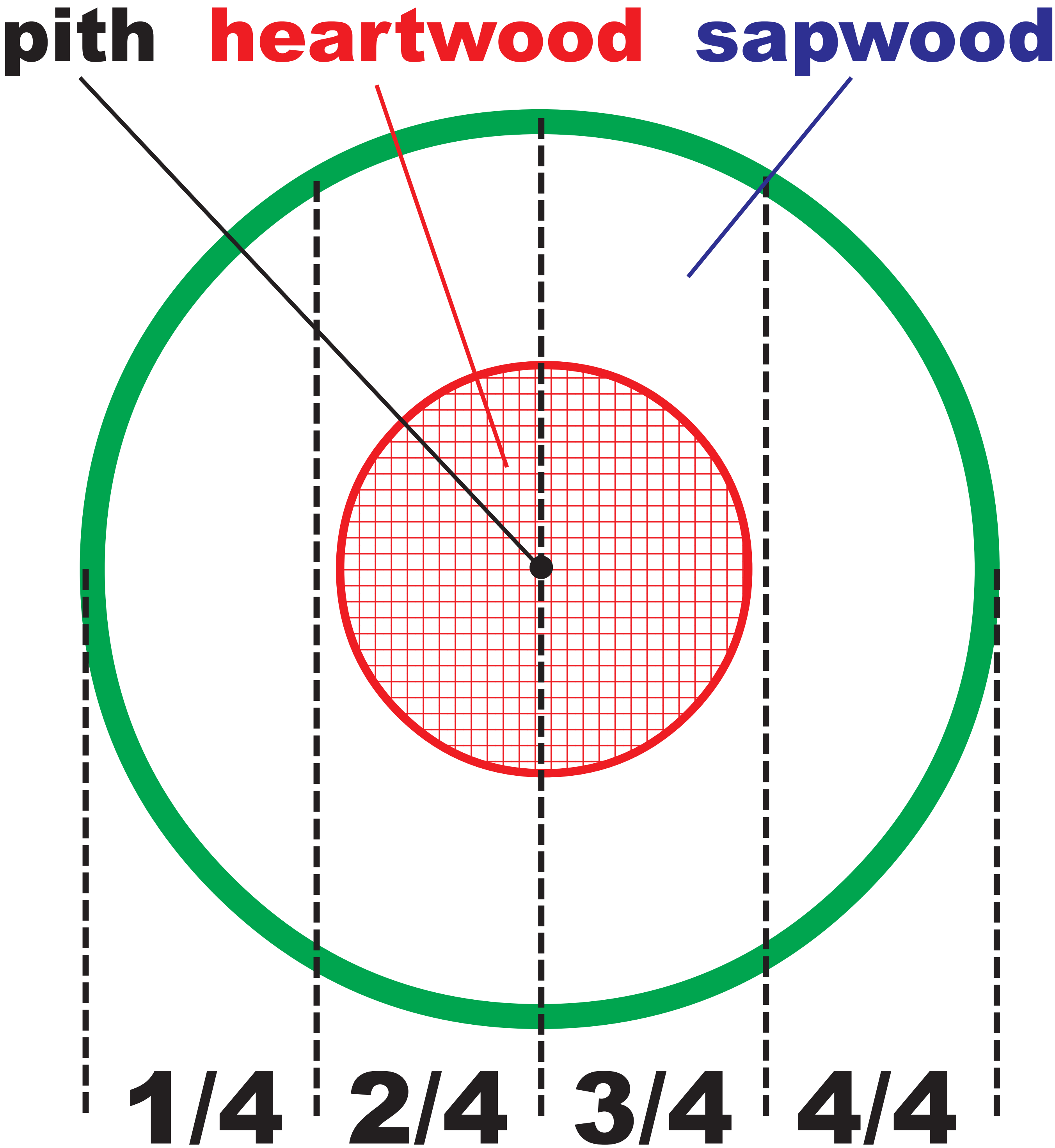
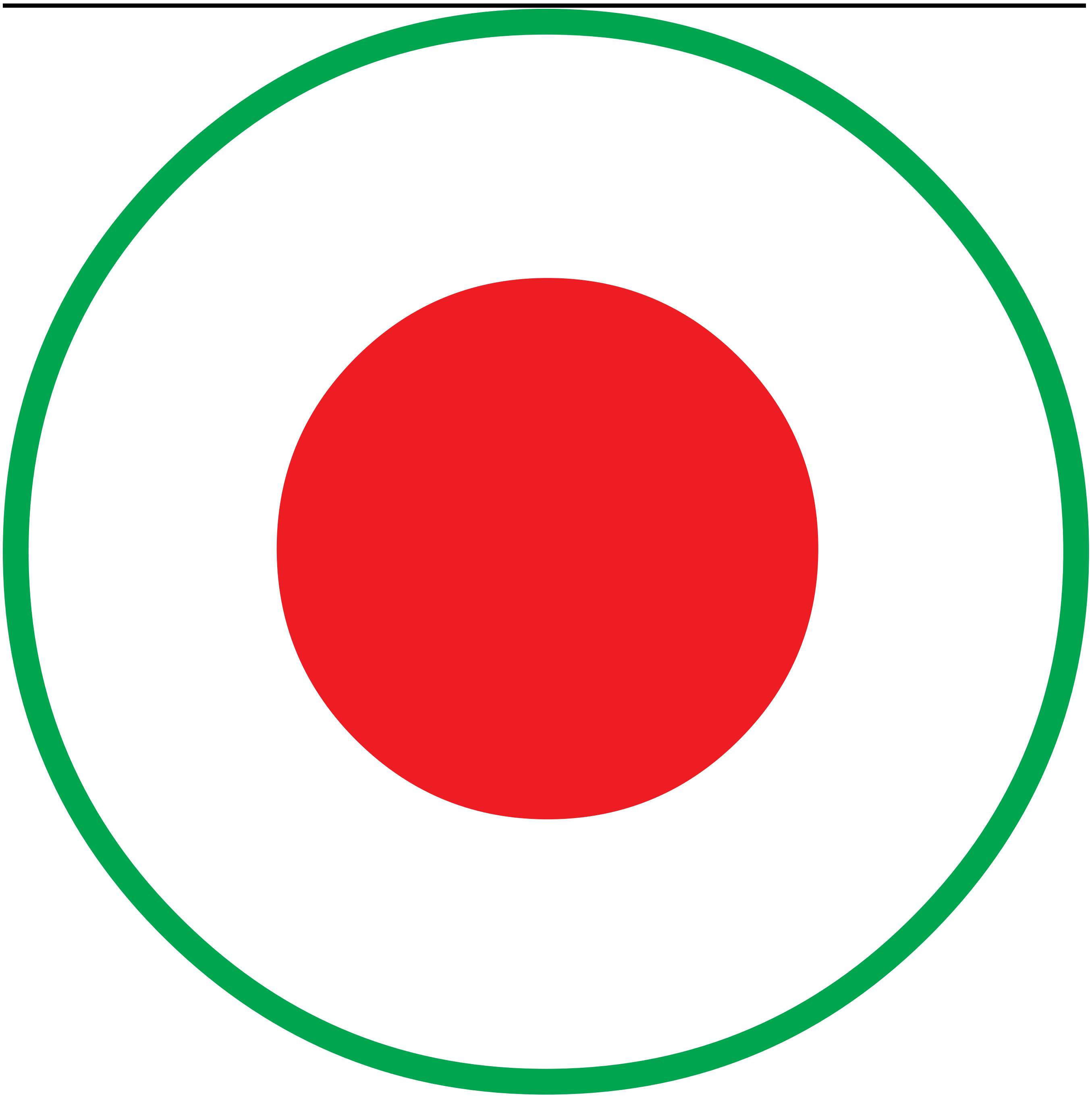


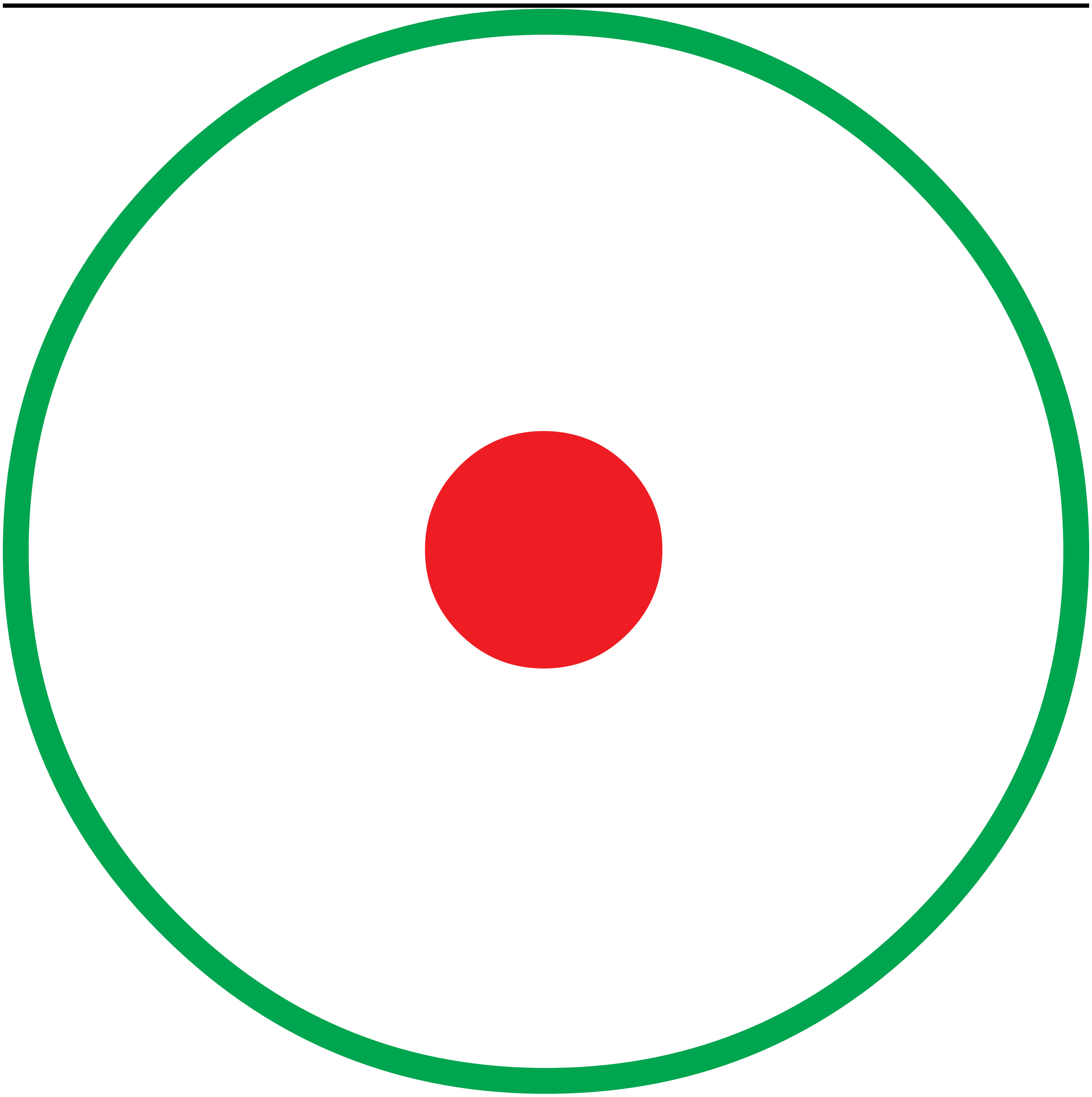
Figure 14: Coder Heartwood Exposure on Pruning Wounds Assessment for trees pruned, tipped or topped showing heartwood exposure >1/4 wound diameter.



MAJOR WOUND

heartwood exposure
>1/4 diameter of wound

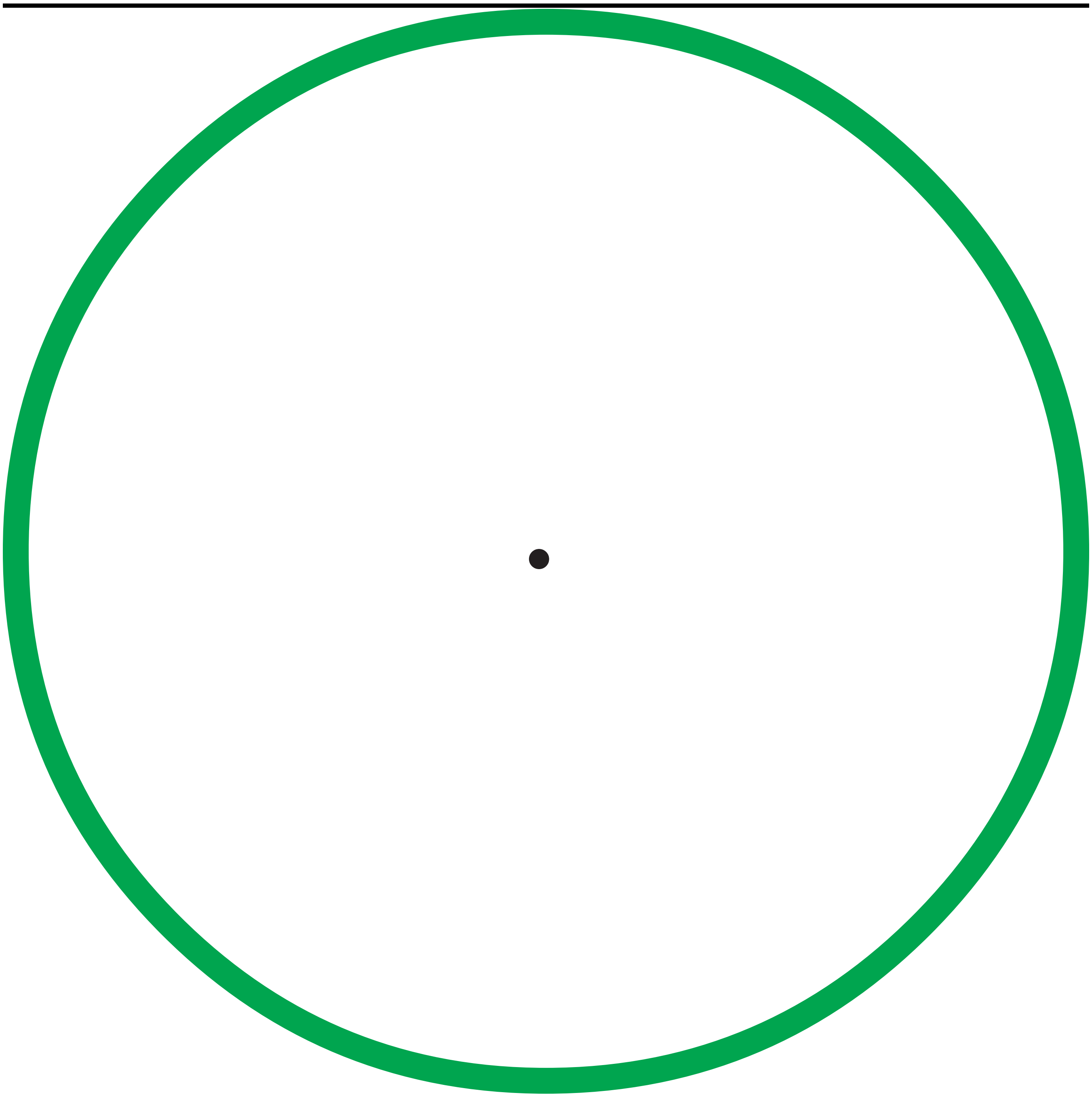
Figure 15: Coder Heartwood Exposure on Pruning Wounds Assessment for major wounds.



LARGE WOUND

heartwood exposure
<1/4 diameter of wound

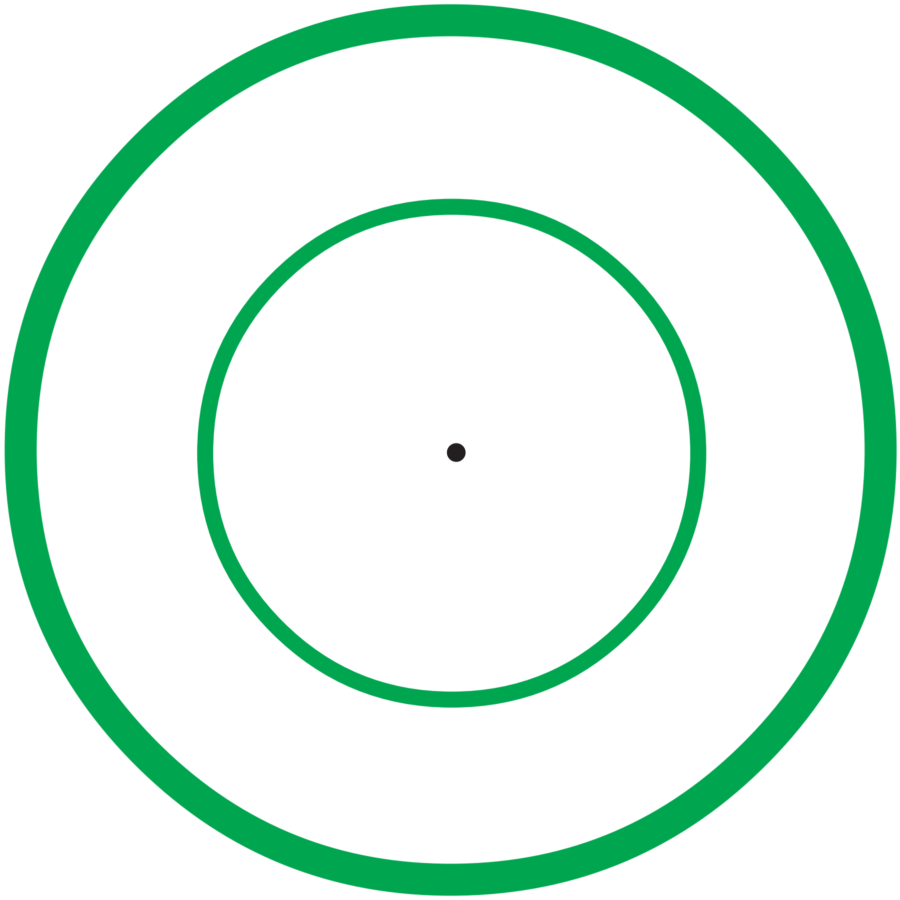
Figure 16: Coder Heartwood Exposure on Pruning Wounds Assessment for large wounds.



STANDARD WOUND

100% sapwood exposure

Figure 17: Coder Heartwood Exposure on Pruning Wounds
Assessment for standard wound.



MINOR WOUNDS

sapwood exposure across last 2 annual increments & point periderm penetrations

Figure 18: Coder Heartwood Exposure on Pruning Wounds Assessment for minor wounds (sprouts).

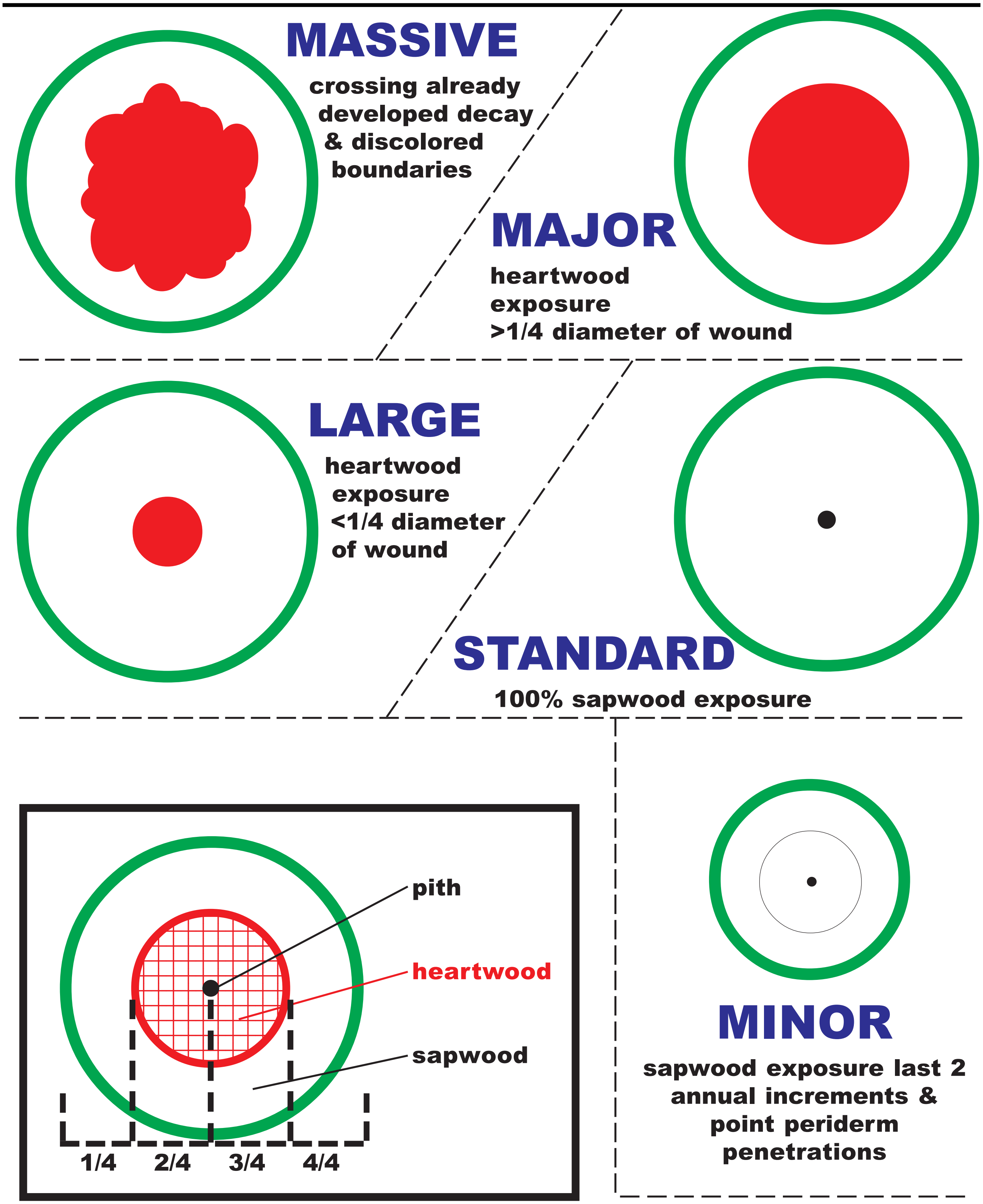


Figure 19: Coder Heartwood Exposure on Pruning Wounds Assessment for trees pruned, tipped or topped.

pruning wound type	maximum number of pruning wounds to single tree
massive	1
major	3
large	7
standard	15
minor	31

Figure 20: Maximum number of pruning wounds applied to a single tree by wound type.
Exceeding this count magnifies tree damage.

Assessment #4 -- Sapwood Area Removed

Most means of determining pruning dose try and estimate volume, density, or surface area of leaves. The more leaves a tree sustains over time, the greater chance it will be productive. Health and productivity of individual leaves and branches are difficult to estimate, allowing leaf-based or biomass removal pruning dose estimates to be error-prone depending upon the observer.

One way of approximating leaf number and activity is by examining non-photosynthetic living tissue supported by leaves. These tissues are generically called sapwood and depend upon leaves for food and growth materials, and in turn, support leaves by defending and maintaining resource supply transport systems. Sapwood must be fed (grown and sustained) by leaf productivity. Low leaf productivity increases heartwood volume and decreases sapwood volume. Figure 21. Greater leaf productivity sustains more sapwood. Depending upon species, site and tree age, there is a relationship between leaf productivity and sapwood area.

Living Volume

Sapwood area in a branch or stem, supported by and supporting a set of leaves, can be measured by increment core, by recording diameters within pruning wounds, and by estimating growth rates. As trees grow larger, more sapwood is generated and less leaves per unit of sapwood are sustained, reaching some biological equilibrium. Sapwood volume, as estimated by its cross-sectional area, can be used as a simple assessment of the volume of leaves present.

For example from research literature, the proportion of tree leaf area to sapwood area (m^2/cm^2) is 0.4 for redwood (*Sequoia*), 0.67 for cherrybark oak (*Quercus*), 0.24 for green ash (*Fraxinus*), 0.5 / 0.41 for eucalyptus (*Eucalyptus*). [change units of measure: m^2/cm^2 X 69.4 = ft^2/in^2]. The proportion of leaf weight to sapwood area (kg/cm^2) was found in one study to be 0.12. The proportion of leaf area to sapwood area divided by tree diameter ($(m^2/m^2)/mm$) was found in one study to be 2.6. All of these proportions from research represent a highly limited set of species, individual trees, and sites, but demonstrate how leaves and their productivity can be estimated by other tree measures.

Sapwood ID

One usable / measurable ratio in trees is leaf area to sapwood area, which acts as an approximation of tree (i.e. leaf) productivity. The more leaves, and the more productive each remains, the greater cross-sectional area of sapwood sustained. As trees grow, especially under harsh conditions, the amount of sapwood area can decline while the amount of heartwood area can increase. Measuring sapwood area estimates productivity of a branch or stem above.

Figure 22 provides sapwood area in square inches for various branch and stem diameters, with varying amounts of sapwood visible outside the heartwood core. Note these values are only effective for species with clearly visible heartwood, and for circumstances where discolored wood from injury and decay plus heartwood, can be differentiated from sapwood.

For example, a 10 inch diameter stem has about 79 square inches of sapwood area if the entire cross-section is sapwood (100% sapwood). If this tree is cored and is found to have only 1 inch of sapwood around the outside of a heartwood core (i.e. 1 inch radius of sapwood), there is only about 29 square inches of sapwood area. Additionally, if a branch 4 inches in diameter (branch diameter not stem flange / branch collar diameter) is pruned and is 100% sapwood, it would have 13 square inches of sapwood area.

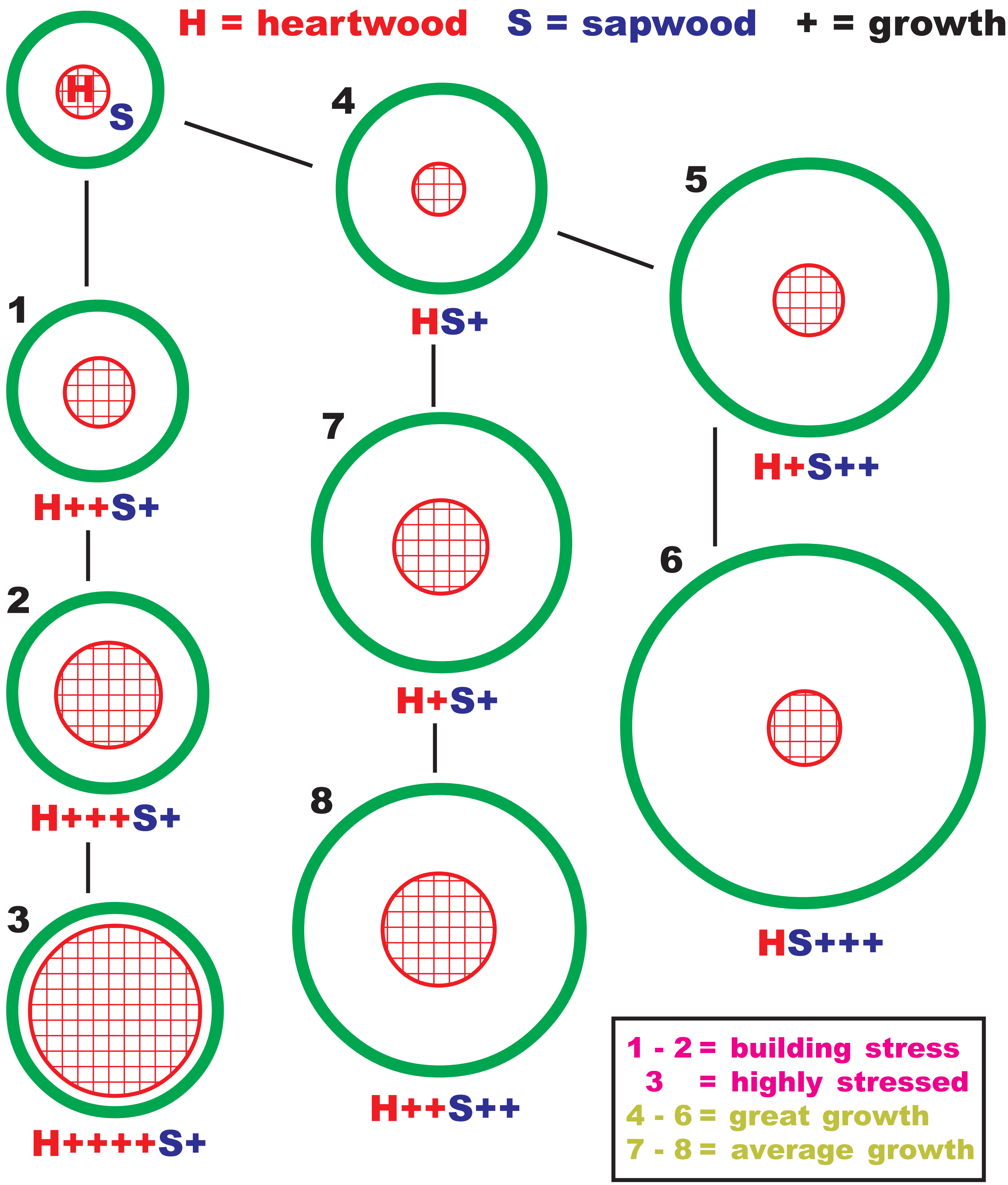


Figure 21: Diagram showing various sapwood / heartwood area expansion and growth combinations representing different environmental constraints on trees.

diameter (inches)	sapwood depth to heartwood (inches) 0.5”	1”	1.5”	2”	2.5”	3”	3.5”	4”	100% sapwood
0.2 in									0.03
0.4									0.13
0.6									0.28
0.8	--								0.5
1	--	--							0.8
2	2 in^2	--	--						3
3	4	6	--	--					7
4	6	10	3	--	--				13
5	7	13	17	19	--	--			20
6	8	15	21	25	27	--	--		28
7	11	19	26	32	36	38	--	--	39
8	11	22	30	37	43	47	49	--	50
9	14	25	36	44	51	57	61	63	64
10	15	29	40	51	59	66	72	76	79
11	16	31	45	56	67	75	82	88	95
12	18	34	49	63	74	85	93	100	113
13	20	38	54	69	83	94	105	113	133
14	21	41	59	75	90	104	115	126	154
15	23	44	64	82	98	113	127	138	177
16	24	47	68	88	106	122	137	151	201
17	26	50	73	94	114	132	148	163	227
18	27	53	77	100	121	141	159	175	254
19	29	56	82	106	129	150	170	188	283
20	31	60	87	113	137	160	181	201	314
21	32	63	92	119	145	169	192	213	346
22	34	66	97	126	153	179	203	226	380
23	35	69	101	132	161	188	214	238	415
24	37	72	106	138	169	198	225	251	452
25	39	76	111	145	177	208	237	264	491
26	40	79	116	151	185	217	248	277	531
27	41	81	120	157	192	226	258	289	572
28	43	84	124	163	200	235	269	301	615

Figure 22: Sapwood area in square inches for tree or branch diameters (inches) of various sapwood depths (inches). [1 square inch = 6.45 square centimeters; 1 inch = 2.54 centimeters; 1 centimeter = 0.394 inches.]

Counting Cuts

The amount of pruning allowed in a tree for any pruning cycle can be estimated by using the Coder Sapwood Area Pruning Dose Assessment formula. This formula calculates the cumulative amount of sapwood area pruned off a tree from branches compared with the amount of sapwood area present in its main stem. Figure 23

The Coder Sapwood Area Pruning Dose Assessment formula uses tree sapwood area in square inches multiplied by 0.334. The result is divided by a sum of all branch sapwood areas in square inches which were pruned off a tree. Each branch sapwood area is multiplied by a crown position value within a tree -- crown position value is a multiplier for branch sapwood area based upon whether a pruned branch was in the highest crown position, lowest or internal crown position, or was a new sprout.

Figure 24 presents generalized tree crown positions. Pruned sprouts anywhere are given a multiplier for their sapwood areas of one (1). Pruned upper or high crown position branches are given a multiplier for their sapwood areas of three (3). Branches pruned in the lower or internal crown positions are given a multiplier of two (2) for their sapwood areas.

Pruning Dose

The final calculated value is the pruning cycle dose (PCD). If the PCD is greater than 1 (one), then current pruning was within biologically sustainable limits. If the PCD is less than 1 then pruning exceeded biological limits, stressed the tree, and is a treatment overdose. For this assessment, a tree must be well established on its permanent site and not a juvenile. Counting pruning cuts seems daunting, but estimating pruned branch diameters, crown positions and sapwood areas can be done quickly with practice, and lends itself to data pad collection in real time. Real time estimation allows pruning to stop when the sustainability limit (PCD = 1.0) is reached.

Figure 25 provides an example of making six pruning cuts on a small 10 inch diameter tree. Each of the pruning cut faces are measured for size of sapwood area. Sapwood area for all six wounds is multiplied by each crown position value yielding a sapwood area value. Final area values are added togther for a total pruned sapwood area. The tree's sapwood area measured on the stem is divided by the total pruned sapwood area. The resulting number is a decimal percent of whether a tree has been over- or under-pruned. Values above a PCD 1.0 is sustainable. Values below PCD 1.0 provide the decimal percent a tree has been over-pruned. In this example, if the whole tree has a 1 inch band of sapwood around its stem, the PDC = 0.41, or 59% pruning over-dose (1.0 - 0.41 = 0.59).

Conclusions

The amount of pruning a tree can sustain at any one time or event can be estimated by experienced tree health care professionals. Applying the proper pruning dose -- especially not too much -- is key to sustainable trees. Minimizing damage and maintaining tree health assures long-lived trees generating many valuable benefits and minimizing liability issues. Only by counting, calculating, and estimating tree impacts from pruning wounds and tissue loss can an accurate and consistent pruning level be maintained. Assessments used here, from simple to complex, can help a tree health care provider determine the appropriate response in prescribing pruning treatments.

$$\frac{(\text{tree sapwood area in}^2 \times 0.334)}{\text{sum of all } [\text{sapwood area pruned} \times \text{crown position value}]}$$

crown position vales:
1 = <2 year old sprouts
2 = lowest & internal crown positions
3 = highest crown positions

=

PRUNING CYCLE DOSE or PCD

> 1.0 = within biological limits
< 1.0 = exceeded biological limits -- stress

Figure 23: Amount of pruning allowed in one pruning cycle based upon sapwood area measures.
(Coder Sapwood Area Pruning Dose Assessment).

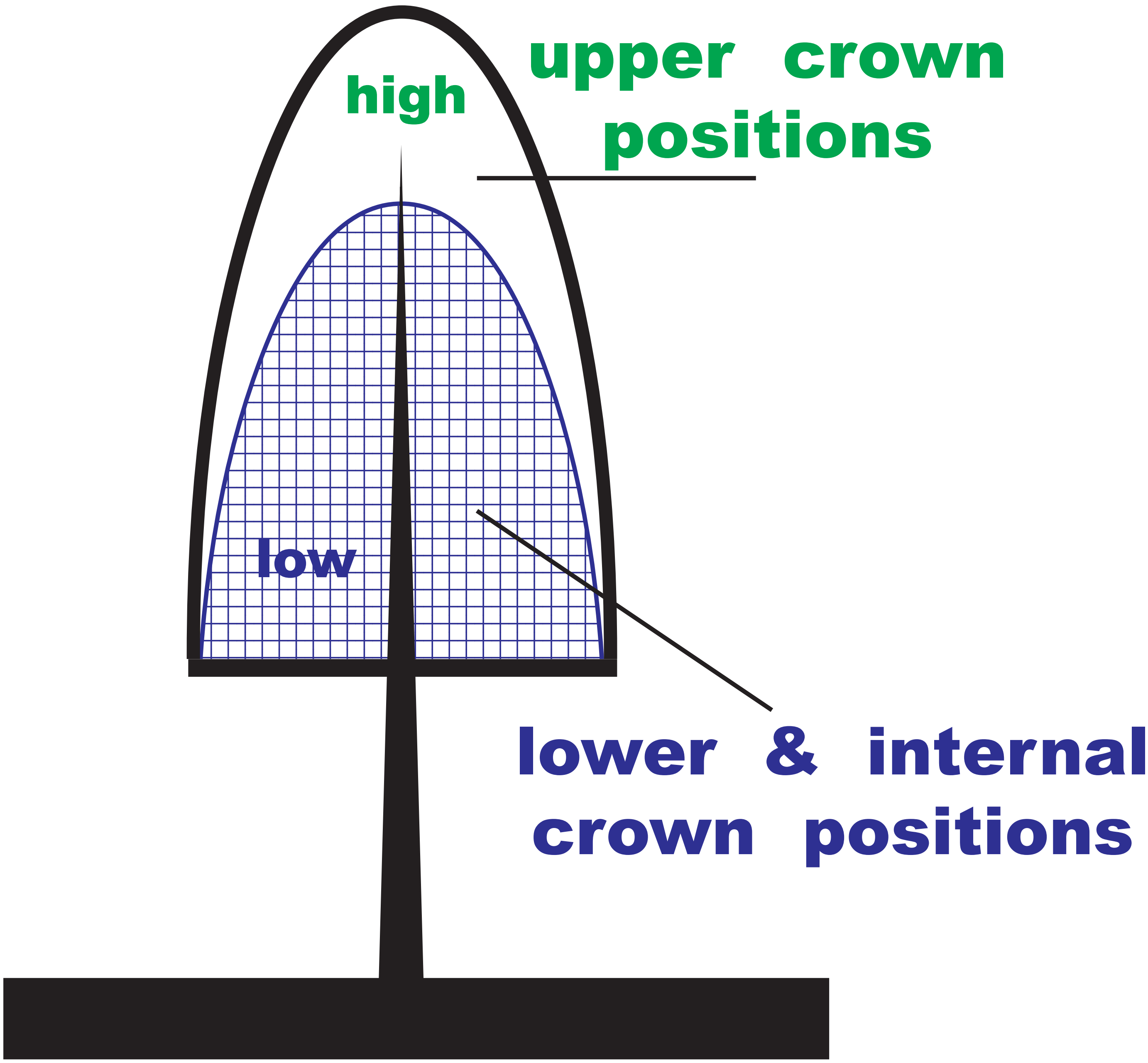


Figure 24: Diagram of crown positions in a tree where different leaf area, leaf productivity, and sapwood volume proportions exist.

Example: 10" dbh established tree

(5 branches + one sprout pruned)

diameter branch pruned	sapwood area	crown position	crown position value	values
3"	7 in^2	low	2	14 in^2
2"	3	low	2	6
1"	.8	low	2	1.6
1"	.8	high	3	2.4
0.6"	.28	high	3	0.84
0.4"	.13	sprout	1	0.13
			sum (in^2) =	23.37

Plug into formula -- if example tree is:

100% sapwood: pruning cycle dose = 1.13

3" sapwood: pruning cycle dose = 0.94
(6% overdose)

1" sapwood: pruning cycle dose = 0.41
(59% overdose)

Figure 25: Example use of Coder Sapwood Area Pruning Dose Assessment for pruning allowed in one pruning cycle.

Citation:

Coder, Kim D. 2021. Assessing tree pruning dose & damage. Warnell School of Forestry & Natural Resources, University of Georgia, Outreach Publication WSFNR-21-52C. Pp.34.