

Proposed Revisions to *NADP Site Selection and Installation Manual. (2023).*
Wisconsin State Laboratory of Hygiene EHD NADP PO GENOP 002 OB Version: 1

QAAG Siting Criteria Workgroup

05-April-2023

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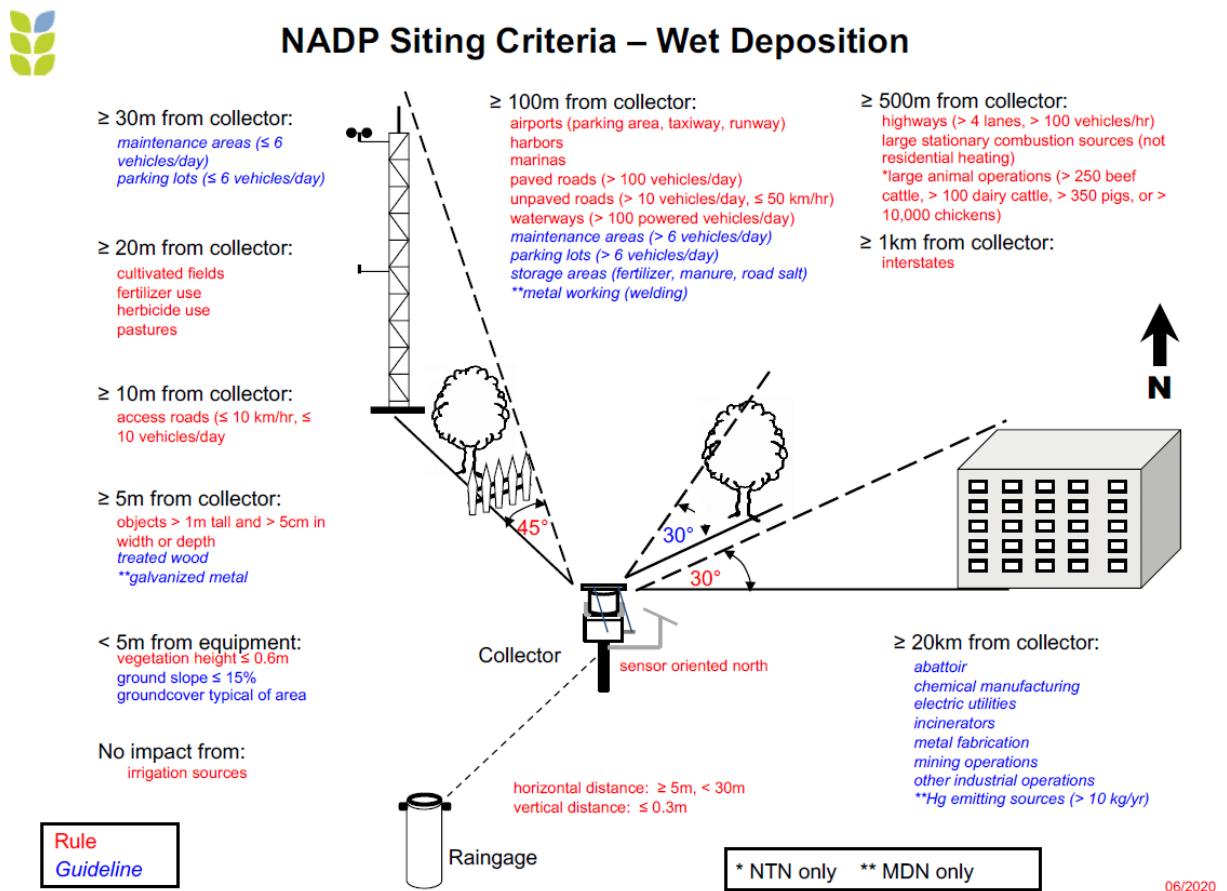
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1. Introduction

The NADP 2010 Site Selection and Installation Manual lists twenty-four* siting criteria rules for both NTN and MDN wet deposition collectors and sixteen or nineteen siting criteria guidance guidelines, for NTN or MDN, respectively (see Figure 1). Reviews of siting criteria evaluations published within the National Atmospheric Deposition Program Site Survey Program Annual Report produced by the NADP auditor, Environmental Engineering and Measurement Services (EE-MS), showed approximately 80% of sites failed to meet all siting criteria. An investigation into the impact of siting criteria violations began through the creation of a NADP QAAG Siting Criteria Subcommittee in 2020.

Figure 1. Current NADP wet deposition siting criteria



*Earlier versions of Figure 1 contained a siting criteria rule for the horizontal width of a building not to exceed 30° from the vantage point of the wet deposition collector

2. Analysis on siting criteria violations and data completeness

The NADP program office provided data from the NADP National Trends Network (NTN) database for analysis, which consisted of weekly sample concentrations, sample debris count and type, quality assurance field and laboratory notes codes, precipitation type, raingage precipitation amounts, sample volume, and quality rating codes (i.e., A, B, C) for samples collected from 2010 to 2019.

EE-MS provided a siting criteria audit database from 2010 to 2019 including fifteen siting criteria rule variables and six siting criteria guidance variables. The siting criteria variables correspond to twenty-three of twenty-four siting criteria rules, where a given database variable may reflect multiple siting criteria rules. There is not presently a database variable for the “No impact from irrigation sources” within the database. An example of linking the siting criteria rules to a corresponding audit database variable would be where the “Collector orifice position audit variable” may apply to either of the following two siting criteria rules: a) the horizontal distance between the raingage and collector must be between 5m and 30m, or b) the vertical distance between the raingage and collector must be $\leq 0.3\text{m}$. The statistics for this analysis apply to audit variables, not different siting criteria rules that were grouped by the audit variables.

Annual percent data completeness values were calculated with respect to weekly samples for every NADP site in the database. Weekly samples had to observe the following criteria to be included within this analysis:

1. Sample volume > 0.01 milliliters
2. Raingage amount > 0.01 inches
3. Sample volume must be between 85% to 110% of raingage precipitation collected
4. Notes codes must not include “b”, “e”, or “u”

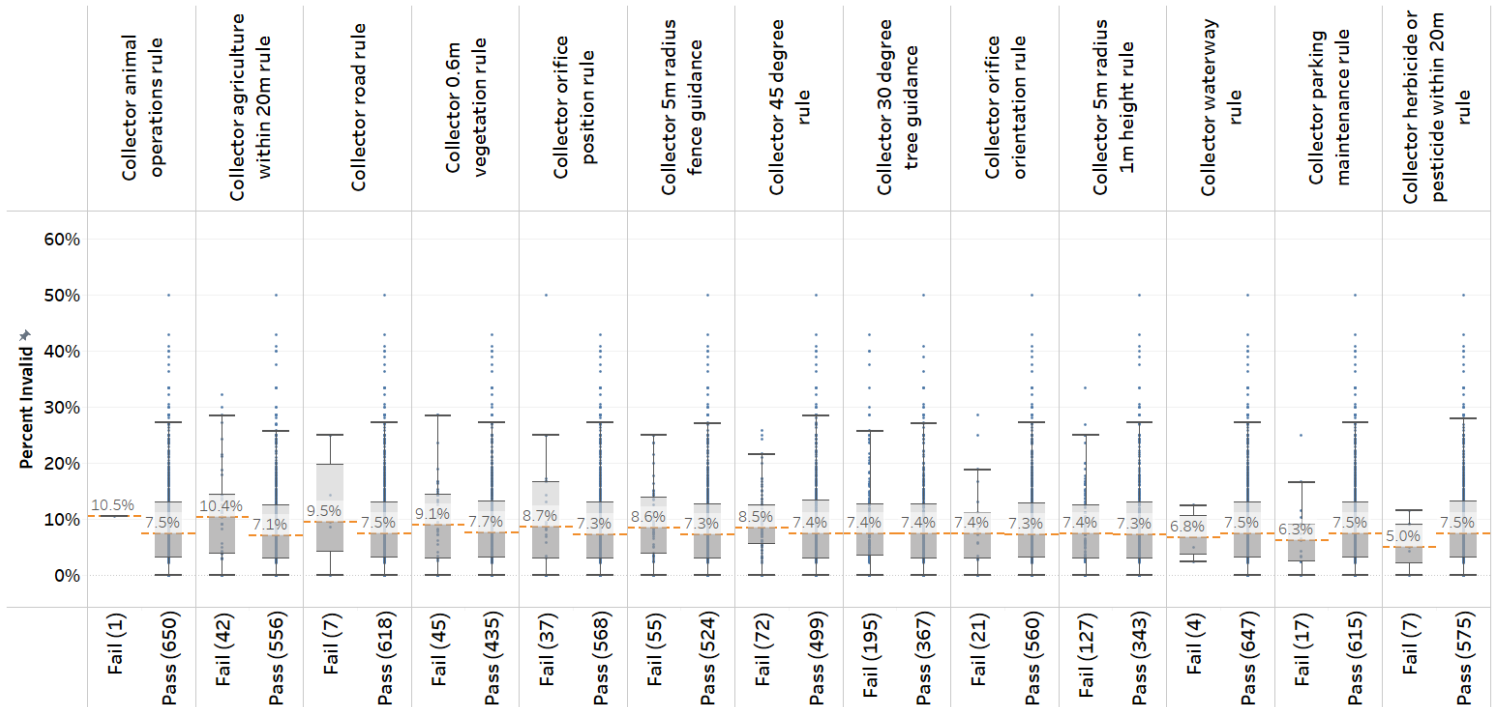
The annual percent data completeness values were compared against selected siting criteria rule and guideline violations for the year that the audit was performed. The assumption was that siting criteria violations should result in higher percentages of invalid samples.

Samples are invalidated by NADP using a scoring system. First, samples are identified as being potentially invalidated due to visible debris in the samples detected by either the site operator or the laboratory or both. If concentrations in a sample are higher than the 95th percentiles for six or more analytes, then the sample is considered contaminated and invalidated. Higher quality data should have the property of lower percent invalid samples. A box and whisker plot of annual percent invalid samples as a function of meeting siting criteria is displayed in Figure 2. Only siting criteria that had both passing and failing results were displayed.

The box and whisker plot's x-axis is labeled with the count of sites that pass or fail each respective criteria, and the median annual percent invalid values are labeled. The box and whisker plots are sorted by descending median percent invalid values that fail the siting criteria. The quantity of sites that pass siting criteria is dramatically larger than the number of sites that fail siting criteria resulting in a significant sample size imbalance when comparing these two groups. There appear to be slightly higher percentages of invalid data from sites that fail the following siting criteria: ‘Collector animal operations rule’, ‘Collector agriculture within 20m rule’, ‘Collector road rule’, ‘Collector 0.6m vegetation rule’, ‘Collector orifice position rule’, ‘Collector 5m fence guidance’, and ‘Collector 45-degree rule’. Lastly,

there appear to be slightly improved data completeness when sites fail the following siting criteria: 'Collector waterway rule', 'Collector parking maintenance rule', and 'Collector herbicide or fertilizer used within 20m rule'.

Figure 2. Box and whisker plot of Percent Invalid Samples for NTN Sites that Passed or Failed Siting Criteria



Statistical comparisons were performed using two different approaches. The first approach was performed in R where subsamples of the annual percent invalid values that passed siting criteria had the same sample size as the number of failures. Only sites with more than four siting criteria failures were evaluated using the Fisher's exact t-test at the 95 percent confidence level ($\alpha < 0.05$). Fifty iterations of randomly subsampling sites that passed siting criteria were compared against sites that failed. Out of fifty iterations of subsamples, the number of iterations where there was observed statistically significant differences in annual percent invalid samples between sites that passed siting criteria versus sites that failed were counted. The 'Collector 45-degree rule' siting criteria had the highest count of statistically significant differences in percent invalid samples, where 24% of the iterations showed statistically significant differences. Also, 12% of the 'Collector orifice position rule' siting violation iterations had statistically significant differences in percent invalid samples.

The second method for evaluating siting criteria violations consisted of using a covariance table within R to compare subsamples of sites in three different categories.

- 1) Sites with less than 5% vs sites that had 5% or greater annual invalid data,
- 2) Sites that had less than 10% vs sites that had 10% or greater annual invalid data, and

- 3) Sites that had less than 20% vs sites that had 20% or greater annual invalid data and whether the sites passed or failed the respective siting criteria.

The results of this evaluation showed a statistically significant difference for the 'Collector 45-degree rule' and sites that were binned by above or below 5% annual invalid data. Another criteria that showed significant differences was the 'Collector agriculture within 20m rule' at above or below 10% annual invalid data.

Three siting criteria rules stand out as showing significant differences when they are violated, including:

- 1) 'Collector 45-degree rule',
- 2) 'Collector agriculture within 20m rule', and
- 3) 'Collector orifice position rule'.

It is noteworthy that the 'Collector 45-degree rule' is the third most commonly violated siting criteria.

Despite having the highest frequency of siting criteria violations, 'Collector 5m radius 1m height rule', 'Collector 0.6m vegetation rule', and 'Collector 30-degree tree guidance' did not have statistically significant impacts with respect to percent invalid data for this study; but were found to have impacts by Wetherbee et al. (2011) and Graham et al. (1990). This result is important because these violations have the highest sample size of failures, but the violations do not appear to be detrimental to data quality.

Wetherbee et al. (2011) found significantly higher numbers of samples containing debris when the collector was in violation of:

- 1) The 45-degree building or tree rule,
- 2) vegetation exceeded 0.6m within 5m of the collector rule,
- 3) Object >1m height within 5m of the collector rule, and
- 4) The 30-degree tree guidance.

Wetherbee et al. (2011) actually found that fewer weekly NTN samples had debris when the vegetation exceeded 0.6m around the collector, suggesting that violation of this siting criteria resulted in better data completeness. Graham (1990) also found statistically significant impacts when there was a violation of the 45-degree building or tree rule and for the object >1m height within 5m of the collector rule. Graham also displayed an unusual finding that wet deposition samples closer to a road appeared to show less cation contamination than samples farther from the road. Lastly, Graham suggested that sample collectors should utilize wind shields when they are present on the raingages, which is supported by Wetherbee et al. (2013).

Table 1 summarizes how the NADP siting criteria rules (columns A to C) are grouped within the EEMS audit database (columns D and E) by shading the rows. Table 2 summarizes the evaluations performed on the siting criteria rules from Table 1, including the quantity of sites that pass, fail, and percent that fail each siting criteria, respectively. Table 2 also reports the results of the Fisher's Exact t-test with corresponding percentages of statistically significant differences of annual percent invalid samples using 50 iterations between sites that pass or fail respective siting criteria (column J), column K reports the contingency table results where there were differences at 5% and 10% invalid data. Table 2's columns L

and M provide references for supporting evidence. Lastly, column N shows the suggested revisions to the siting criteria, where three siting criteria rules are proposed to be changed to guidance.

Table 3 is identical to Table 1, but for select NADP siting criteria guidance. Similarly, Table 4 is identical to Table 2, for these same NADP siting criteria guidance.

Abbreviations used within Tables 1 to 4 include: [hr, hour; m, meter; cm, centimeters; km, kilometer; % fail, percentage of sites that fail siting criteria; Qty, quantity; n, number or sample size; “Stat Diff” and “Statistically significant”, differences are statistically significant with 95 percent confidence ($\alpha=0.05$); Proposal, designation of NADP siting criteria rule or guidance based on this study; Rule, auditable siting criteria per NADP practices; Guidance, non-auditable best practice per NADP recommendation]

Table 1. Summary of the NADP siting criteria rules and associated EEMS audit database variables

A	B	C	D	E
C1	NADP Siting Criteria (label)	NADP Siting Criteria (units)	C2	Audit Database Criteria
Rules				
1	Large stationary combustion sources (not residential heating)	≥ 500m from collector	1	Collector large combustion source rule
2	Buildings	30-degrees (horizontal)	2	Collector 30-degree building rule (horizontal)
3	Large animal operations (> 250 beef cattle, > 100 dairy cattle, > 350 pigs, or >10,000 chickens)	≥ 500m from collector	3	Collector animal operations rule
4	Buildings	30-degrees (vertical)	4	Collector building 30-degree rule (vertical)
5	Airports (parking area, taxiway, runway)	≥ 100m from collector	5	Collector airport rule
6	Waterways (> 100 powered vehicles/day)	≥ 100m from collector	6	Collector waterway rule
7	Harbors	≥ 100m from collector	6	Collector waterway rule
8	Marinas	≥ 100m from collector	6	Collector waterway rule
9	Access roads (≤ 10 km/hr, ≤ 10 vehicles/day)	≥ 10m from collector	7	Collector road rule
10	Paved roads (> 100 vehicles/day)	≥ 100m from collector	7	Collector road rule
11	Unpaved roads (> 10 vehicles/day, ≤ 50 km/hr)	≥ 100m from collector	7	Collector road rule
12	Highways (> 4 lanes, > 100 vehicles/hr)	≥ 500m from collector	7	Collector road rule
13	Interstates	≥ 1km from collector	7	Collector road rule
14	Herbicide use	≥ 20m from collector	8	Collector herbicide or fertilizer within 20m rule
15	Fertilizer use	≥ 20m from collector	8	Collector herbicide or fertilizer within 20m rule
16	Collector orientation	45-degrees +/- of West; grid sensor North	9	Collector orifice orientation rule
17	Rain gage position to collector	horizontal distance must be ≥ 5m, < 30m	10	Collector orifice position rule
18	Rain gage position to collector	vertical distance must be ≤ 0.3m	10	Collector orifice position rule
19	Cultivated fields	≥ 20m from collector	11	Collector agriculture within 20m rule
20	Pastures	≥ 20m from collector	11	Collector agriculture within 20m rule
21	Trees, fences, etc	45-degrees (horizontal)	12	Collector 45-degree rule
22	Vegetation height ≤ 0.6m	<5 m from collector	13	Collector 0.6m vegetation rule
23	Objects > 1m tall and > 5cm in width or depth	≥ 5m from collector	14	Collector 5m radius 1m height rule
24	Irrigation sources	All distances		{Irrigation sources}

Table 2. Summary Evaluation of the NADP siting criteria rules, T-test and Contingency Results, Supporting Peer-reviews, and QAAG Proposal

E	F	G	H	I	J	K	L	M	N
Audit Database Criteria	Qty Pass	Qty Fail	% Fail	Evaluated	Fisher t-test (n=50)	Contingency Table	Wetherbee et al., 2011	Graham 1990	Proposal
Collector large combustion source rule	651	0	0%	No					Rule
Collector 30-degree building rule (horizontal)	649	0	0%	No					Rule
Collector animal operations rule	650	1	0%	No					Rule
Collector building 30-degree rule (vertical)	651	0	0%	No					Rule
Collector airport rule	649	0	0%	No					Rule
Collector waterway rule	647	4	1%	Yes	2% of subsamples				Rule
Collector waterway rule	647	4	1%	Yes	2% of subsamples				Rule
Collector waterway rule	647	4	1%	Yes	2% of subsamples				Rule
Collector road rule	618	7	1%	Yes				Possible contamination	Rule
Collector road rule	618	7	1%	Yes				Possible contamination	Rule
Collector road rule	618	7	1%	Yes				Possible contamination	Rule
Collector road rule	618	7	1%	Yes				Possible contamination	Rule
Collector road rule	618	7	1%	Yes				Possible contamination	Rule
Collector herbicide or fertilizer within 20m rule	612	41	6%	Yes					Guidance
Collector herbicide or fertilizer within 20m rule	612	41	6%	Yes					Rule
Collector orifice orientation rule	560	21	4%	Yes					Rule
Collector orifice position rule	568	37	6%	Yes	12% of subsamples				Rule
Collector orifice position rule	568	37	6%	Yes	12% of subsamples				Rule
Collector agriculture within 20m rule	575	7	1%	Yes	8% of subsamples	Stat Diff at 10% Invalid			Rule
Collector agriculture within 20m rule	575	7	1%	Yes	8% of subsamples	Stat Diff at 10% Invalid			Rule
Collector 45-degree rule	499	72	13%	Yes	24% of subsamples	Stat Diff at 5% Invalid	Statistically significant	Statistically significant	Rule
Collector 0.6m vegetation rule	435	45	9%	Yes			Statistically significant		Guidance
Collector 5m radius 1m height rule	343	127	27%	Yes			Statistically significant	Statistically significant	Guidance
{Irrigation sources}				No					Rule

Table 3. Summary of selected NADP siting criteria guidelines and associated EEMS audit database variables

A	B	C	D	E
Guidance				
1	Storage areas	>100m	1	Collector storage area guidance
2	Maintenance areas (>6 vehicles/day)	30m	2	Collector parking maintenance rule
3	Parking lots (>6 vehicles/day)	30m	2	Collector parking maintenance rule
4	Should not be impacted by fence (not shown in figure)		3	Collector 5m radius fence guidance
5	30-degree tree	All distances	4	Collector 30-degree tree guidance

Table 4. Summary Evaluation of selected NADP siting criteria guidelines, T-test and Contingency Results, Supporting Peer-reviews, and QAAG Proposal

E	F	G	H	I	J	K	L	M	N
Audit Database Criteria	Qty Pass	Qty Fail	% Fail	Evaluated	Fisher t-test (n=50)	Contingency Table	Wetherbee et al., 2011	Graham 1990	Proposal
Collector storage area guidance	638	0	0%	No					Guidance
Collector parking maintenance rule	615	17	3%	Yes					Guidance
Collector parking maintenance rule	615	17	3%	Yes					Guidance
Collector 5m radius fence guidance	524	55	9%	Yes	2% of subsamples				Guidance
Collector 30-degree tree guidance	367	195	35%	Yes	2% of subsamples		Statistically significant		Guidance

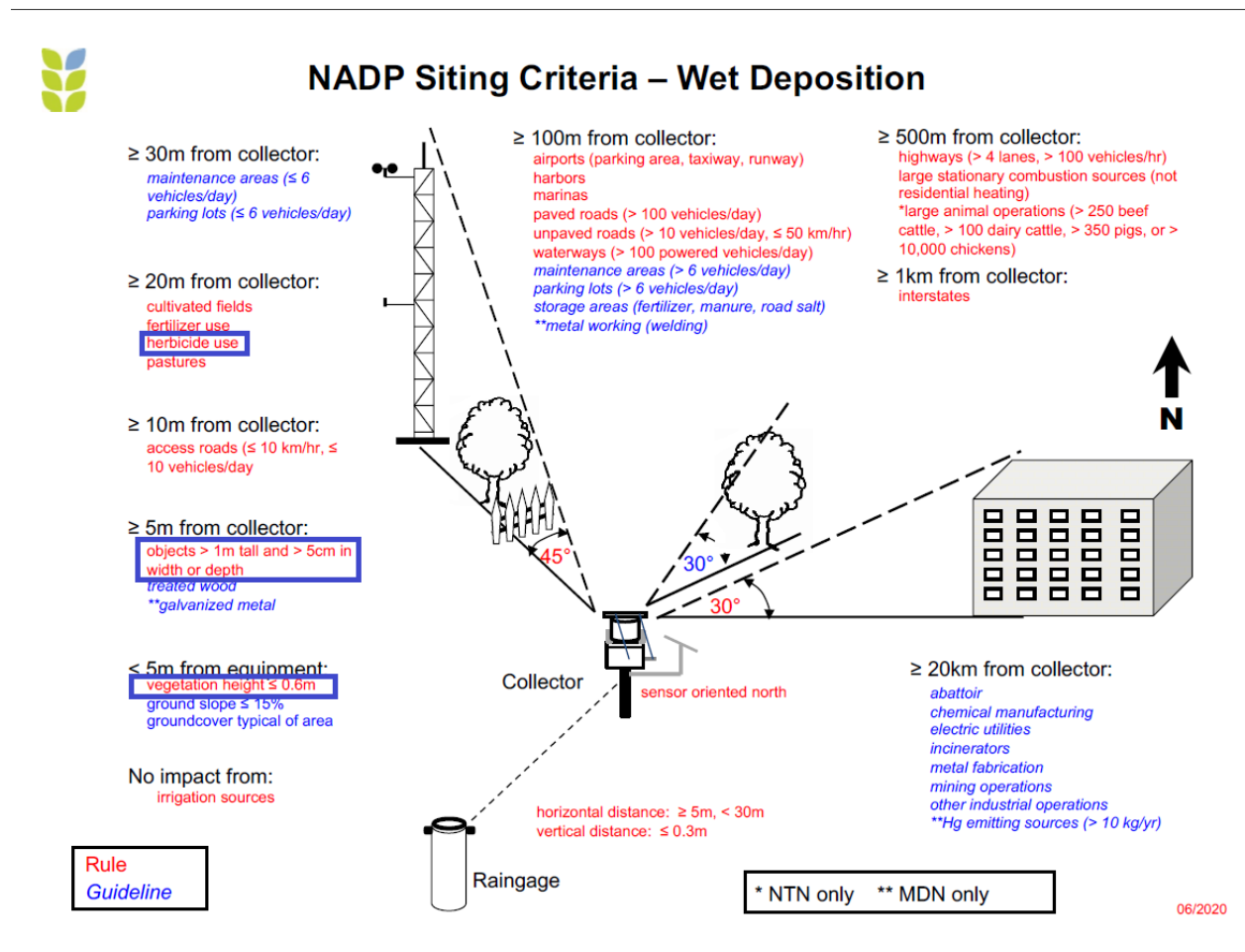
3. Conclusions

Despite wide-spread siting criteria violations throughout NTN, it appears that only a few siting criteria have statistically significant negative impacts to the data completeness. The results indicate that the most common siting criteria violations do not appear to have significant impacts to the data integrity. It appears that the following three rules should be changed to guidance:

- 1) 'Collector 0.6m vegetation rule',
- 2) 'Collector 5m radius 1m height rule', and
- 3) 'Collector herbicide use rule'.

The herbicide rule should be changed to guidance because while data completeness was not significantly different when there was a violation of this criteria, the analysis (Fig. 1) showed an improvement in data completeness when this criterion was violated. Other considerations for this herbicide criteria include the health and safety of the site operator who may also need to spray insecticides to control dangerous insects that nest in or near NADP instruments. A table of siting criteria violations and the years of the respective audits will be shared on the NADP website for data users.

Figure 3. Proposed revisions to the NADP wet deposition siting criteria. Changes to three siting criteria from rules to guidance are denoted by the blue rectangles.



Cited References

Graham, R.C. and Robertson, J.K., 1990, An assessment of performance of wet atmospheric deposition samplers: U.S. Geological Survey Water-Resources Investigations Report 90-4042, 101 p.

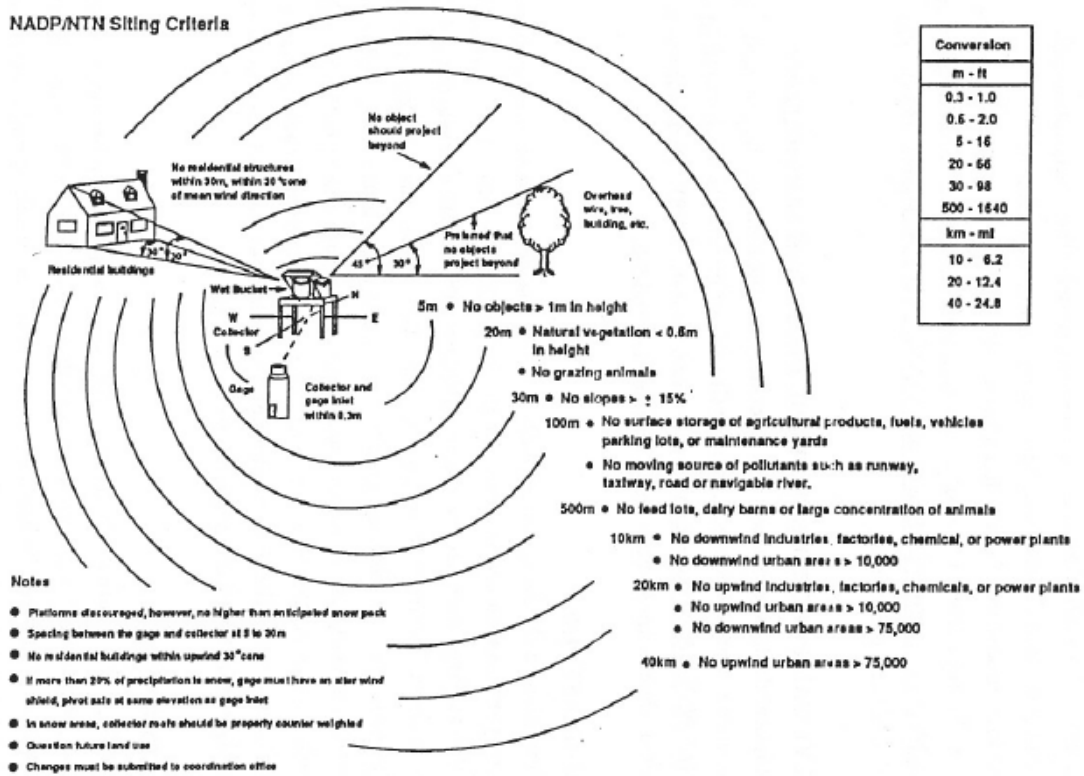
Graham, R.C., 1990, An assessment of performance of wet atmospheric deposition samplers, part 2—validation of siting criteria: *Water, Air, and Soil Pollution*, v. 52, p. 97–114.

Wetherbee, G.A., Latysh, N.E., Lehmann, C.M.B., and Rhodes, M.F., 2011, Four studies on effects of environmental factors on the quality of National Atmospheric Deposition Program measurements: U.S. Geological Survey Open-File Report 2011–1170, 36 p.

Wetherbee, G.A., and Rhodes, M.F., 2013, Effects of equipment performance on data quality from the National Atmospheric Deposition Program/National Trends Network and the Mercury Deposition Network: U.S. Geological Survey Open-File Report 2013–1031, 53 p.

NTN Sample Condition Flags		
Notes	Description	QR Code ¹
a	Incomplete laboratory analysis	B
b	Bulk sample	C
c	Grossly contaminated sample	C
d	Visible debris in sample	B
e	Extended sampling period (>194 hr.)	C
f	Major field protocol issue	C
h	Sample handling issue	B
i	Low volume (diluted) sample	B
l	Laboratory error	C
m	Missing data	B
n	No sample deployed	---
p	Precipitation value unknown	C
u	Undefined sample	C
v	Inadequate sample volume for full analysis	C
z	Site operation issue	B
¹ Quality Rating (QR) Code Definitions: A – Fully qualified data B – Valid data with minor issues C – Invalid data		

NADP/NTN Siting Criteria



Conversion	
m - ft	
0.3 - 1.0	
0.6 - 2.0	
5 - 16	
20 - 66	
30 - 98	
500 - 1640	
km - mi	
10 - 6.2	
20 - 12.4	
40 - 24.8	

Figure 2-1. NADP/NTN Siting Criteria.