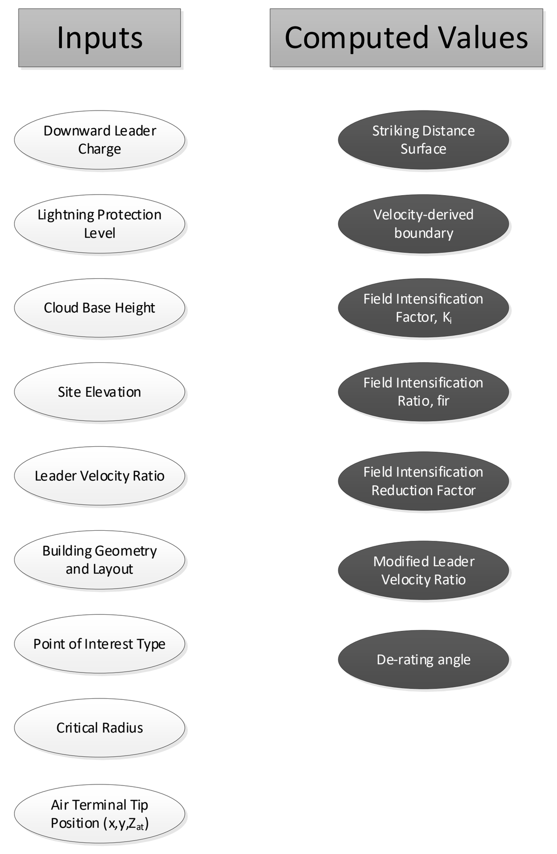
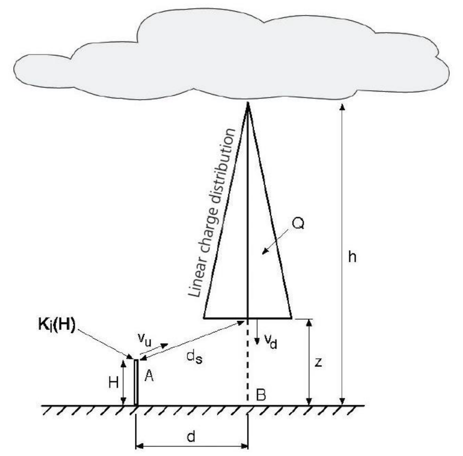


$$E_A = \frac{Q}{\pi\varepsilon d^2\left(\frac{h}{d}-\frac{z}{d}\right)^2}\left[\frac{\left(\frac{h}{d}-\frac{z}{d}\right)}{\left\{1+\left(\frac{z}{d}\right)^2\right\}^{0.5}} + \sinh^{-1}\left(\frac{z}{d}\right) - \sinh^{-1}\left(\frac{h}{d}\right)\right]$$

$$E_B = \frac{Q}{\pi\varepsilon(h-z)^2}\left[\left(\frac{h-z}{z}\right) + \ln\left(\frac{z}{h}\right)\right]$$

$$\frac{(d_s - z_m)}{v_u} \leq \frac{(z - z_m)}{v_d}$$

$$d = \sqrt{\left[\frac{z_m(K_v - 1) + z}{K_v}\right]^2 - (z-H)^2} .$$



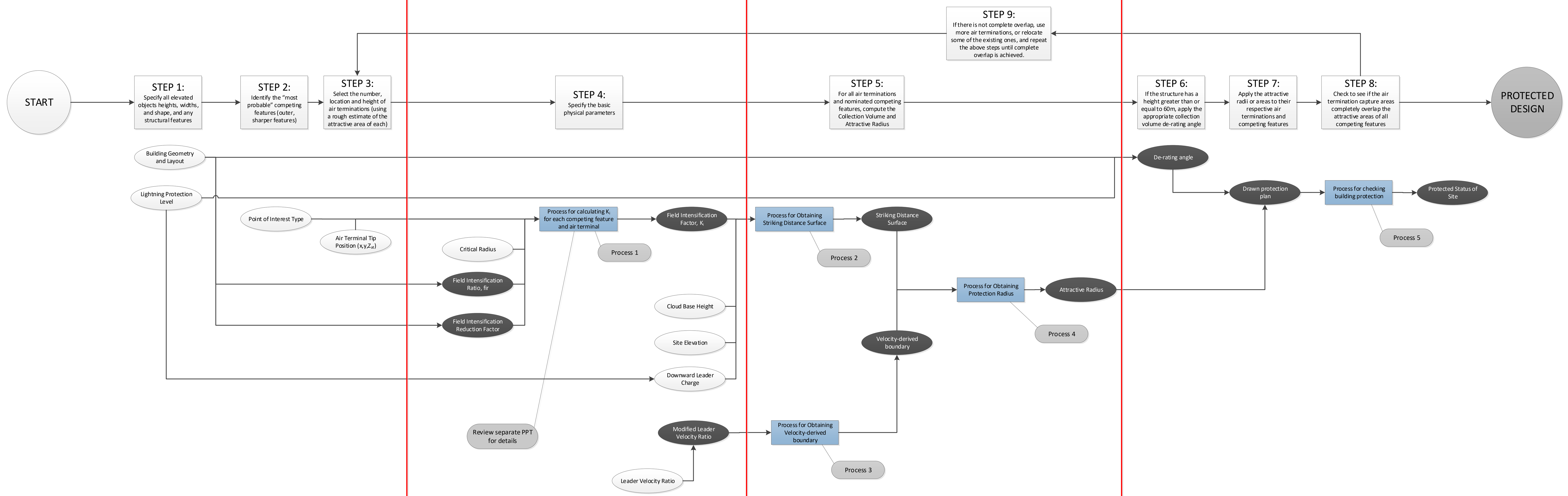


Table 2: De-rating angles applied in the CVM for tall structures (H ≥ 60 m).

LPL	Interception Efficiency	De-rating Angle
I	99	26°
II	97	23°
III	91	20°
IV	84	15°

Table 1: Summary of the key parameters and probabilities associated with the lightning protection levels used to design a lightning protection system (LPS) for ordinary structures.

LPL	Leader charge Q (C)	Peak current I_P (kA)	Striking distance (m)	% strikes > I_P (Interception Efficiency)
I	0.16	2.9	20	99
II	0.38	5.4	30	97
III	0.93	10.1	45	91
IV	1.80	15.7	60	84

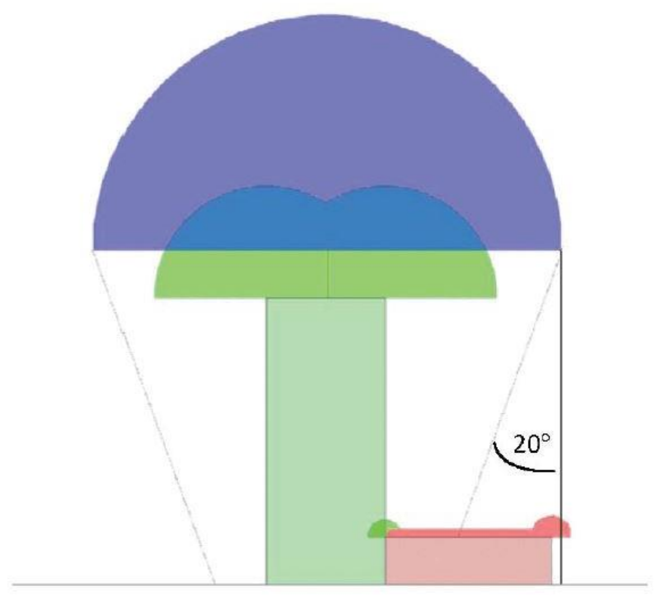


Figure 5: Application of collection volume de-rating to tall structures (example for LPL III). Note that, in this particular example, the lower structure would not have been deemed to be protected anyhow, since the collection volume of the air termination on top of the main building does not overlap the small collection volume of the corners of the lower structure.

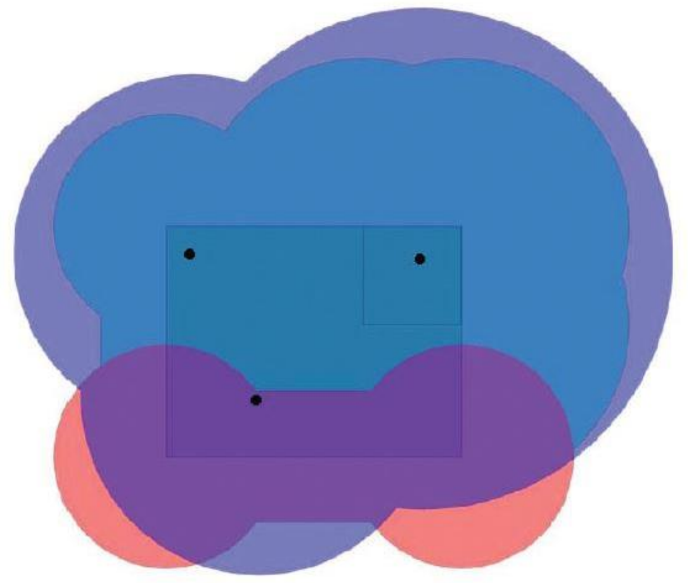


Figure 6: 2D plan view display of the three air termination attractive areas (light blue) and the competing features attractive areas (darker blue), including those not shielded or protected by the air terminations (red areas).

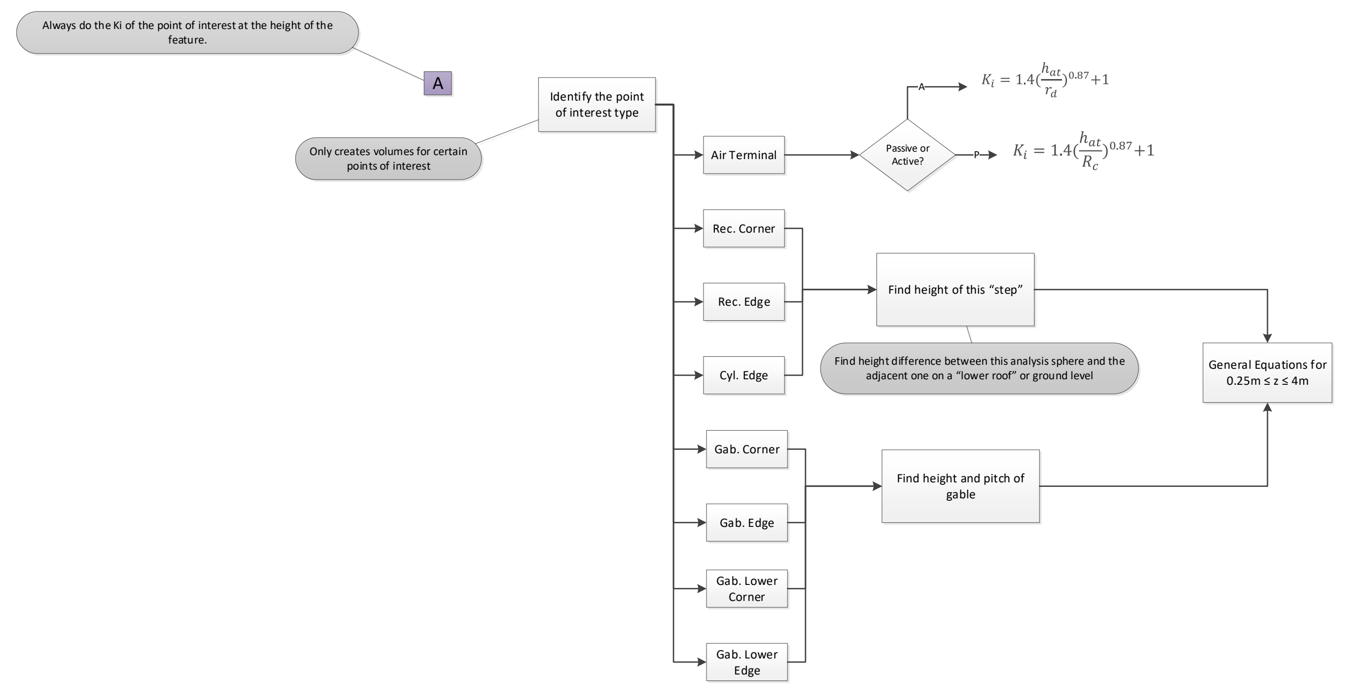
Process for calculating K_i for each competing feature and air terminal

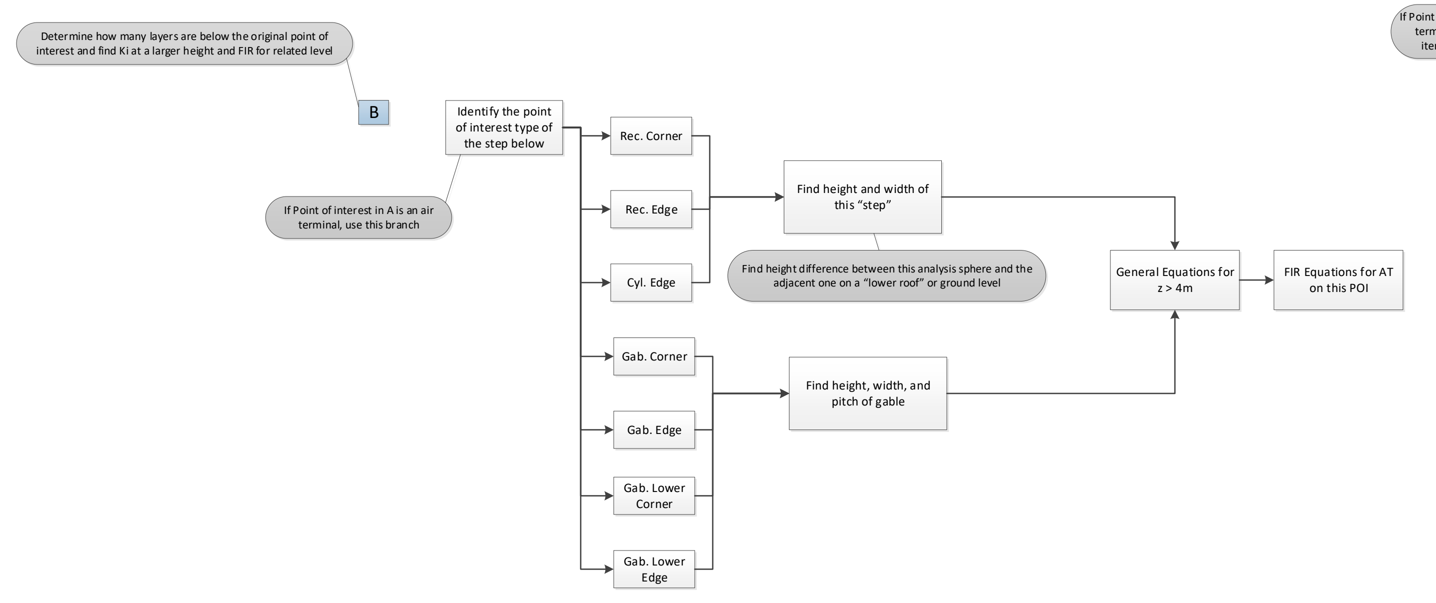
Always do the Ki of the point of interest at the height of the feature. — A

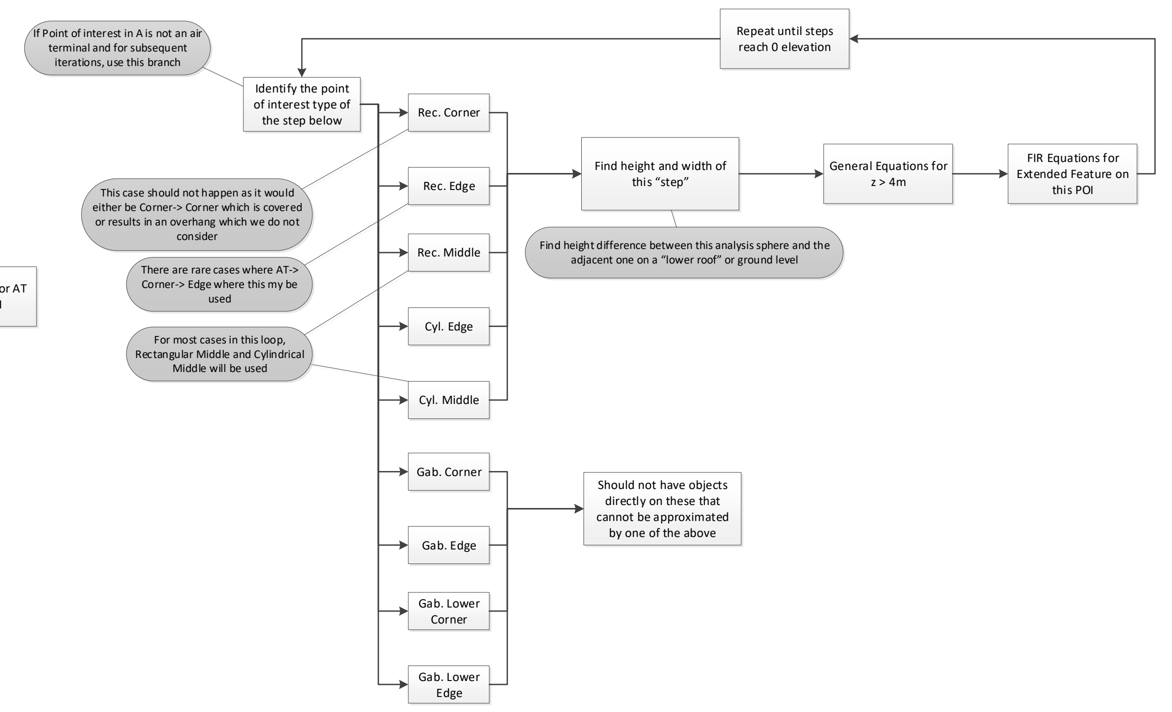
Determine how many layers are below the original point of interest and find Ki at a larger height and FIR for related level — B

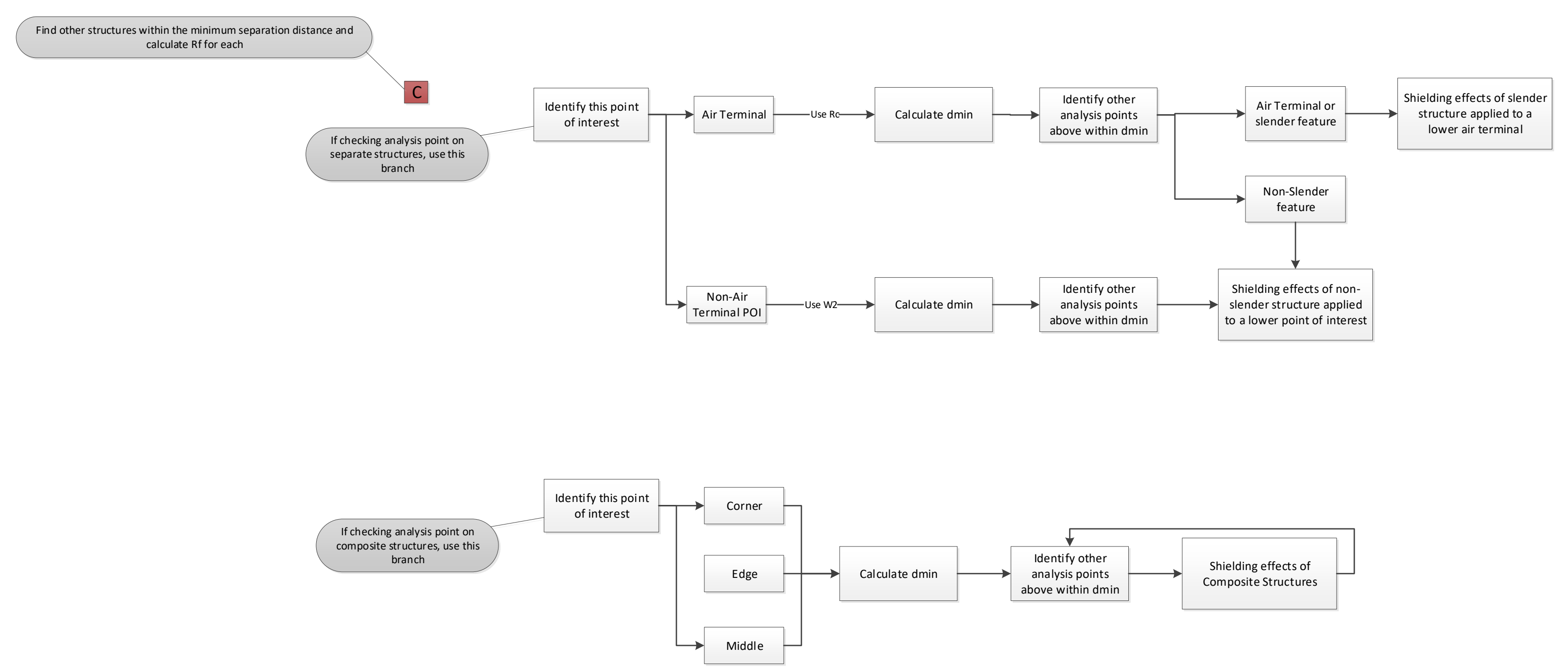
$$K_{i\,tot} = K_i(POI\ @\ h) \times \frac{K_i(POI\ below\ @h) \times FIR(POI\ below)}{R_f(nearby\ items\ above)}$$

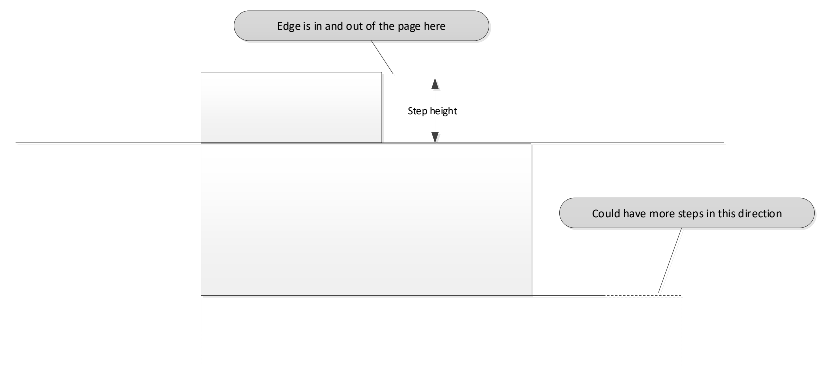
Find other structures within the minimum separation distance and calculate Rf for each — C

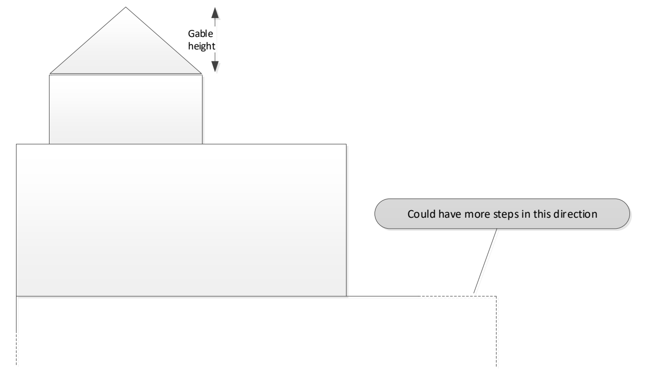


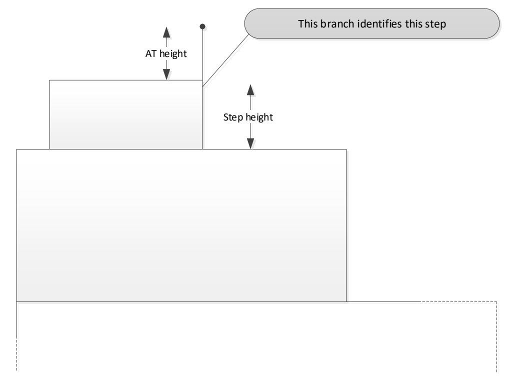


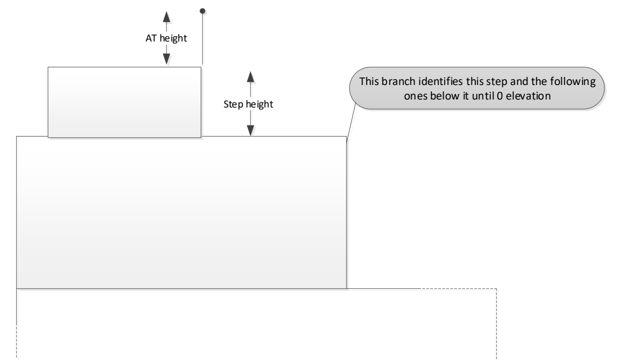


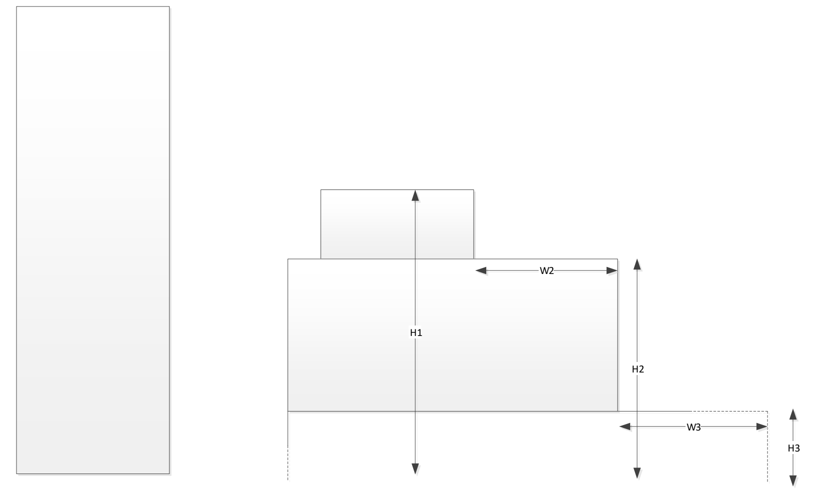












Always do the Ki of the point of interest based on its own level dimensions or AT height

When the point of interest is stacked on an extended feature or base feature, determine the influence of these features at the height above these lower levels

Use the FIR as an adjustment factor when multiplying the Ki values together. This changes based on which Ki factors you are multiplying.

A-I | J-P | Q-Z

$$R_c = 0.38m$$

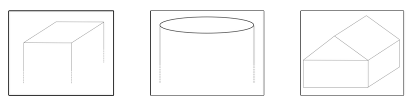
$$r_d = 0.175m$$

$$H_{X.X} = height\ above\ ground\ of\ sublevel\ X.X$$

$$W_{X.X} = minimum\ width\ of\ sublevel\ X.X$$

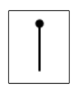
$$P = \frac{\alpha}{\beta} = 2\frac{\alpha}{W}$$

Single Level Structures POI
$K_i = K_i(Base\ Str\ @\ z)$



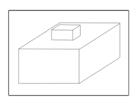
A-E

Single Level Air Terminal
$K_i = K_i(Air\ Terminal\ @\ z)$



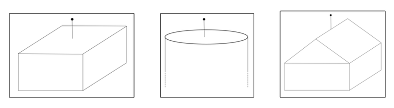
H-I

Extended Feature on Base Structure
$K_i = K_i(Ext\ Feat\ @\ z) * K_i(Base\ Str\ @\ h_{ext}) * FIR(Base\ Str\ @h_{ext})$



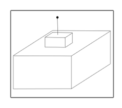
A-G | J-N | Q-S

Air Terminal on Base Structure
$K_i = K_i(Air\ Terminal\ @\ z) * K_i(Base\ Str\ @\ h_{at}) * FIR(Base\ Str\ @h_{at})$



H-I | J-N | T-Z

Air Terminal on Extended Feature on Base Structure
$K_i = K_i(Air\ Terminal\ @\ z) * K_i(Ext\ Feat\ @\ h_{at}) * FIR(Ext\ Feat\ @h_{at}) * K_i(Base\ Str\ @\ h_{at}) * FIR(Base\ Str\ @h_{at})$



H-I | J-N | T-Z | J-N | Q-S

Equations A through I
General Equations for single level structures
Rectangular - Purple
Cylindrical - Blue
Gable Roof - Orange
Air Terminal - Gray

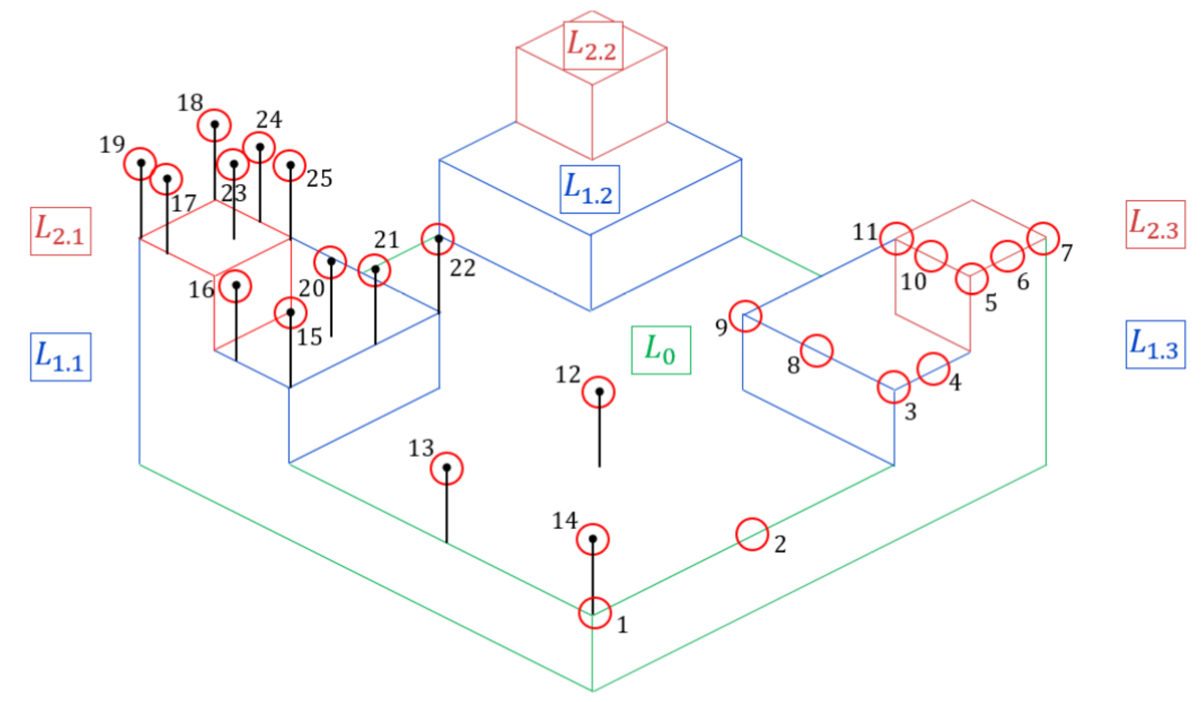
A	$K_i = 0.43H^{0.8}W^{-0.14}R_c^{-0.57} + 1$	(Corner)
B	$K_i = 0.55H^{0.544}W^{-0.14}R_c^{-0.367} + 1$	(Edge)
C	$K_i = 0.95(\frac{H}{W})^{0.57}e^{-0.55(\frac{R_c}{W})^{1.33}} + 1$	(Middle)
D	$K_i = 0.56H^{0.82}W^{-0.31}R_c^{-0.45} + 1$	(Edge)
E	$K_i = 1.375(\frac{H}{W})^{0.839}e^{-1.33(\frac{R_c}{W})^{1.43}} + 1$	(Middle)
F	**Gable Roof - Corner** • $K_{imax} = 0.47(H+W)^{0.76}W^{-0.1}R_c^{-0.61} + 1$ MAX • $K_{imin} = 0.55H^{0.544}W^{-0.14}R_c^{-0.367} + 1$ MIN • $K_i = \left(\frac{K_{imax}-K_{imin}}{2}\right)P + K_{imin}$ Interpolation	
G	**Gable Roof – Edge** • $K_{imax} = 0.48(H+W)^{0.568}W^{-0.037}R_c^{-0.508} + 1$ MAX • $K_{imin} = 0.95(\frac{H}{W})^{0.57}+1$ MIN • $K_i = \left(\frac{K_{imax}-K_{imin}}{2}\right)P + K_{imin}$ Interpolation	
H	$K_i = 1.4(\frac{h_{at}}{r_d})^{0.87}+1$	DYNASPHERE
I	$K_i = 1.4(\frac{h_{at}}{R_c})^{0.87}+1$	PASSIVE

Equations J through P
General Equations for influence of lower levels for multi-level structures
Rectangular - Purple
Cylindrical - Blue
Gable Roof - Orange

J	$K_i = 0.57H^{0.75}W^{-0.13}H_f^{-0.53} + 0.4$	(Corner)
K	$K_i = 0.84H^{0.474}W^{-0.109}H_f^{-0.326} + 0.27$	(Edge)
L	$K_i = 0.95(\frac{H}{W})^{0.57}e^{-0.55(\frac{H_f}{W})^{1.33}} + 1$	(Middle)
M	$K_i = 0.68H^{0.78}W^{-0.28}H_f^{-0.43} + 0.45$	(Edge)
N	$K_i = 1.375(\frac{H}{W})^{0.839}e^{-1.33(\frac{H_f}{W})^{1.43}} + 1$	(Middle)
O	**Gable Roof - Corner** • $K_{imax} = (H+W)^{0.63}W^{-0.1}H_f^{-0.49} - 1$ MAX • $K_{imin} = 0.84H^{0.474}W^{-0.109}H_f^{-0.326} + 0.27$ MIN • $K_i = \left(\frac{K_{imax}-K_{imin}}{2}\right)P + K_{imin}$ Interpolation	
P	**Gable Roof – Edge** • $K_{imax} = 0.72(H+W)^{0.51}W^{-0.034}H_f^{-0.45} + 0.34$ MAX • $K_{imin} = 0.95(\frac{H}{W})^{0.57}e^{-0.55(\frac{H_f}{W})^{1.33}} + 1$ MIN • $K_i = \left(\frac{K_{imax}-K_{imin}}{2}\right)P + K_{imin}$ Interpolation	

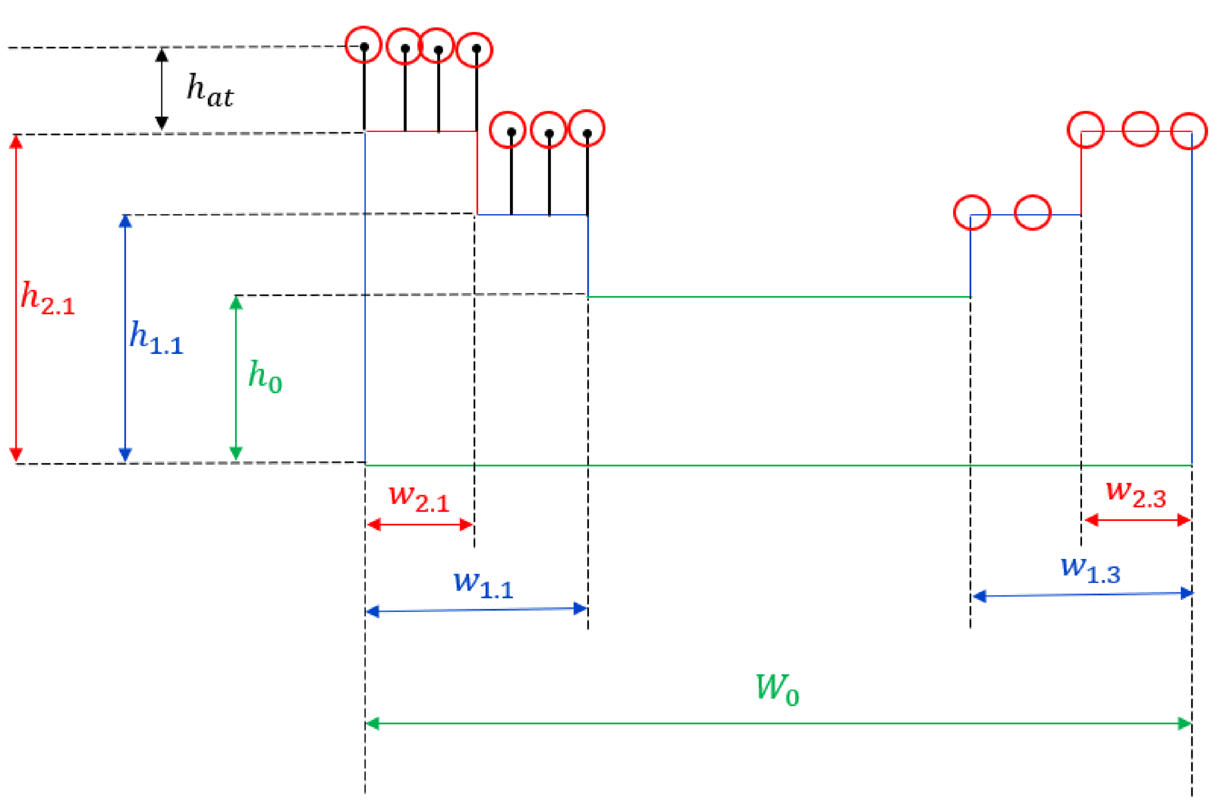
Equations Q through Z
Field Intensification Ratios (FIR) for adjusting the relationship between Equations A-I and Equations J-P
Extended feature on Base – Red
Air terminal on Rectangular Ext. Feat. or Base – Purple
Air terminal on Cylindrical Ext. Feat. or Base – Blue
Air terminal on Gable Roof - Orange

Q	$FIR = 0.1z + 1.2$ – With $FIR_{max} = 1.8$	(Corner)
R	$FIR = 1.4$	(Edge)
S	$FIR = 1.35 - 0.2z$ – With $FIR_{min} = 0.9$	(Middle)
T	$FIR = 1.5$	(Corner)
U	$FIR = 0.9H^{0.25}W^{-0.13} + 0.2$	(Edge)
V	$FIR = 0.4H^{0.4}W^{-0.3} + 0.7$	(Middle)
W	$FIR = 0.5H^{-0.3}W^{0.18} + 1$	(Edge)
X	$FIR = 0.12H^{0.4}W^{-0.6} + 1$	(Middle)
Y	**FIR of air terminal on the "corner" of a gable structure** • $FIR_{max} = 1.8(H+W)^{-0.12} + 1$ MAX • $FIR_{min} = 0.9H^{0.25}W^{-0.13} + 0.2$ MIN • $FIR = \left(\frac{FIR_{max}-FIR_{min}}{2}\right)P + FIR_{min}$ Interpolation	
Z	**FIR of air terminal on the "edge" of a gable structure** • $FIR_{max} = 0.55(H+W)^{0.4}W^{-0.35} + 1$ MAX • $FIR_{min} = 0.4H^{0.4}W^{-0.3} + 0.7$ MIN • $FIR = \left(\frac{FIR_{max}-FIR_{min}}{2}\right)P + FIR_{min}$ Interpolation	



Points 1 through 11
Critical points on a rectangular structure with multiple levels

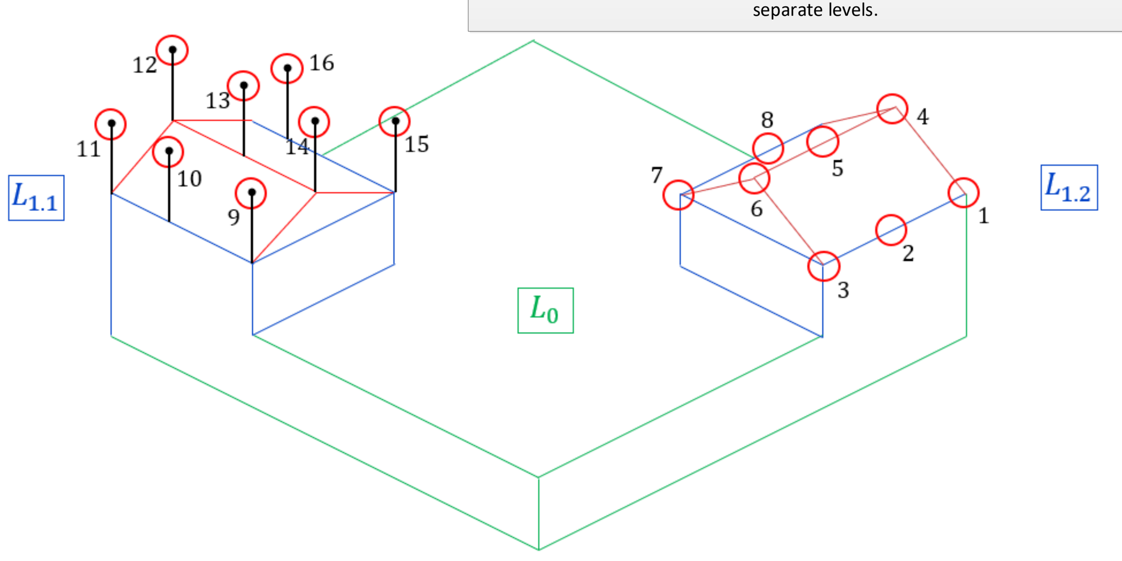
Point	Eq.	Parameters	Eq.	Parameters	FIR
1	A	$H = H_0$ $W = W_0$			
2	B	$H = H_0$ $W = W_0$			
3	A	$H = H_{1.3}$ $W = W_0$			
4	B	$H = H_{1.3}$ $W = W_0$			
5	A	$H = H_{2.3}$ $W = W_0$			
6	B	$H = H_{2.3}$ $W = W_0$			
7	A	$H = H_{2.3}$ $W = W_0$			
8	B	$H = (H_{1.3}-H_0)$ $W = W_{1.3}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{1.3}-H_0)$	R
9	A	$H = (H_{1.3}-H_0)$ $W = W_{1.3}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{1.3}-H_0)$	Q
10	B	$H = (H_{2.3}-H_0)$ $W = W_{2.3}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{2.3}-H_0)$	R
11	A	$H = (H_{2.3}-H_0)$ $W = W_{2.3}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{2.3}-H_0)$	Q

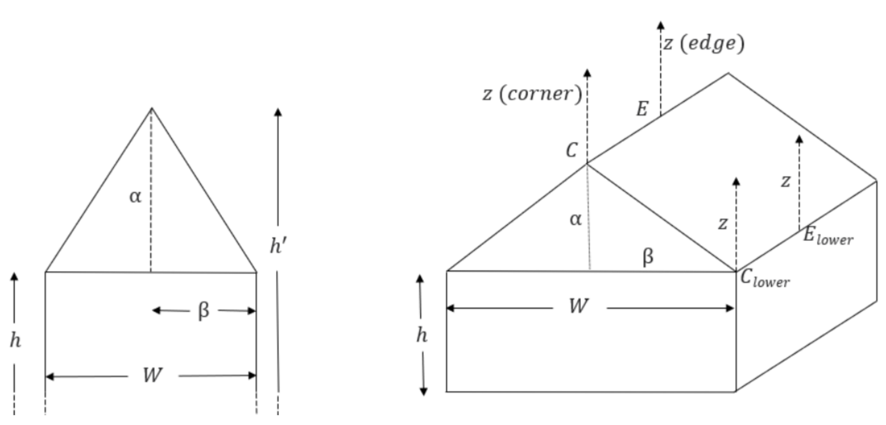


Points 12 through 25
Dynasphere terminals on a rectangular structure with multiple levels

Point	Eq.	Eq.	Parameters	FIR	Parameters	Eq.	Parameters	FIR
12	H	L	$H = H_0$ $W = W_0$ $H_f = H_{at}$	V	$H = H_0$ $W = W_0$			
13	H	K	$H = H_0$ $W = W_0$ $H_f = H_{at}$	U	$H = H_0$ $W = W_0$			
14	H	J	$H = H_0$ $W = W_0$ $H_f = H_{at}$	T				
15	H	J	$H = H_{1.1}$ $W = W_0$ $H_f = H_{at}$	T				
16	H	K	$H = H_{1.1}$ $W = W_0$ $H_f = H_{at}$	U	$H = H_{1.1}$ $W = W_0$			
17	H	K	$H = H_{2.1}$ $W = W_0$ $H_f = H_{at}$	U	$H = H_{2.1}$ $W = W_0$			
18	H	J	$H = H_{2.1}$ $W = W_0$ $H_f = H_{at}$	T				
19	H	J	$H = H_{2.1}$ $W = W_0$ $H_f = H_{at}$	T				
20	H	L	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$ $H_f = H_{at}$	V	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{1.1}-H_0)$	S
21	H	K	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$ $H_f = H_{at}$	U	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{1.1}-H_0)$	S
22	H	J	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$ $H_f = H_{at}$	T		L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{1.1}-H_0)$	S
23	H	L	$H = (H_{2.1}-H_0)$ $W = W_{2.1}$ $H_f = H_{at}$	V	$H = (H_{2.1}-H_0)$ $W = W_{2.1}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{2.1}-H_0)$	S
24	H	K	$H = (H_{2.1}-H_0)$ $W = W_{2.1}$ $H_f = H_{at}$	U	$H = (H_{2.1}-H_0)$ $W = W_{2.1}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{2.1}-H_0)$	S
25	H	J	$H = (H_{2.1}-H_0)$ $W = W_{2.1}$ $H_f = H_{at}$	T		L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{2.1}-H_0)$	S

NOTE
Intended only for Pitch values 2 or less.
Sloped or gable roofs that have a higher pitch than two should be treated as separate levels.





Points 1 through 8
Critical points on a rectangular structure with gable roofs on multiple levels

Point	Eq.	Parameters	Eq.	Parameters	FIR
1	F	$H = \frac{H_{1.2}}{P\alpha + 1}$ $W = W_{Gable}$			
2	G	$H = \frac{H_{1.2}}{P\alpha + 1}$ $W = W_{Gable}$			
3	F	$H = \frac{H_{1.2}}{P\alpha + 1}$ $W = W_{Gable}$			
4	F	$H = H_{1.2}$ $W = W_{1.2}$			
5	G	$H = (H_{1.2}-H_0)$ $W = W_{1.2}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{1.2}+\alpha - H_0)$	Q
6	F	$H = (H_{1.2}-H_0)$ $W = W_{1.2}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{1.2}+\alpha - H_0)$	Q
7	F	$H = \frac{(H_{1.2}-H_0)}{P\alpha + 1}$ $W = W_{Gable}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{1.2}-H_0)$	Q
8	G	$H = \frac{(H_{1.2}-H_0)}{P\alpha + 1}$ $W = W_{Gable}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{1.2}-H_0)$	R

Points 9 through 16
Air Terminals on a rectangular structure with gable roofs on multiple levels

Point	Eq.	Eq.	Parameters	FIR	Parameters	Eq.	Parameters	FIR
9	H	O	$H = \frac{H_{1.1}}{P\alpha + 1}$ $W = W_{Gable}$ $H_f = H_{at}$	Y	$H = \frac{H_{1.1}}{P\alpha + 1}$ $W = W_{Gable}$			
10	H	P	$H = \frac{H_{1.1}}{P\alpha + 1}$ $W = W_{Gable}$ $H_f = H_{at}$	Z	$H = \frac{H_{1.1}}{P\alpha + 1}$ $W = W_{Gable}$			
11	H	O	$H = \frac{H_{1.1}}{P\alpha + 1}$ $W = W_{Gable}$ $H_f = H_{at}$	Y	$H = \frac{H_{1.1}}{P\alpha + 1}$ $W = W_{Gable}$			
12	H	O	$H = H_{1.1}$ $W = W_{1.1}$ $H_f = H_{at}$	Y	$H = H_{1.1}$ $W = W_{1.1}$			
13	H	P	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$ $H_f = H_{at}$	Z	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+\alpha + H_{1.1} - H_0)$	R
14	H	O	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$ $H_f = H_{at}$	Y	$H = (H_{1.1}-H_0)$ $W = W_{1.1}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+\alpha + H_{1.1} - H_0)$	Q
15	H	O	$H = \frac{(H_{1.1}-H_0)}{P\alpha + 1}$ $W = W_{Gable}$ $H_f = H_{at}$	Y	$H = \frac{(H_{1.1}-H_0)}{P\alpha + 1}$ $W = W_{Gable}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{1.1} - H_0)$	Q
16	H	P	$H = \frac{(H_{1.1}-H_0)}{P\alpha + 1}$ $W = W_{Gable}$ $H_f = H_{at}$	Z	$H = \frac{(H_{1.1}-H_0)}{P\alpha + 1}$ $W = W_{Gable}$	L	$H = H_0$ $W = W_0$ $H_f = (H_{at}+H_{1.1} - H_0)$	R

Shielding Effects of Composite Structures

1. Find all corner and edge points on the same building with a higher z-value than the point being evaluated
2. Find horizontal distance Δ(x,y) and Δz relative to the point being evaluated
3. Calculate MN equation for all these points, return the Δ(x,y) and Δz for the point with the highest MN
4. Calculate Rf using selected Δ(x,y) and Δz, cannot be less than 1

Shielding Effects of Separate Structures

1. Find all corner and edge points on other buildings with a higher z-value than the point being evaluated
2. Find horizontal distance Δ(x,y) and Δz relative to the point being evaluated
3. Remove any points that have a Δ(x,y) that is greater than d_{min}
4. Calculate MN equation for all the remaining points, return the Δ(x,y) and Δz for the point with the highest MN
5. Calculate Rf using selected Δ(x,y) and Δz
6. Interpolate Rf using Δ(x,y) and d_{min}

d_{min}: $$d_{min} = \frac{3.8H_2^{0.78}W_2^{0.28}}{2}$$

d_{2D}: $$d_{2D} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

Δz: $$\Delta z = H_2 - H_1$$

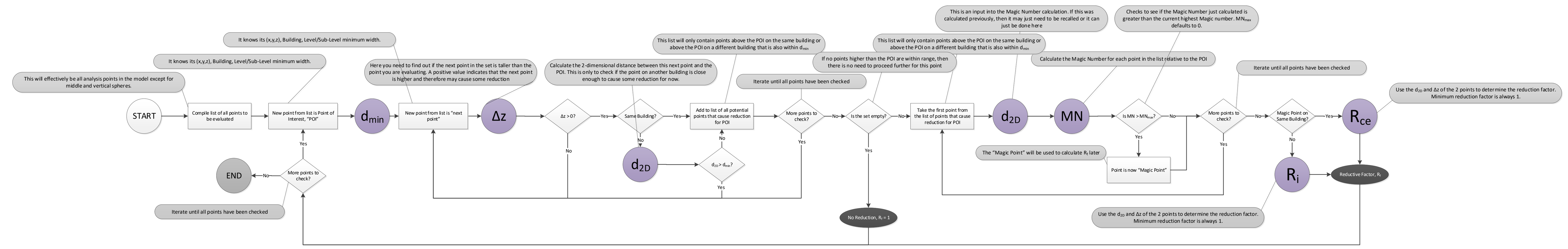
MN: $$M = \frac{1}{d_{2D} + 1} * H_P^{\ 0.8} * W_P^{\ 0.3}$$

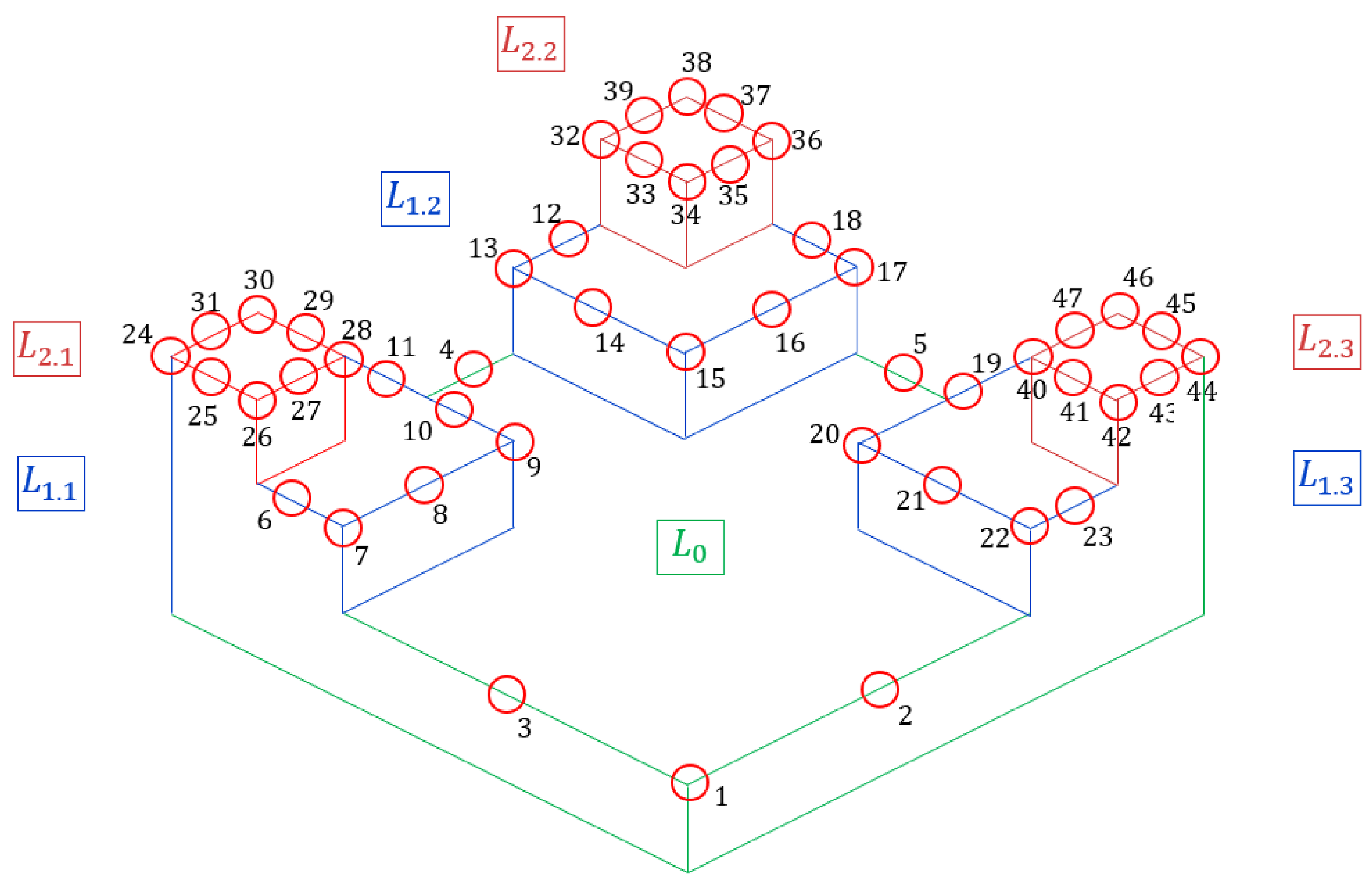
R_{ce}: $$R_f = 0.9(H_1 - H_2)^{0.51}W_2^{-0.35}$$

R_m: $$R_f = 0.679(H_1 - H_2)^{0.76}W_2^{-0.24}$$

R_i:
$$R_{f\,max} = 0.9(H_1 - H_2)^{0.51}W_2^{-0.35}$$ MAX
$$R_{f\,min} = 1$$ MIN
$$R_f = R_{f\,max} - \left(\frac{R_{f\,max} - R_{f\,min}}{d_{min}}\right)d$$ Interpolation

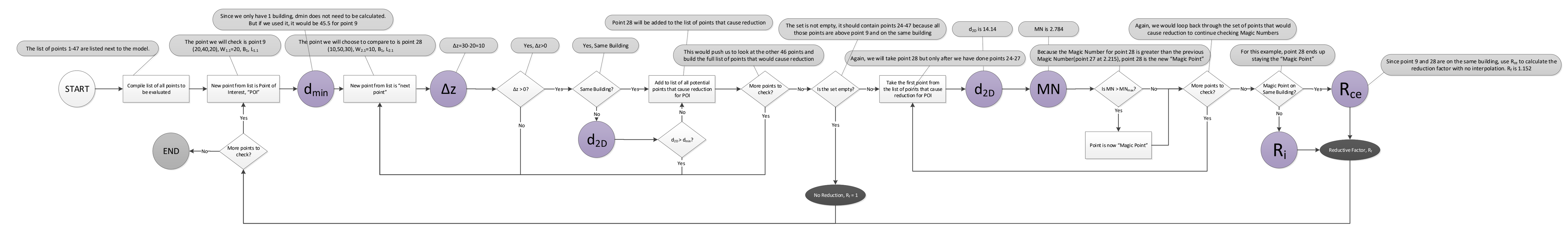
Process Flow for Total Reduction Calculation

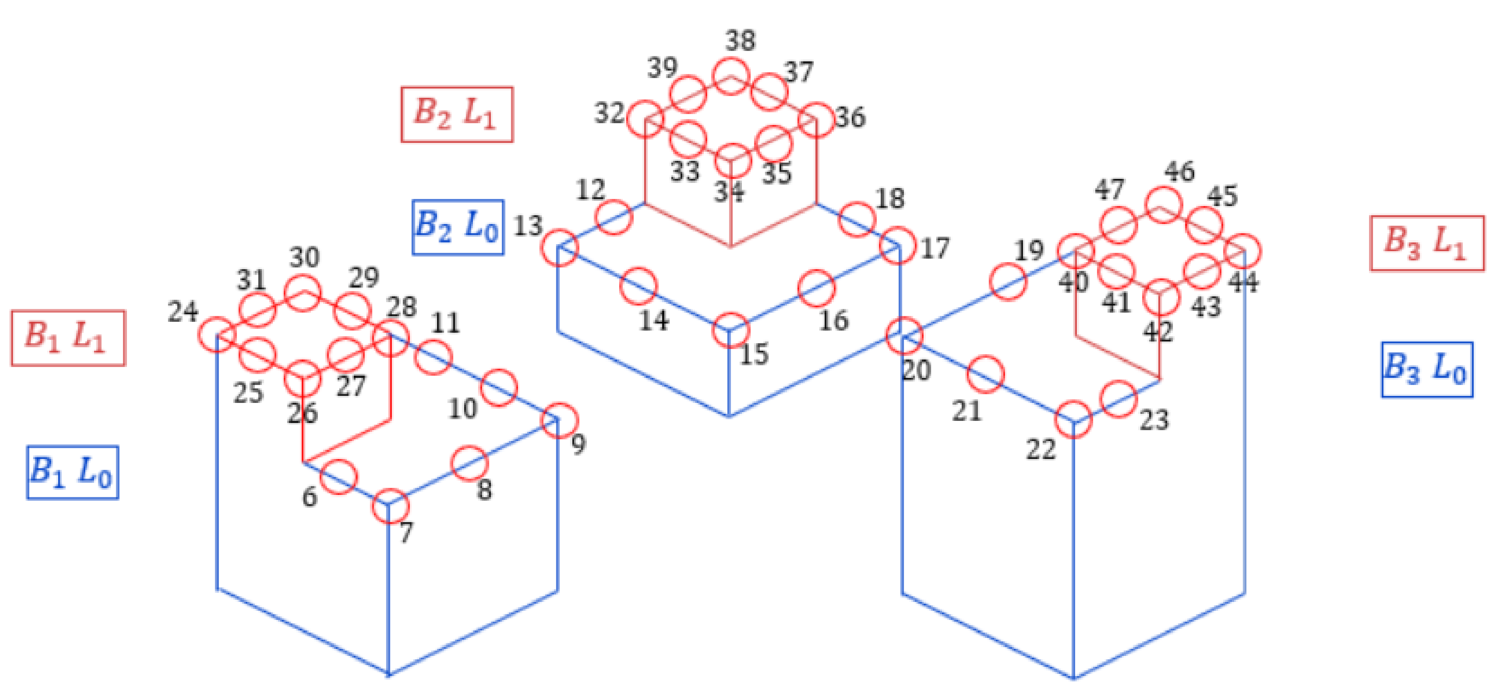




Point #	x	y	z	w	Max Magic Number	Magic Point	Reductive Factor
1	0	0	10	60	0.827	26	1.054698445
2	20	0	10	60	1.360	42	1.261175043
3	0	20	10	60	1.360	26	1.261175043
4	35	60	10	60	4.498	13	1.658070559
5	60	35	10	60	4.498	17	1.658070559
6	0	45	20	20	7.026	26	1.658070559
7	0	40	20	20	3.832	26	1.300895794
8	10	40	20	20	3.832	28	1.300895794
9	20	40	20	20	2.784	28	1.15229124
10	20	45	20	20	3.461	28	1.251074745
11	20	55	20	20	3.832	29	1.300895794
12	45	60	20	20	7.026	32	1.658070559
13	40	60	20	20	3.832	32	1.300895794
14	40	50	20	20	3.832	34	1.300895794
15	40	40	20	20	2.784	34	1.15229124
16	50	40	20	20	3.832	34	1.300895794
17	60	40	20	20	3.832	36	1.300895794
18	60	45	20	20	7.026	36	1.658070559
19	50	20	20	20	3.832	40	1.300895794
20	40	20	20	20	2.784	40	1.15229124
21	40	10	20	20	3.832	40	1.300895794
22	40	0	20	20	3.832	42	1.300895794
23	45	0	20	20	7.026	42	1.658070559
24	0	60	30	10	0.000		1
25	0	55	30	10	0.000		1
26	0	50	30	10	0.000		1
27	5	50	30	10	0.000		1
28	10	50	30	10	0.000		1
29	10	55	30	10	0.000		1
30	10	60	30	10	0.000		1
31	5	60	30	10	0.000		1
32	50	60	30	10	0.000		1
33	50	55	30	10	0.000		1
34	50	50	30	10	0.000		1
35	55	50	30	10	0.000		1
36	60	50	30	10	0.000		1
37	60	55	30	10	0.000		1
38	60	60	30	10	0.000		1
39	55	60	30	10	0.000		1
40	50	10	30	10	0.000		1
41	50	5	30	10	0.000		1
42	50	0	30	10	0.000		1
43	55	0	30	10	0.000		1
44	60	0	30	10	0.000		1
45	60	5	30	10	0.000		1
46	60	10	30	10	0.000		1
47	55	10	30	10	0.000		1

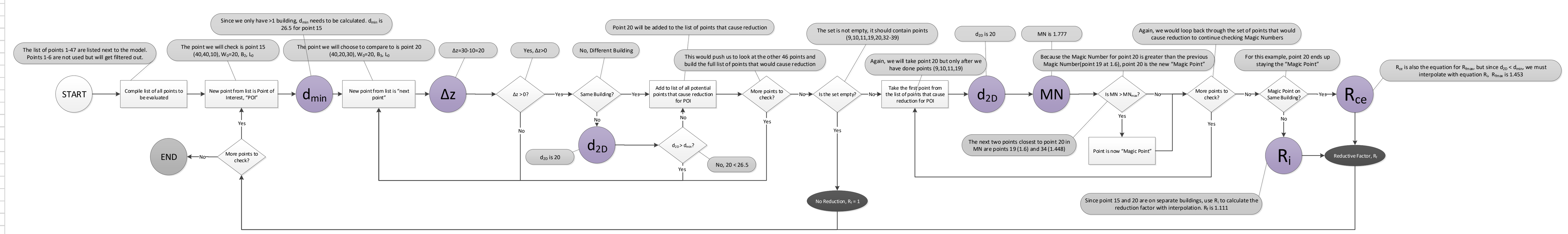
Example 1: Composite building for POI 9





Point #	Building	x	y	z	w	dmin	Max Magic Number	Magic Point	Max Reductive Factor	Total Reductive Factor
1	0	0	0	0	60	0.000	0.000		1.000	1.000
2	0	0	0	0	60	0.000	0.000		1.000	1.000
3	0	0	0	0	60	0.000	0.000		1.000	1.000
4	0	0	0	0	60	0.000	0.000		1.000	1.000
5	0	0	0	0	60	0.000	0.000		1.000	1.000
6	1	0	45	20	20	45.483	5.053	26	1.658	1.658
7	1	0	40	20	20	45.483	2.756	26	1.301	1.301
8	1	10	40	20	20	45.483	2.756	28	1.301	1.301
9	1	20	40	20	20	45.483	2.002	28	1.152	1.152
10	1	20	45	20	20	45.483	2.489	28	1.251	1.251
11	1	20	55	20	20	45.483	2.756	29	1.301	1.301
12	2	45	60	10	20	26.488	3.653	32	1.658	1.658
13	2	40	60	10	20	26.488	1.993	32	1.301	1.301
14	2	40	50	10	20	26.488	1.993	34	1.301	1.301
15	2	40	40	10	20	26.488	1.777	20	1.453	1.111
16	2	50	40	10	20	26.488	1.993	34	1.301	1.301
17	2	60	40	10	20	26.488	1.993	36	1.301	1.301
18	2	60	45	10	20	26.488	3.653	36	1.658	1.658
19	3	50	20	30	20	62.402	3.469	40	1.301	1.301
20	3	40	20	30	20	62.402	2.520	40	1.152	1.152
21	3	40	10	30	20	62.402	3.469	40	1.301	1.301
22	3	40	0	30	20	62.402	3.469	42	1.301	1.301
23	3	45	0	30	20	62.402	6.361	42	1.658	1.658
24	1	0	60	30	10	51.393	0.000		1.000	1.000
25	1	0	55	30	10	51.393	0.000		1.000	1.000
26	1	0	50	30	10	51.393	0.000		1.000	1.000
27	1	5	50	30	10	51.393	0.000		1.000	1.000
28	1	10	50	30	10	51.393	0.000		1.000	1.000
29	1	10	55	30	10	51.393	0.000		1.000	1.000
30	1	10	60	30	10	51.393	0.000		1.000	1.000
31	1	5	60	30	10	51.393	0.000		1.000	1.000
32	2	50	60	20	10	37.459	0.000		1.000	1.000
33	2	50	55	20	10	37.459	1.037	19	1.000	1.000
34	2	50	50	20	10	37.459	1.204	19	1.000	1.000
35	2	55	50	20	10	37.459	1.188	19	1.000	1.000
36	2	60	50	20	10	37.459	1.144	19	1.000	1.000
37	2	60	55	20	10	37.459	0.998	19	1.000	1.000
38	2	60	60	20	10	37.459	0.000		1.000	1.000
39	2	55	60	20	10	37.459	0.000		1.000	1.000
40	3	50	10	40	10	64.322	0.000		1.000	1.000
41	3	50	5	40	10	64.322	0.000		1.000	1.000
42	3	50	0	40	10	64.322	0.000		1.000	1.000
43	3	55	0	40	10	64.322	0.000		1.000	1.000
44	3	60	0	40	10	64.322	0.000		1.000	1.000
45	3	60	5	40	10	64.322	0.000		1.000	1.000
46	3	60	10	40	10	64.322	0.000		1.000	1.000
47	3	55	10	40	10	64.322	0.000		1.000	1.000

Example 2: Separate buildings for POI 15



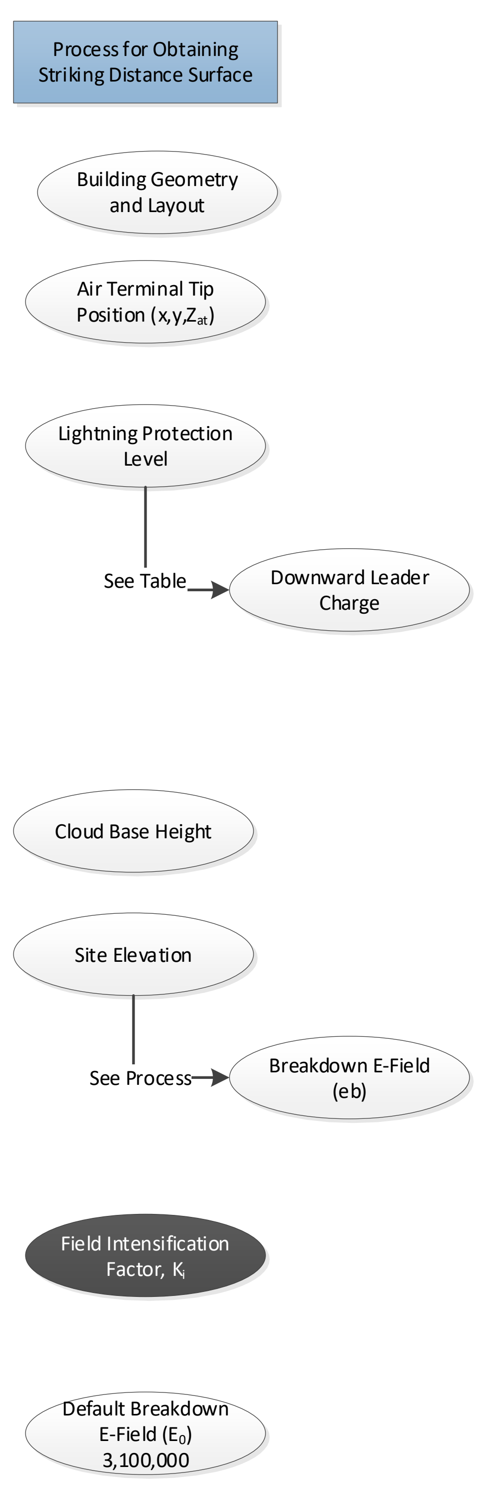
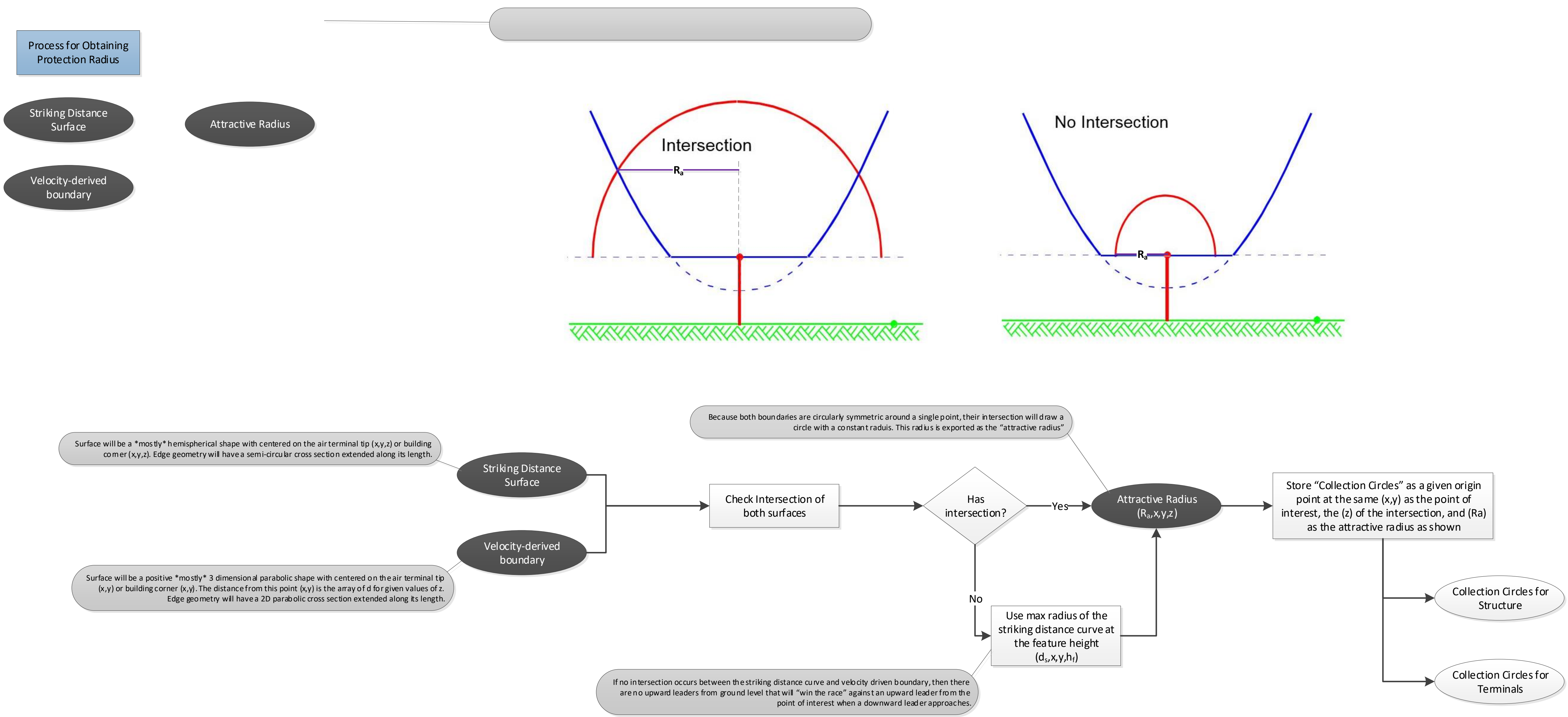


Table 1: Summary of the key parameters and probabilities associated with the lightning protection levels used to design a lightning protection system (LPS) for ordinary structures.

LPL	Leader charge Q (C)	Peak current I_p (kA)	Striking distance (m)	% strikes > I_p (Interception Efficiency)
I	0.16	2.9	20	99
II	0.38	5.4	30	97
III	0.93	10.1	45	91
IV	1.80	15.7	60	84

Process for Obtaining Velocity-derived boundary
Building Geometry and Layout
Air Terminal Tip Position (x,y,Z_{at})
Point of Interest Height, H
Leader Velocity Ratio
Modified Leader Velocity Ratio
Height of DL when breakdown occurs above ground, z_m
Striking Distance, d_s
Linear charge di
Q
h
(d_s-z_m)
z_m
$(z-z_m)$
d_s
H
A
z_m
B
z
d
Linear charge distribution
Q
h
$K_i(H)$
v_u
v_d
d_s
H
A
B
z
d
Comparing Distance over velocity gives time.
$\frac{(d_s - z_m)}{v_u} \leq \frac{(z - z_m)}{v_d}$
Generating the Velocity Driven Boundary is tricky because there is no y=ax^2 +b equation. Rather the function d(z) is a square root function that is undefined for z values less than z0 here.
$z_0 = \frac{K_v H - z_m(K_v - 1)}{K_v + 1}$
d
H
z_0
d_z
z
The default velocity ratio of 1.1 is usually saved as a global variable. The ratio is modified to be 1.075 for LPL 3 and to 1.05 for LPL4
$K_v = \frac{v_d}{v_u}$
Height of DL when breakdown occurs above ground, z_m
Point of Interest Height, H
Leader Velocity Ratio
Luckily, the velocity driven boundary is truncated for all values of z that are less than the height of the point of interest (H). Therefore, before starting any iteration to generate the velocity driven boundary, d(H) should be compared to the striking distance ds (from Process 2) to determine intersection.
Striking Distance, d_s
$d = \frac{z_m(K_v + 1) + H}{K_v}$
Is d_s > d?
Yes
No
The Velocity driven boundary has no intersection with the striking distance curve. Attractive radius is equal to the striking distance, d_s
Build the Velocity driven boundary starting at z = H
$d = \sqrt{\left[\frac{z_m(K_v - 1) + z}{K_v}\right]^2 - (z - H)^2}$
Store (z, d)
Is z > 5H?
Yes
No
Iterate z
Is z > (H+d_s)?
Yes
No
Fill rest of z values with last value
Velocity-derived boundary
Surface will be a positive *mostly* 3 dimensional parabolic shape with centered on the air terminal tip (x,y) or building corner (x,y). The distance from this point (x,y) is the array of d for given values of z. Edge geometry will have a 2D parabolic cross section extended along its length.
The function d(z) has an inflection point where values of d begin to decrease after values of z get too large. In the case where H is small compared to d_s the rest of the values for d should remain vertical when intersecting the striking distance curve.



Process for Obtaining Protection Radius
Striking Distance Surface
Attractive Radius
Velocity-derived boundary
Intersection
R_a
No Intersection
R_a
Because both boundaries are circularly symmetric around a single point, their intersection will draw a circle with a constant raduis. This radius is exported as the "attractive radius"
Surface will be a *mostly* hemispherical shape with centered on the air terminal tip (x,y,z) or building corner (x,y,z). Edge geometry will have a semi-circular cross section extended along its length.
Striking Distance Surface
Velocity-derived boundary
Surface will be a positive *mostly* 3 dimensional parabolic shape with centered on the air terminal tip (x,y) or building corner (x,y). The distance from this point (x,y) is the array of d for given values of z. Edge geometry will have a 2D parabolic cross section extended along its length.
Check Intersection of both surfaces
Has intersection?
Yes
No
Attractive Radius (R_a,x,y,z)
Use max radius of the striking distance curve at the feature height (d_s,x,y,h_f)
If no intersection occurs between the striking distance curve and velocity driven boundary, then there are no upward leaders from ground level that will "win the race" against an upward leader from the point of interest when a downward leader approaches.
Store "Collection Circles" as a given origin point at the same (x,y) as the point of interest, the (z) of the intersection, and (Ra) as the attractive radius as shown
Collection Circles for Structure
Collection Circles for Terminals

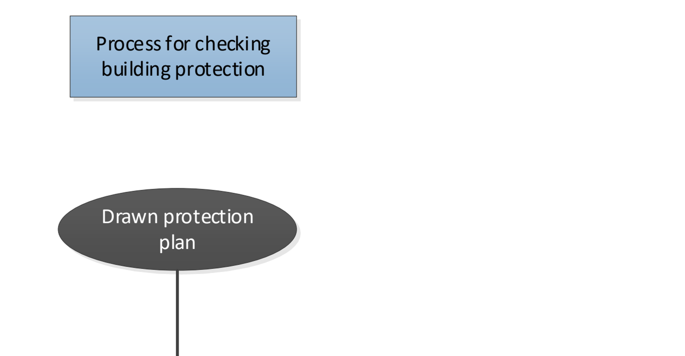
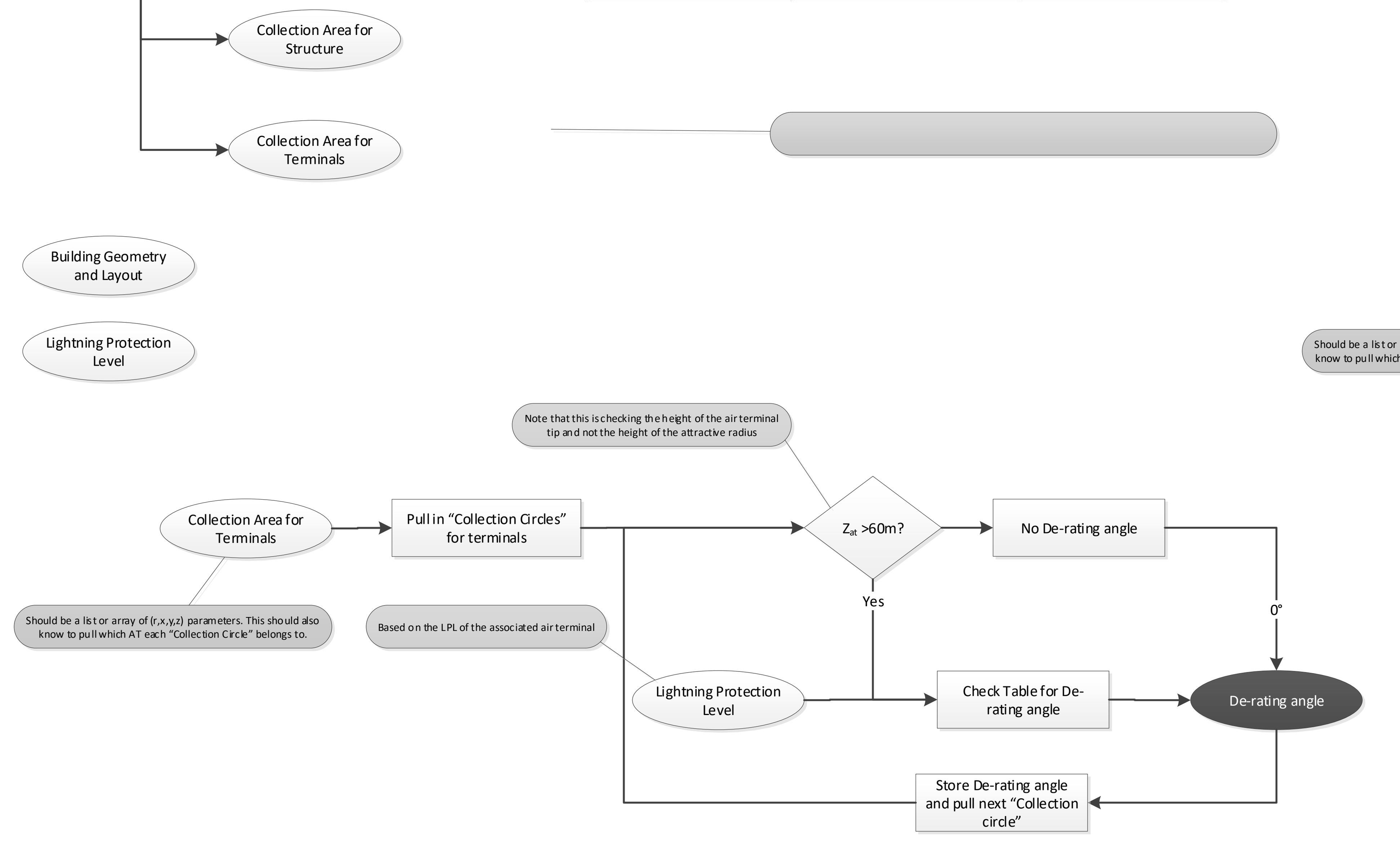
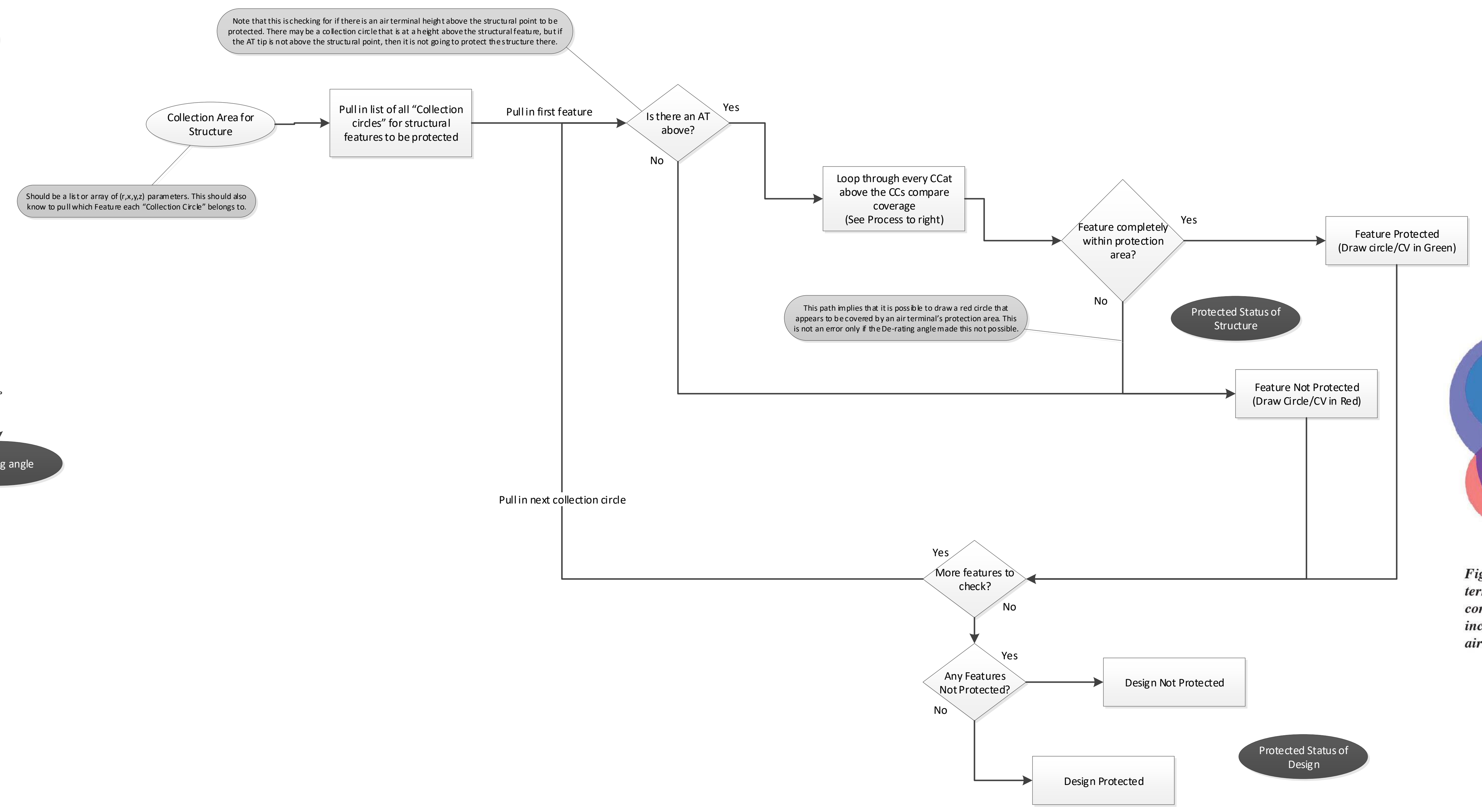


Table 2: De-rating angles applied in the CVM for tall structures (H ≥ 60 m).

LPL	Interception Efficiency	De-rating Angle
I	99	26°
II	97	23°
III	91	20°
IV	84	15°





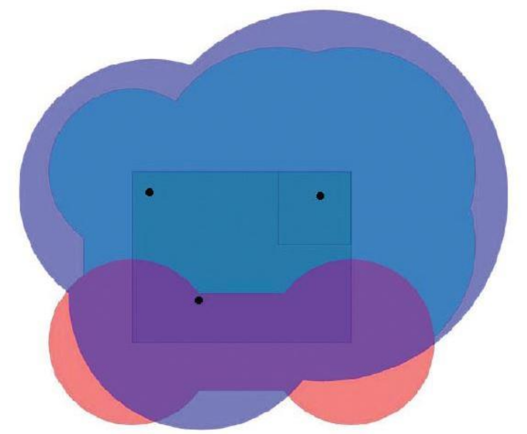


Figure 6: 2D plan view display of the three air termination attractive areas (light blue) and the competing features attractive areas (darker blue), including those not shielded or protected by the air terminations (red areas).

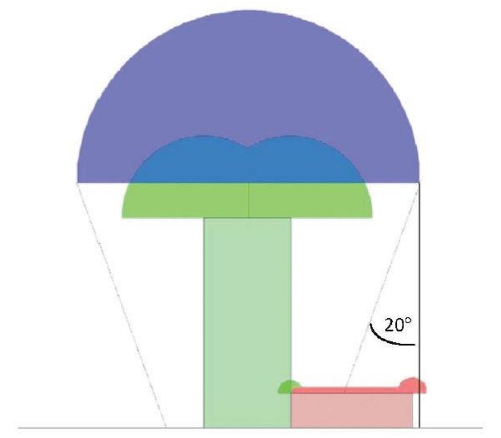


Figure 5: Application of collection volume de-rating to tall structures (example for LPL III). Note that, in this particular example, the lower structure would not have been deemed to be protected anyhow, since the collection volume of the air termination on top of the main building does not overlap the small collection volume of the corners of the lower structure.