D12 FIU SITE CHARACTERIZATION SUPPORTING DATA

PREPARED BY	ORGANIZATION	DATE
E Ayres/ H Luo/ H Loescher/J Taylor	FIU	08/08/2013

APPROVALS (Name)	ORGANIZATION	APPROVAL DATE
David Tazik	CCB PROJ SCI	09/17/2013
Hanne Buur	CCB DIR SE	09/23/2013

RELEASED BY (Name)	ORGANIZATION	RELEASE DATE
Stephen Craft	SE	09/27/2013

See Configuration Management System for approval history.

CHANGE RECORD

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	1/21/2011	ECO-00070	INITIAL RELEASE
B	09/26/2011	ECO-00279	Update to new document numbers/template throughout document
C	09/27/2013	ECO-01352	Update document to include the information for the new Bozeman and Paradise Valley relocatable sites

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1 DESCRIPTION

1.1 Purpose

Data collected, analyzed and described here are used to inform the site design activities for NEON project teams: EHS (permitting), FCC, ENG and FSU. This report was made based on actual site visits to the 3 NEON sites in Domain 12. This document presents all the supporting data for FIU site characterization at D12.

1.2 Scope

FIU site characterization data and analysis results presented in this document are for the three D12 tower locations: Yellowstone National Park (Advanced), Bozeman site (Relocatable 1) and Paradise Valley site (Relocatable 2). Issues and concerns for each site that need further review are also addressed in this document according to our best knowledge.

Disclaimer: all latitude and longitude points are subject to the tolerances of our measurement system, i.e., GPS.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

AD[01]	NEON.DOC.011008	FIU Tower Design Science Requirements
AD[02]	NEON.DOC.011000	FIU Technical and Operation Requirements
AD[03]	NEON.DOC.011029	FIU Precipitation Collector Site Design Requirements

2.2 Reference Documents

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms

2.3 Acronyms

2.4 Verb Convention

"Shall" is used whenever a specification expresses a provision that is binding. The verbs "should" and "may" express non-mandatory provisions. "Will" is used to express a declaration of purpose on the part of the design activity.

3 YELLOWSTONE NATIONAL PARK (ADVANCED TOWER SITE)

3.1 Site Description

Yellowstone National Park covers ~9000 km^2 includes portions of Wyoming, Montana, and Idaho. The Park receives many visitors each day and the National Park would require that the NEON site be as inconspicuous as possible. This has influenced the site design and will likely reduce the quality of the data collected at this site (see Issues and Attentions section). Additional information on Yellowstone can be found at http://www.nps.gov/yell/index.htm.

The original location of the tower at this site was 44.955, -110.54. However, during the site characterization this location was deemed unacceptable to Yellowstone National Park and the NEON tower was microsited to 44.95348, -110.53914 (~180 m from the original location), an opening surrounded by trees that will limit the visibility of the tower. The new tower is located ~230 m from Blacktail Road.

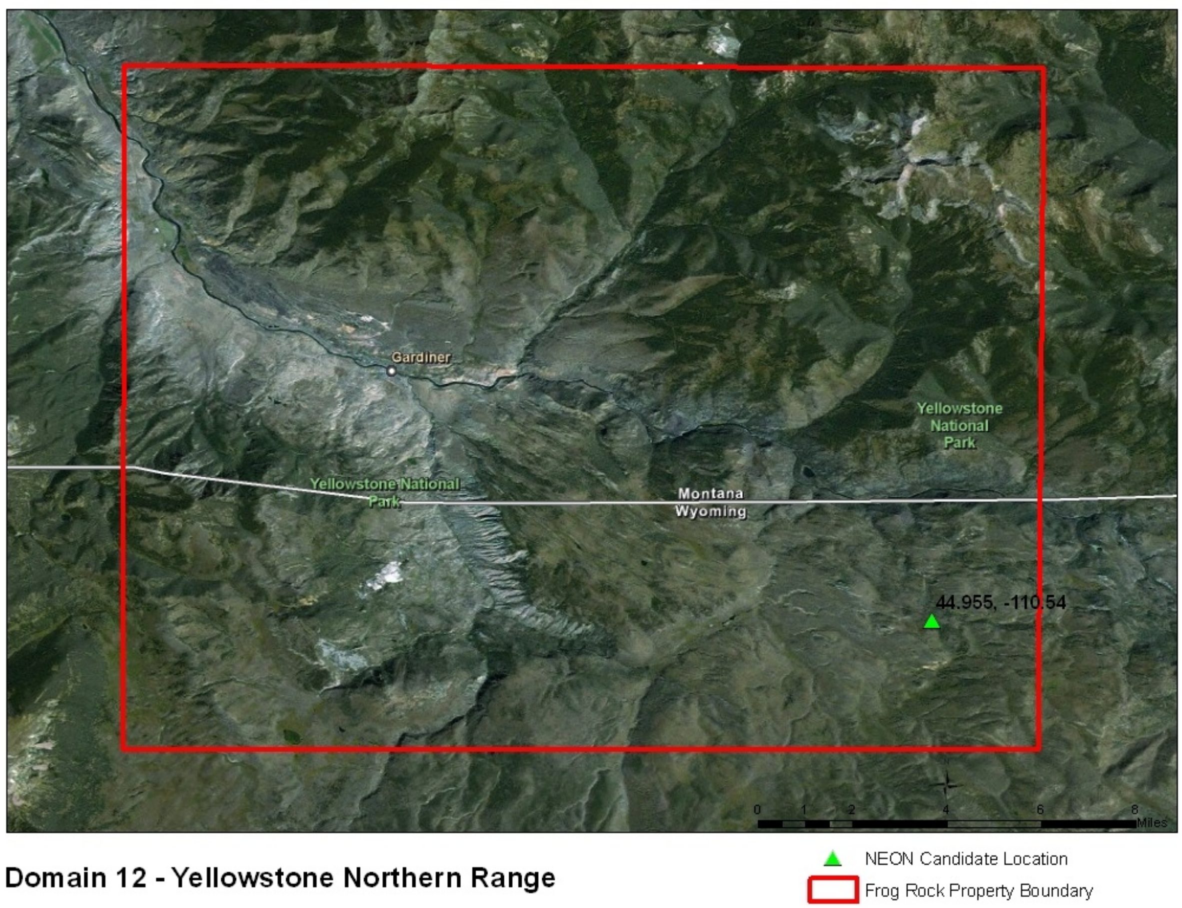
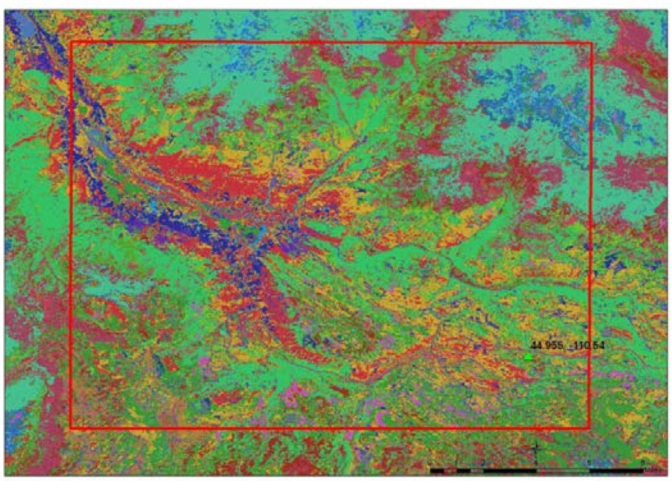


Figure 1. NEON candidate site tower location and boundary map. Coordinates represent the initial (old) tower site prior to micrositing.

3.2 Ecosystem

Vegetation and land cover information at surrounding region are presented below:



Domain 12 - Yellowstone Northern Range

Figure 2. Vegetative cover map of Yellowstone National Park tower site and surrounding areas (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm).

Table 1. Percent Land cover type at Yellowstone National Park Advance site (information is from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Vegetation Type	**Area**	**Percentage**
Open Water	1.89	0.37
Snow-Ice	0.00	0.00
Developed-Open Space	3.03	0.59
Developed-Low Intensity	0.69	0.13
Developed-Medium Intensity	0.20	0.04
Developed-High Intensity	0.00	0.00
Barren	1.18	0.23
Agriculture-Pasture and Hay	1.55	0.30
Agriculture-Cultivated Crops and Irrigated Agriculture	0.07	0.01
Rocky Mountain Aspen Forest and Woodland	21.49	4.17
Rocky Mountain Bigtooth Maple Ravine Woodland	0.04	0.01
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	0.00	0.00
Northern Rocky Mountain Subalpine Woodland and Parkland	52.93	10.28
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	0.72	0.14
Rocky Mountain Foothill Limber Pine-Juniper Woodland	1.05	0.20
Rocky Mountain Lodgepole Pine Forest	19.18	3.72
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	23.61	4.58
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	14.27	2.77
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	4.39	0.85
Rocky Mountain Alpine Dwarf-Shrubland	2.32	0.45
Inter-Mountain Basins Big Sagebrush Shrubland	3.73	0.72
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	5.80	1.13
Inter-Mountain Basins Big Sagebrush Steppe	4.87	0.95
Inter-Mountain Basins Montane Sagebrush Steppe	69.86	13.56
Inter-Mountain Basins Semi-Desert Shrub-Steppe	2.39	0.46
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	14.81	2.88
Northern Rocky Mountain Subalpine-Upper Montane Grassland	9.17	1.78
Rocky Mountain Alpine Turf	5.35	1.04
Rocky Mountain Subalpine-Montane Mesic Meadow	60.50	11.75
Rocky Mountain Montane Riparian Systems	3.96	0.77
Rocky Mountain Subalpine/Upper Montane Riparian Systems	11.10	2.16
Northern Rocky Mountain Conifer Swamp	1.81	0.35
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	24.08	4.68
Rocky Mountain Poor-Site Lodgepole Pine Forest	0.26	0.05
Northern Rocky Mountain Subalpine Deciduous Shrubland	4.82	0.94
Introduced Upland Vegetation-Perennial Grassland and Forbland	4.46	0.87
Artemisia tridentata ssp. vaseyana Shrubland Alliance	55.07	10.69
Pseudotsuga menziesii Forest Alliance	84.36	16.38
Total Area sq km	515.02	100.00

The NEON site at Yellowstone is a mosaic of pine-dominated forest and grassland. The terrain consists of rolling hills with small wetlands in the bottom of the depressions. The pine forest has an open structure. The tower is located on a lava tongue in an opening (~40 m diameter) surrounded by pine trees. There is little soil around the tower (only a few centimeters deep in most places) and 20-30% of the ground is exposed rock. Due to the shallow soil vegetation around the tower is sparse and consists of grasses, forbs, and aspen seedlings. The mean canopy height for the pine trees is ~ 14 m with lowest branch at ~ 2.5 m. Some small trees form top understory with height around 8 m. Some tree seedlings and shrubs form next understory with height around 1 m. Grasses form the understory at floor level with mean height ~ 0.4 m.

Figure 3. The Yellowstone Advanced site consists of patches of pine-dominated forest and grassland.

Table 2. Ecosystem and site attributes for Yellowstone Advanced tower site.

Ecosystem attributes	Measure and units
Mean canopy height	14 m
Surface roughness[a]	2 m
Zero place displacement height[a]	10 m
Structural elements	Open pine-dominated forest
Time zone	Mountain time zone
Magnetic declination	12° 27' E changing by 0° 9' W/year

Note, [a] From field observation.

3.3 Soils

3.3.1 Soil Description

NRCS soil map and data were not available for the Yellowstone site.

3.3.2 Soil Semi-Variogram Description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 4). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 4).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 4), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

The variogram analysis will be used, to determine the spatial scales at which we can consider soil measurements spatially independent. This characterization will directly inform the minimum distance between *i*) soil plots within each soil array, *ii*) the soil profile measurements, *iii*) EP plots, and *iv*) the microbial sampling locations. These data will directly inform NEON construction and site design activities.

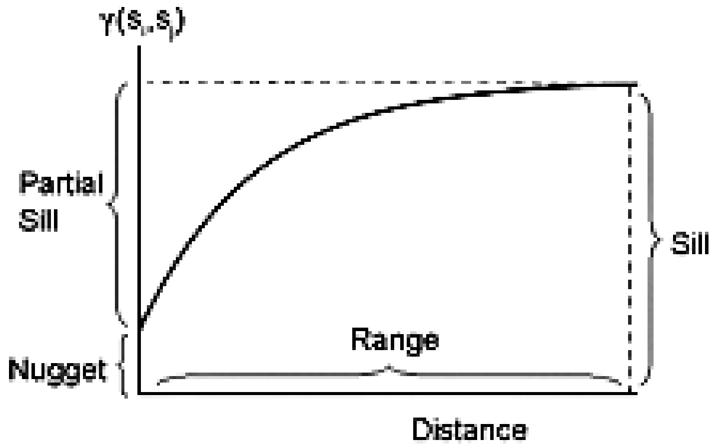


Figure 4. Example semivariogram, depicting range, sill, and nugget.

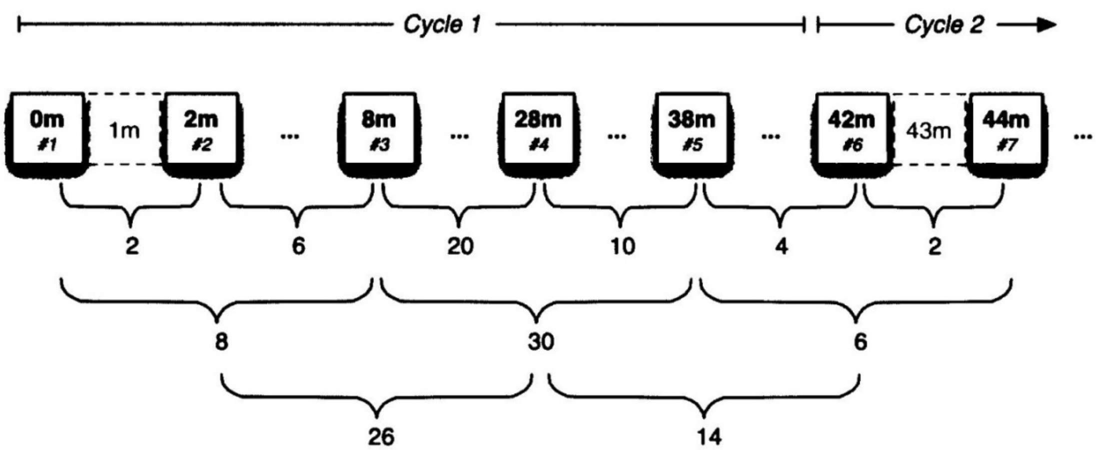


Figure 5. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 22 July 2010 at the Yellowstone site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 5). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Yellowstone. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain dielectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 5, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Trangmar *et al.* 1986; Webster & Oliver 1989; Goovaerts 1997; Riberiro & Diggle 2001) and estimate the distance necessary for independence among soil plots in the soil array. To correct for changes in temperature and moisture over the sampling period, the stationary data was subtracted from the mobile data. In many instances a time of day trend was still apparent in the data even after subtracting the stationary data from the mobile data. This time of day trend was corrected for by fitting a linear regression and using the residuals for the semivariogram analysis. Soil temperature and moisture data, R code, graphs, and R output can be found at: P:\FIU\FIU_Site_Characterization\DXX\YYYYYYY_Characterization\Soil Measurements\Soil Data Analysis (where XX = domain number and YYYYYYY = site name).

3.3.3 Results and Interpretation

3.3.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 6). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 7, left graph) and directional semivariograms do not show anisotropy at lags of <100 m (Figure 7, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 7, right graph). The model indicates a distance of effective independence of 31 m for soil temperature.

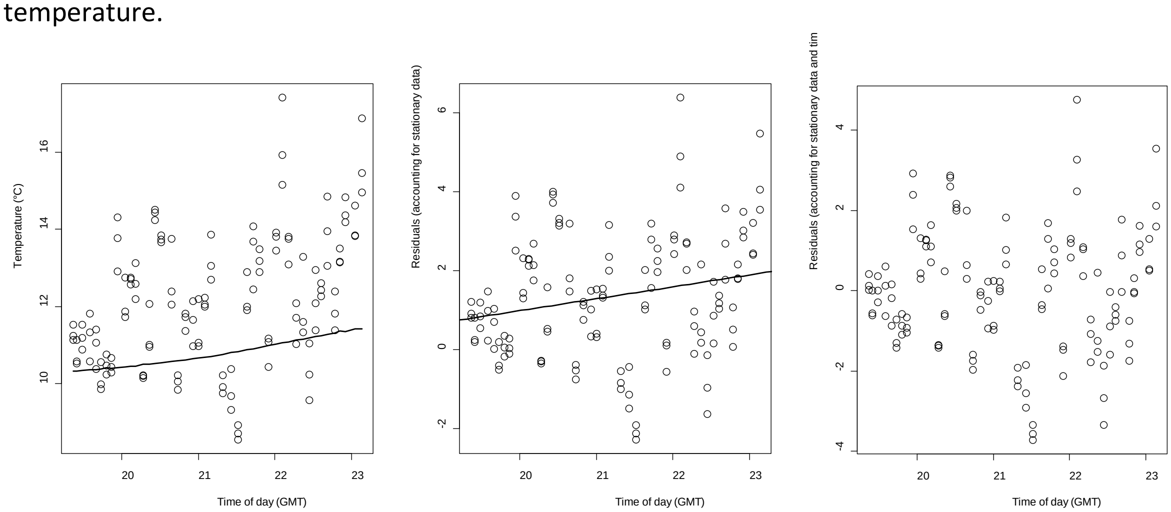


Figure 6. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

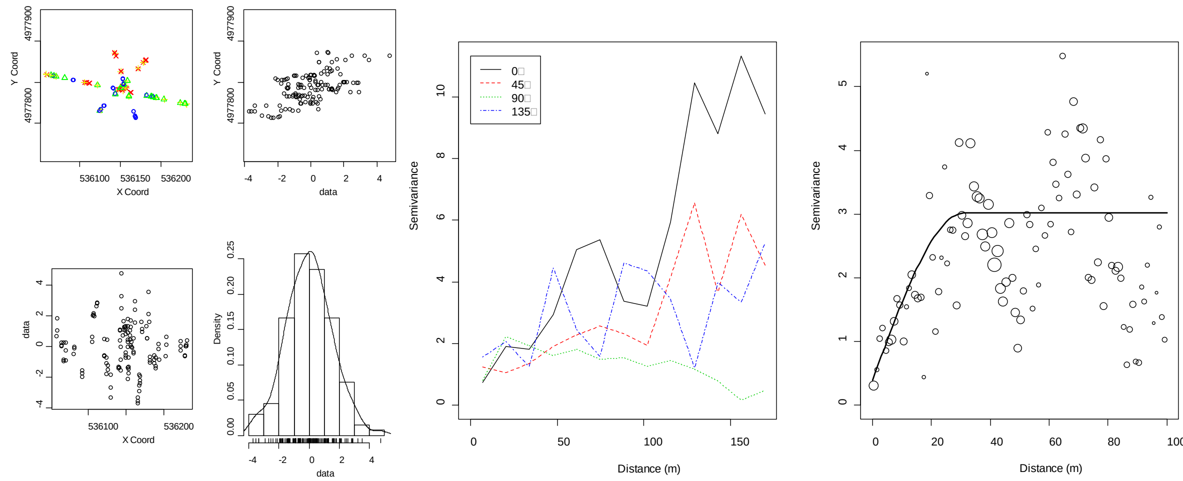


Figure 7. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

3.3.3.2 Soil water content

Soil water content data residuals, after accounting for changes in water content in the stationary data and any remaining time of day trend, were used for the semivariogram analysis (Figure 8). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 9, left graph) and directional semivariograms do not show anisotropy (Figure 9, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 9, right graph). The model indicates a distance of effective independence of 15 m for soil water content.

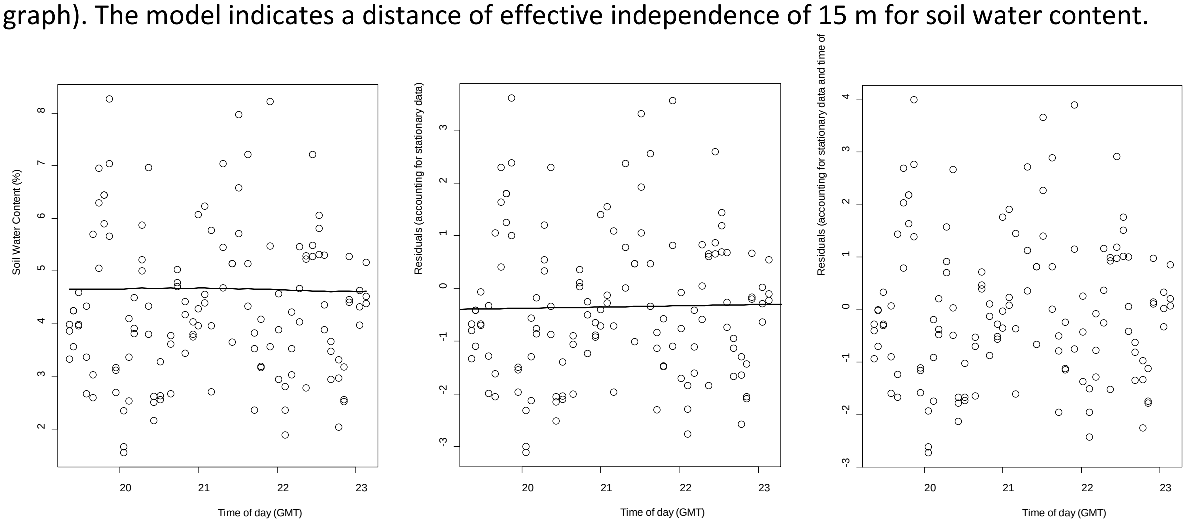


Figure 8. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting for changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

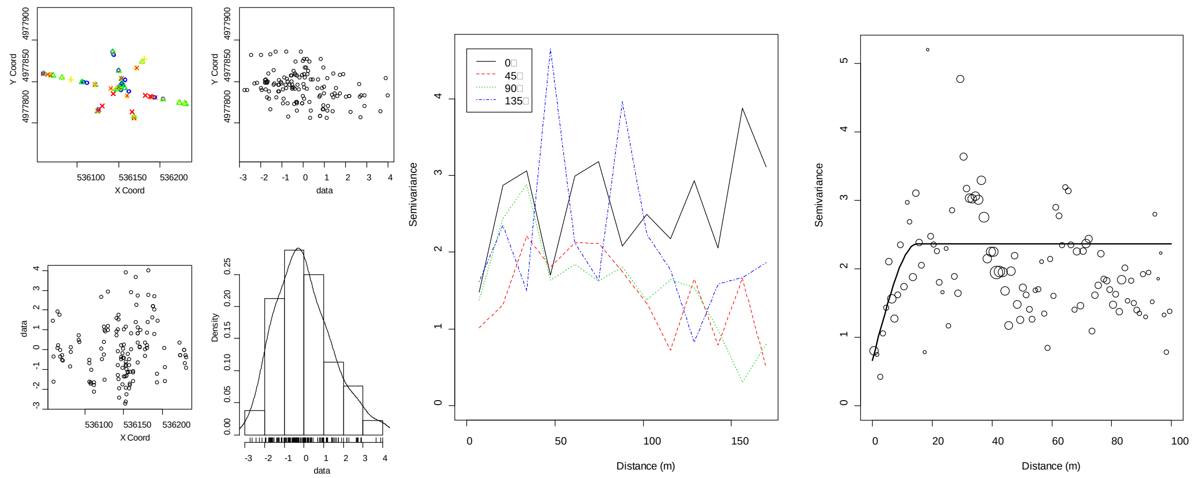


Figure 9. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content

3.3.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 31 m for soil temperature and 15 m for soil moisture. Based on these results and the site design guidelines the soil plots at Yellowstone shall be placed 31 m apart. The soil array shall follow the linear soil array design (Soil Array Pattern B) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 285° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 44.95288, -110.54069. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 44.95597, -110.54197 (primary location); or 44.95598, -110.54149 (alternate location 1 if primary location is unsuitable); or 44.95602, -110.54087 (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 3 and site layout can be seen in Figure 10.

Dominant soil series at the site: Unknown (NRCS soil survey unavailable at this site). The taxonomy of this soil is shown below:
Order: Unknown (NRCS soil survey unavailable at this site)
Suborder: Unknown (NRCS soil survey unavailable at this site)
Great group: Unknown (NRCS soil survey unavailable at this site)
Subgroup: Unknown (NRCS soil survey unavailable at this site)
Family: Unknown (NRCS soil survey unavailable at this site)
Series: Unknown (NRCS soil survey unavailable at this site)

Table 3. Summary of soil array and soil pit information at Yellowstone. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	31 m
Distance from tower to closest soil plot: y	139 m[†]
Latitude and longitude of 1st soil plot OR direction from tower	44.95288, -110.54069
Direction of soil array	285°
Latitude and longitude of FIU soil pit 1	44.95597, -110.54197 (primary location)
Latitude and longitude of FIU soil pit 2	44.95598, -110.54149 (alternate 1)
Latitude and longitude of FIU soil pit 3	44.95602, -110.54087 (alternate 2)
Dominant soil type	Unknown (NRCS soil survey unavailable at this site)
Expected soil depth	Unknown (possibly >2 m)
Depth to water table	Unknown

Expected depth of soil horizons	**Expected measurement depths[*]**
Unknown (NRCS soil survey unavailable at this site)	0.10 m[a]
	0.25 m[a]
	0.50 m[a]
	1.00 m
	2.00 m

[*]Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.
[†]The large distance between the tower and first soil plot is due to the tower being located on a lava tongue where the soil is only a few centimeters deep, which is not suitable for the soil array.
[a]Soil CO_2 sensors

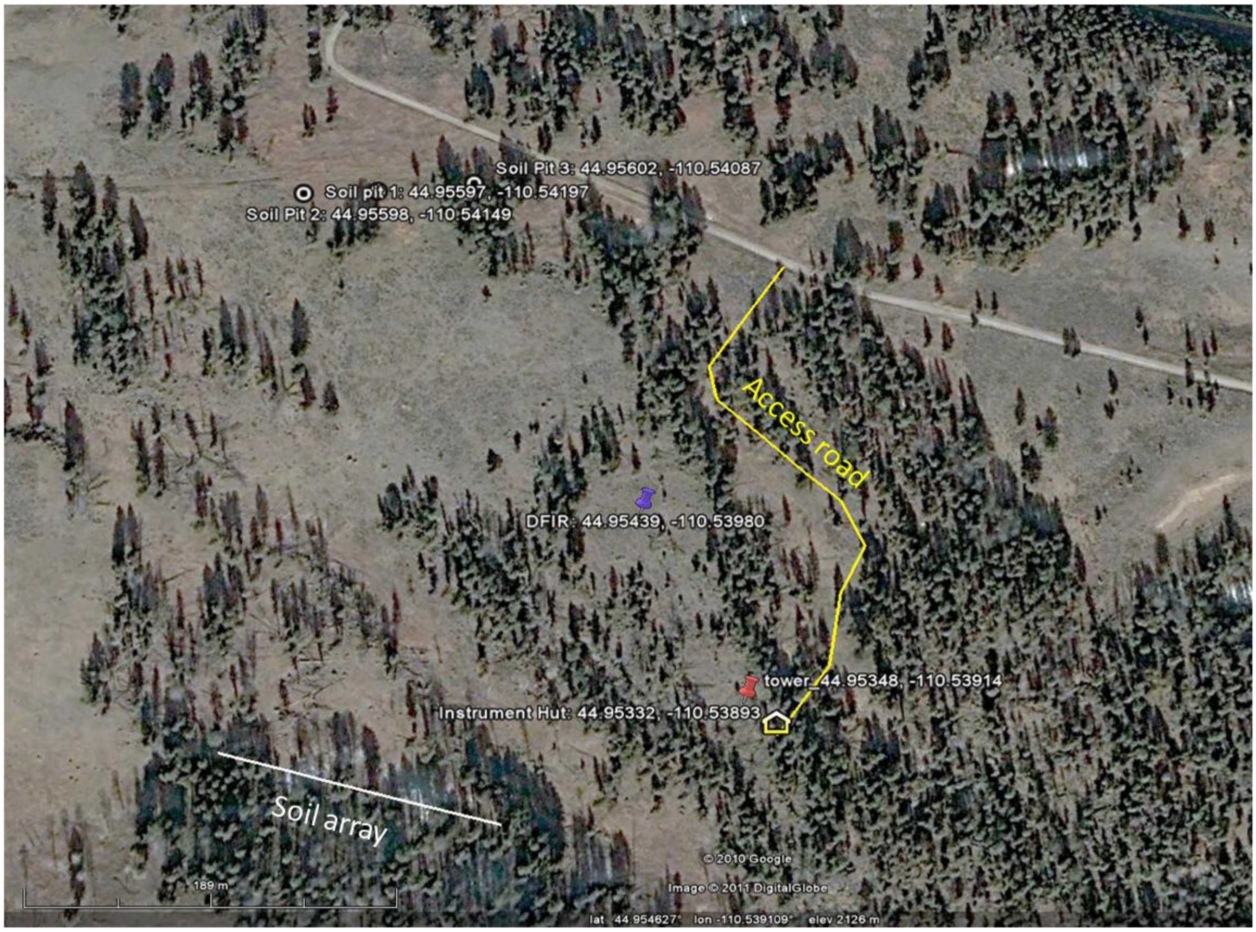


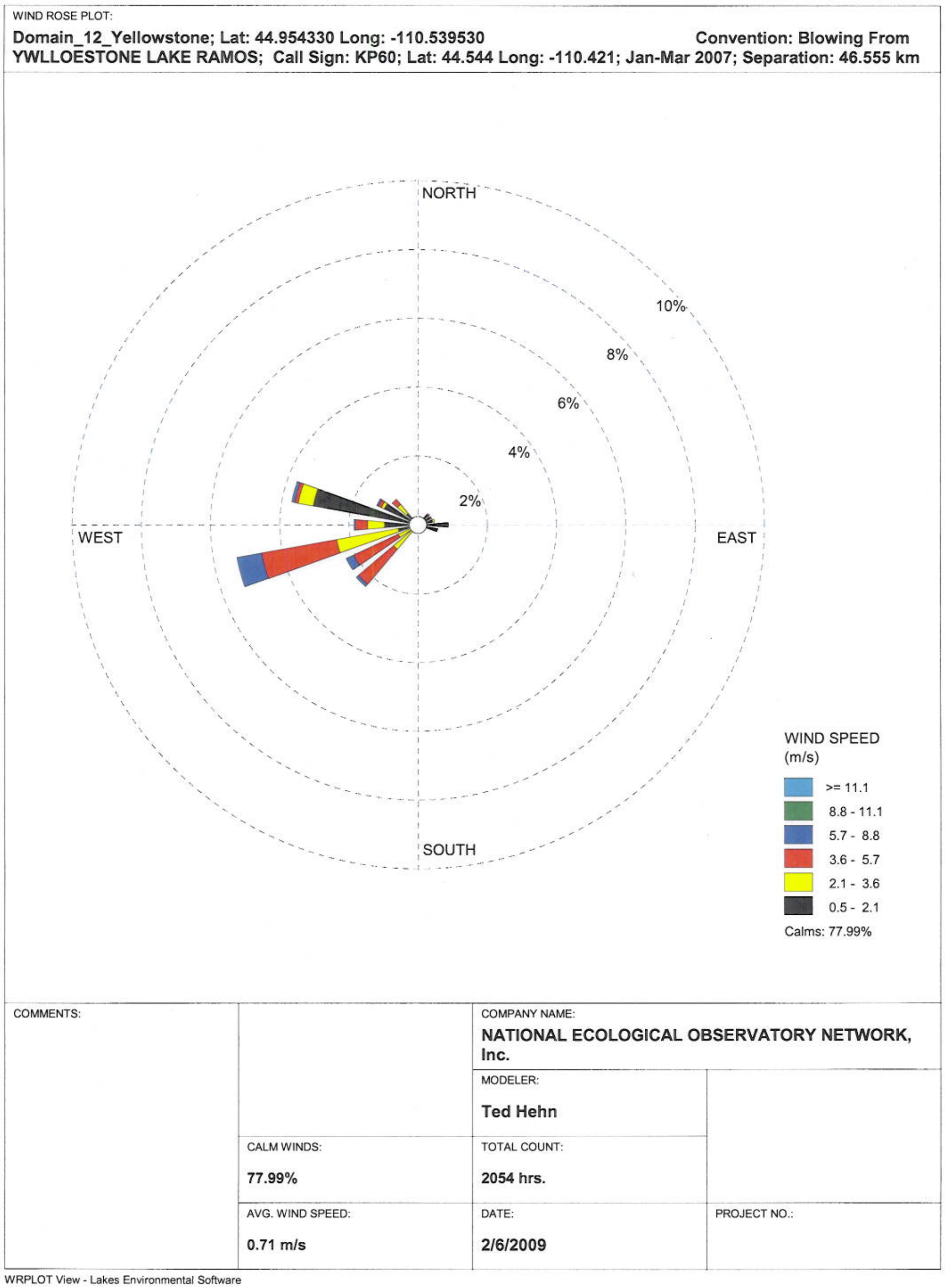
Figure 10. Site layout at Yellowstone showing soil array and location of the FIU soil pit.

3.4 Airshed

3.4.1 Seasonal Windroses

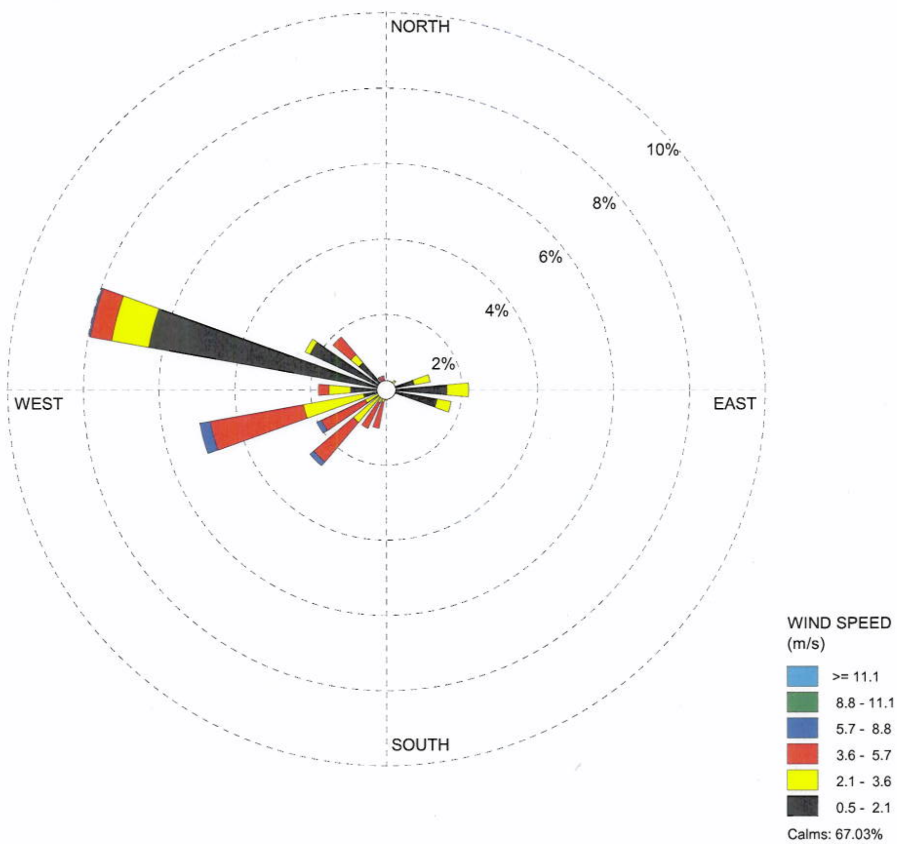
Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given time series. The data used to make the wind roses below are 2007 data from weather station at 44.544, -110.421, which is on the west of the Yellowstone lake and about 47 km away from the tower location. Because of the complexity of the mountain terrain, the wind pattern at this weather station is like not representative the wind patterns at tower location. But, no other wind data at tower location or within a reasonable distance to tower location is available by the time this report is written (closest MesoWest weather station is ~ 10 miles away and at different aspects of the mountains). Therefore, the wind roses presented here is just for reference. Further wind pattern analysis need to be done after NEON tower is established and collects wind data more than a year. According to the local people’s experience, wind mainly blows from south. By examining the terrain map, it is likely that wind mainly blows from southeast direction due to the high mountains on the southeast direction, and may also see some east-west winds due to the local terrain. The orientation of the windrose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions in this case.

3.4.2 Results (graphs for wind roses)



WIND ROSE PLOT:

Domain_12_Yellowstone; Lat: 44.954330 Long: -110.539530 **Convention: Blowing From**
YWLLOESTONE LAKE RAMOS; Call Sign: KP60; Lat: 44.544 Long: -110.421; Apr-Jun 2007; Separation: 46.555 km



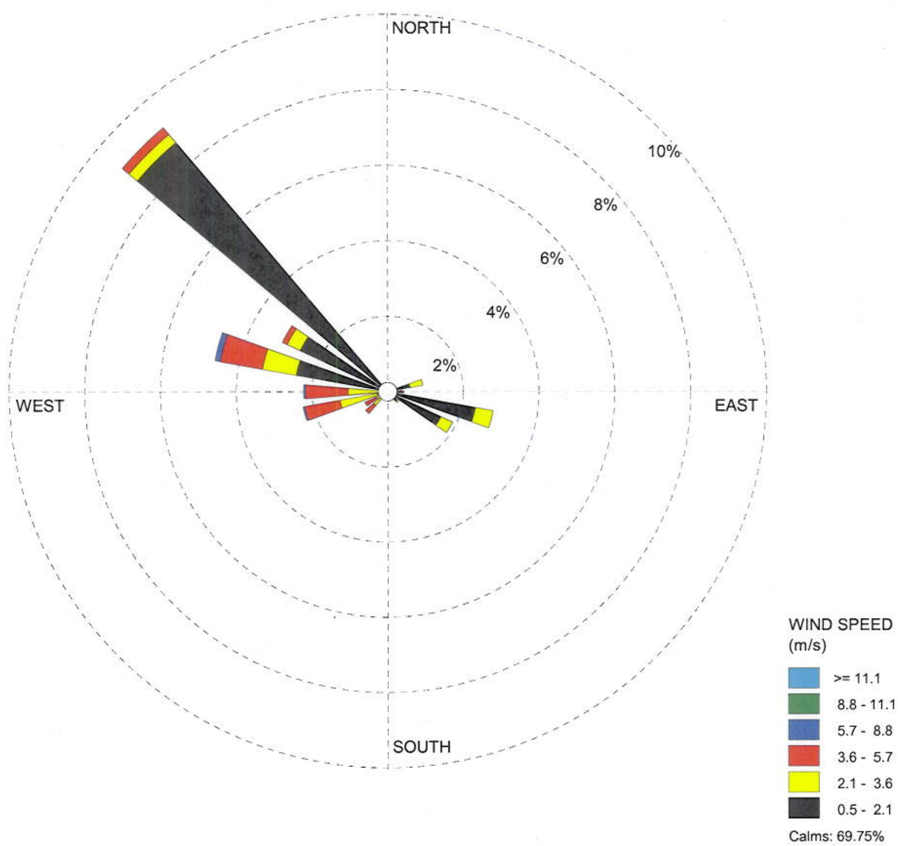
COMMENTS:		COMPANY NAME: **NATIONAL ECOLOGICAL OBSERVATORY NETWORK, Inc.**	
		MODELER: **Ted Hehn**	
	CALM WINDS: **67.03%**	TOTAL COUNT: **2123 hrs.**	
	AVG. WIND SPEED: **0.98 m/s**	DATE: **2/6/2009**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Domain_12_Yellowstone; Lat: 44.954330 Long: -110.539530 **Convention: Blowing From**

YWLLOESTONE LAKE RAMOS; Call Sign: KP60; Lat: 44.544 Long: -110.421; Jul-Sept 2007; Separation: 46.555 km



COMMENTS:		COMPANY NAME: **NATIONAL ECOLOGICAL OBSERVATORY NETWORK, Inc.**	
		MODELER: **Ted Hehn**	
	CALM WINDS: **69.75%**	TOTAL COUNT: **2122 hrs.**	
	AVG. WIND SPEED: **0.73 m/s**	DATE: **2/6/2009**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

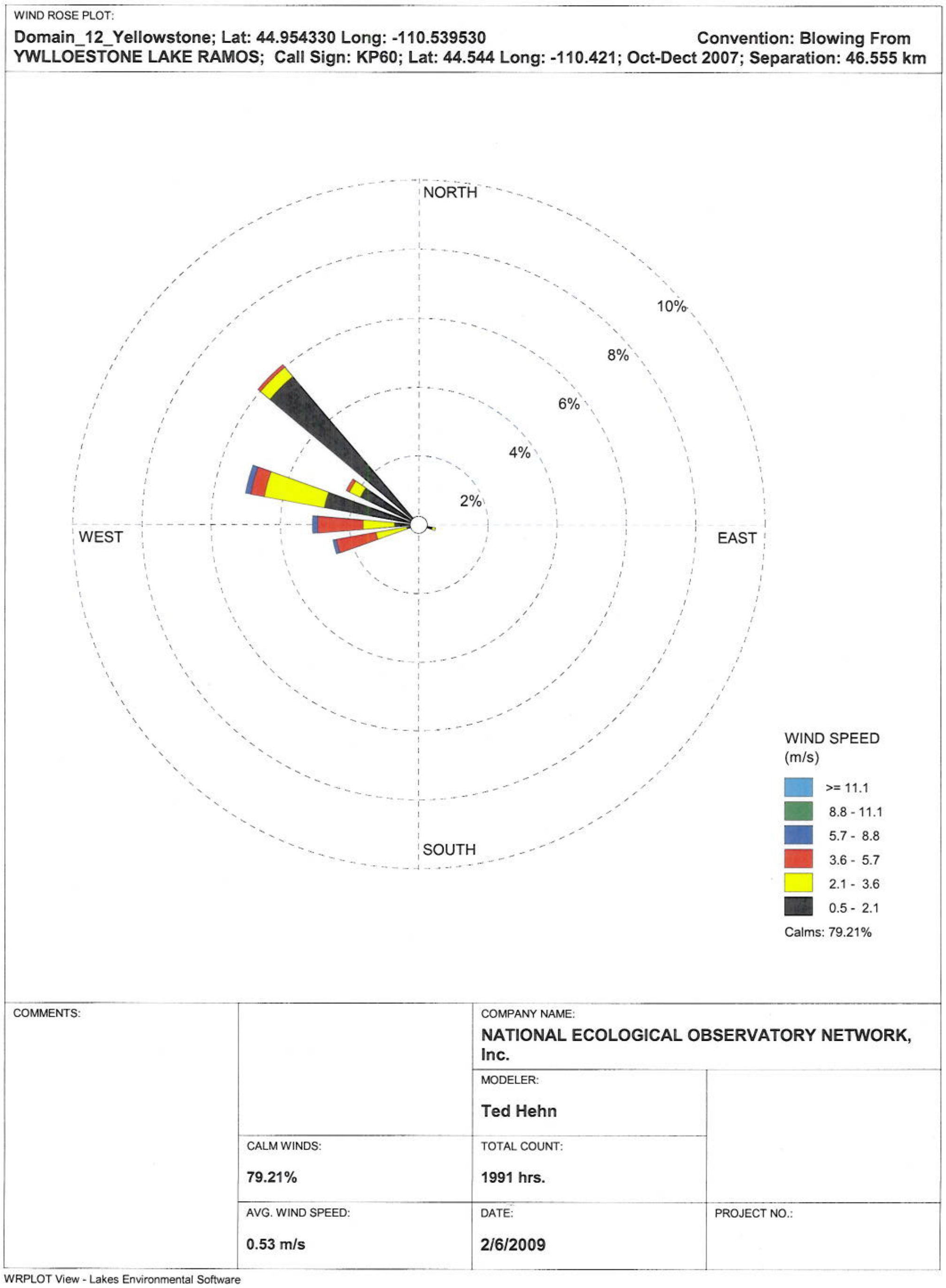


Figure 11. Windroses for Yellowstone Advanced tower site

The data used to make these wind roses are from weather station at 44.544, -110.421, which is on the west of the Yellowstone lake and about 47 km away from the tower location. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) January to December. Because of the complexity of the mountain terrain, the wind pattern at this weather station is like not representative the wind patterns at tower location. According to the local people's experience, wind mainly blows from south. By examining the terrain map, it is likely that wind mainly blows from southeast direction due to the high mountains on the southeast direction, and may also see some east-west winds due to the local terrain.

3.4.3 Resultant vectors

Not available.

3.4.4 Expected environmental controls on source area

Two types of models were commonly used to determine the shape and extent of the source area under different and contrasting atmospheric stability classes. An inverted plume dispersion model with modeled cross wind solutions were used for convective conditions (Horst and Weil 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann and Meixner 2001). The source area models where bounded by the expected conditions depict the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically have long source area and associated waveforms. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime wind speeds, *e.g.,* 1-4 m s^{-2}. Higher wind speeds, like those experienced over the Rockies, are often the product of mechanical turbulence with long waveforms. Because thermal stratification is very efficient in suppressing vertical mixing, stable conditions also have typically very long waveforms.

As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions. The type of turbulence (mechanical verse convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

Here, we used a web-based footprint model to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature and energy information were either from the RFI document, previous site visit report, available data files or best estimated from experienced expert. Measurement height was determined from the Tower Height Info document provided by ENG group, then verify according to the real ecosystem structure after FIU site characterization at site. Runs 1-3 and 4-6 represents the expected conditions for summer and winter conditions, respectively, with maximum and mean windspeeds (daytime convective) and nighttime (stable atmospheres) conditions. The wind vector for each run was estimated from wind roses and is placed as a centerline in the site map included in the graphics. The width of the footprint was also estimated using the length between the isopleth of 80% cumulative flux and center line to calculate the angle from centerline. This information, along with distance of the cumulative flux isopleths and wind direction, will define the source area for the flux measurements on the top of the tower.

Table 4. Expected environmental controls to parameterize the source area model, and associated results for Yellowstone advanced site.

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	20	20	20	20	20	20	m
Canopy Height	14	14	14	14	14	14	m
Canopy area density	2.512	2.512	2.152	1.585	1.585	1.585	m
Boundary layer depth	2000	2000	651	800	800	451	m
Expected sensible heat flux	451	451	161	-26	-26	-100	W m^{-2}
Air Temperature	28	28	14	-5	-5	-10	°C
Max. windspeed	2.8	1.8	1.6	8.8	3.2	1.6	m s^{-1}
Resultant wind vector	316	316	105	255	255	255	degrees
Results							
(z-d)/L	-0.05	-0.28	-0.31	0	0.03	3	m
d	11	11	11	10	10	10	m
Sigma v	2.6	2	1.1	1.8	1.8	1.6	m^2 s^{-2}
Z0	0.69	0.69	0.69	0.85	0.85	0.85	m
u*	0.96	0.54	0.38	1.4	0.5	0.04	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	400	200	200	600	700	1600	m
Distance of 80% cumulative flux	250	150	150	300	350	800	m
Distance of 70% cumulative flux	200	100	100	250	250	700	m
Peak contribution	35	15	15	35	35	1265	m

Note: Model was run based on the wind info extracted from wind roses above. The actual model outputs may be different at the tower location. But currently no wind data from tower location are available for actual assessment.

3.5 Results (source area graphs)

Graphs below were outputted from footprint model based on the wind info extracted from wind roses above. The actual footprint outputs may be different at the tower location. But currently no wind data from tower location are available for actual assessment.

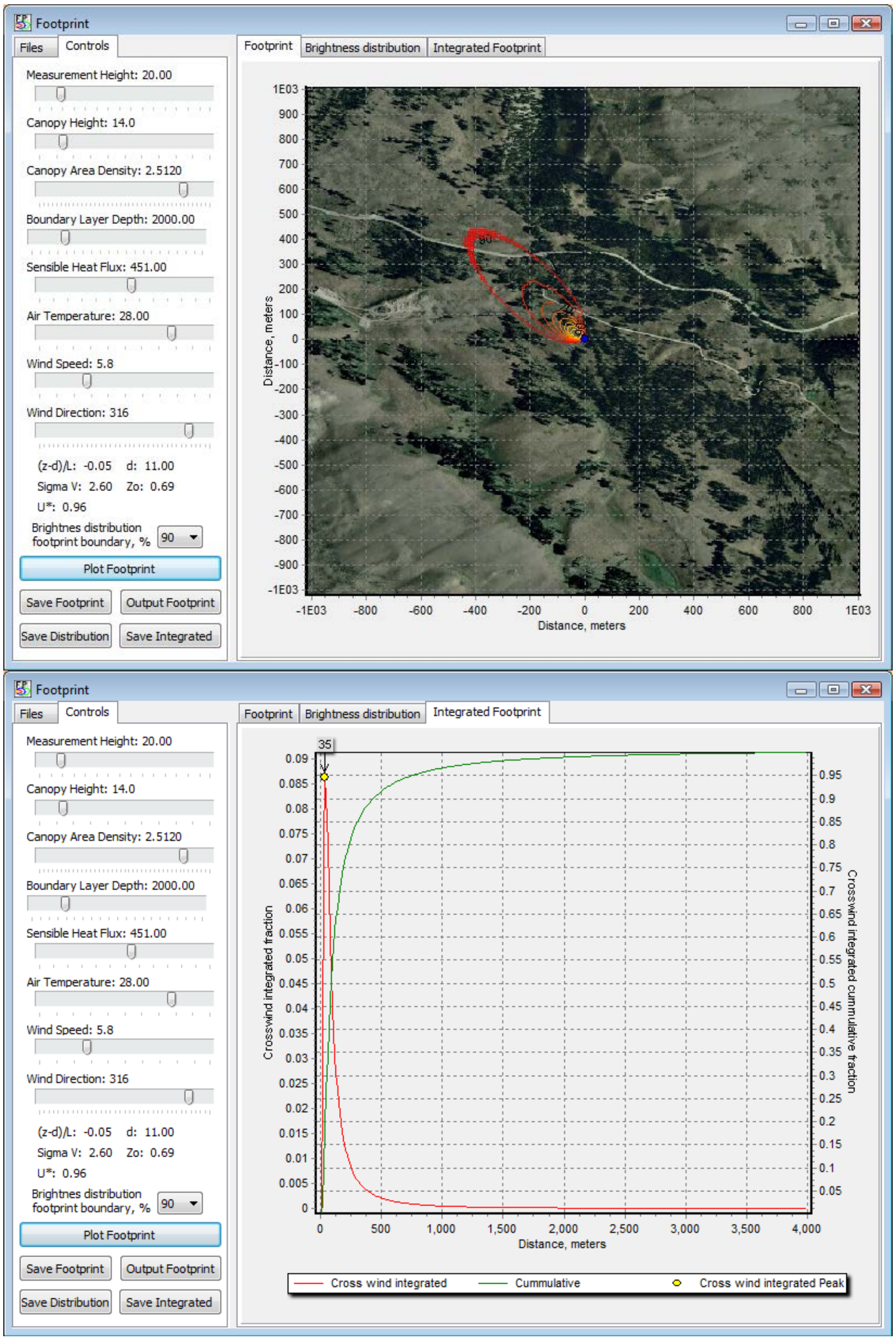


Figure 12. Summer, daytime, max wind speed

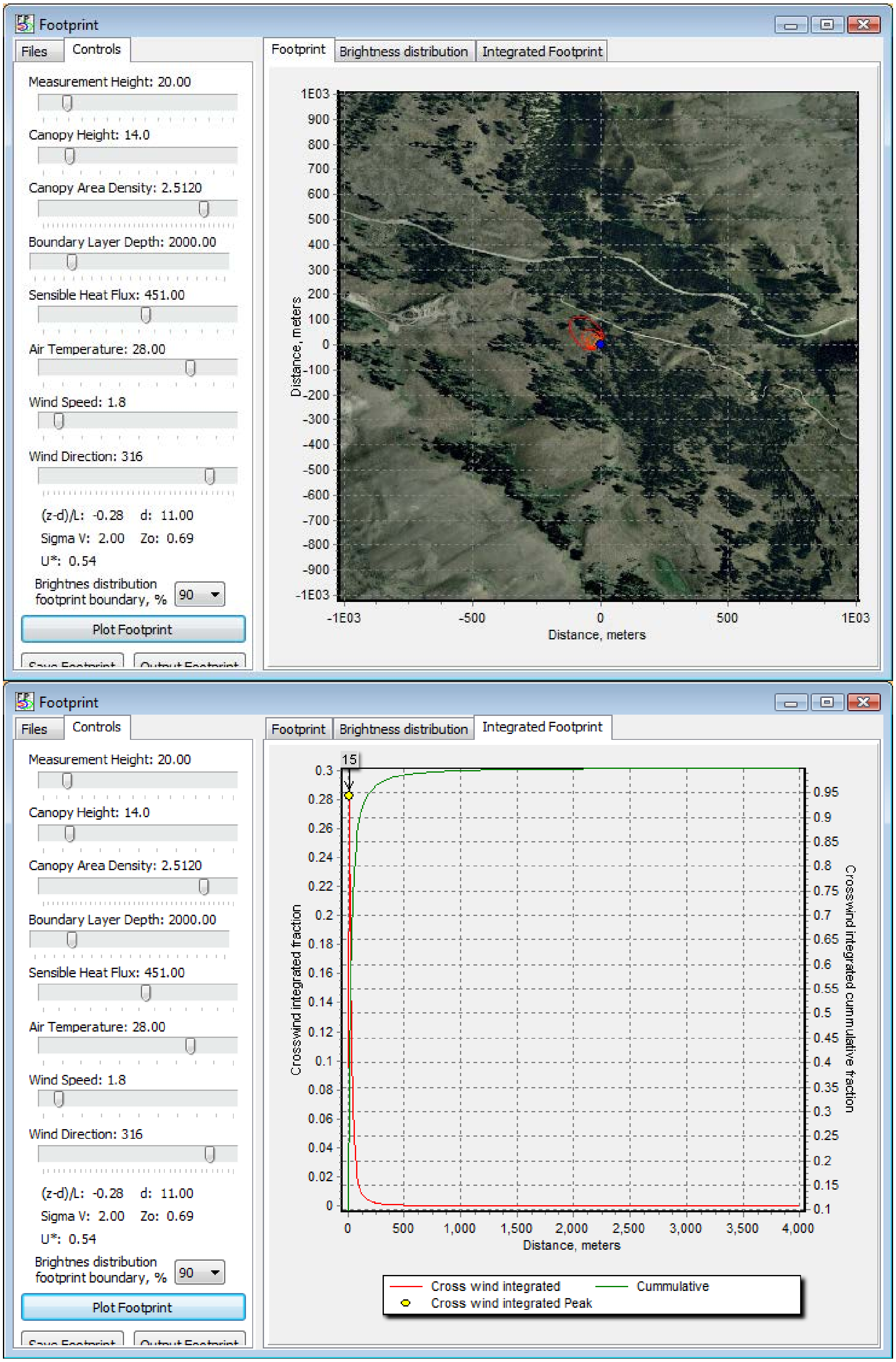


Figure 13. Summer, daytime, mean wind speed

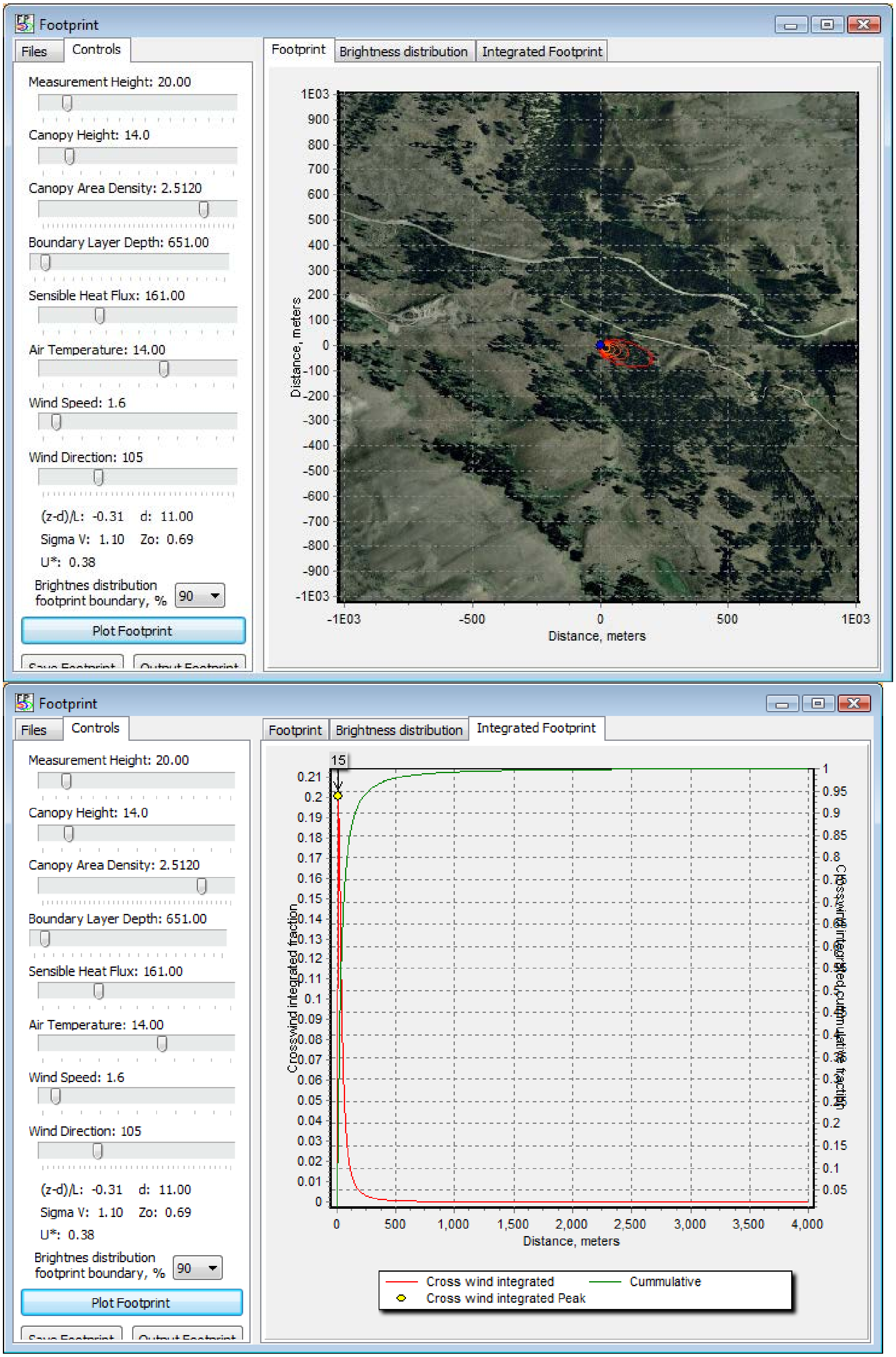


Figure 14. Summer, nighttime, mean wind speed

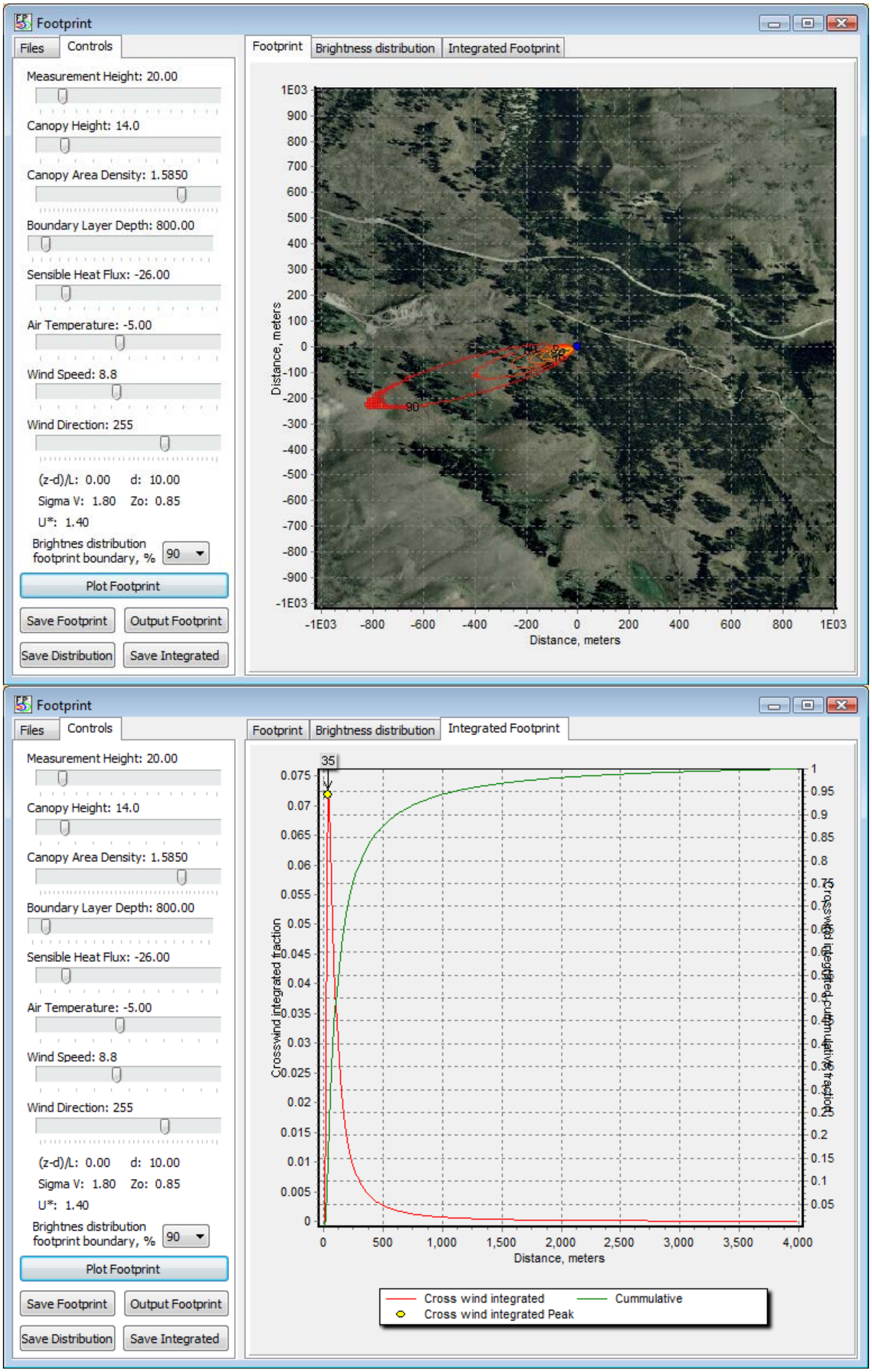


Figure 15. Winter, daytime, max wind speed

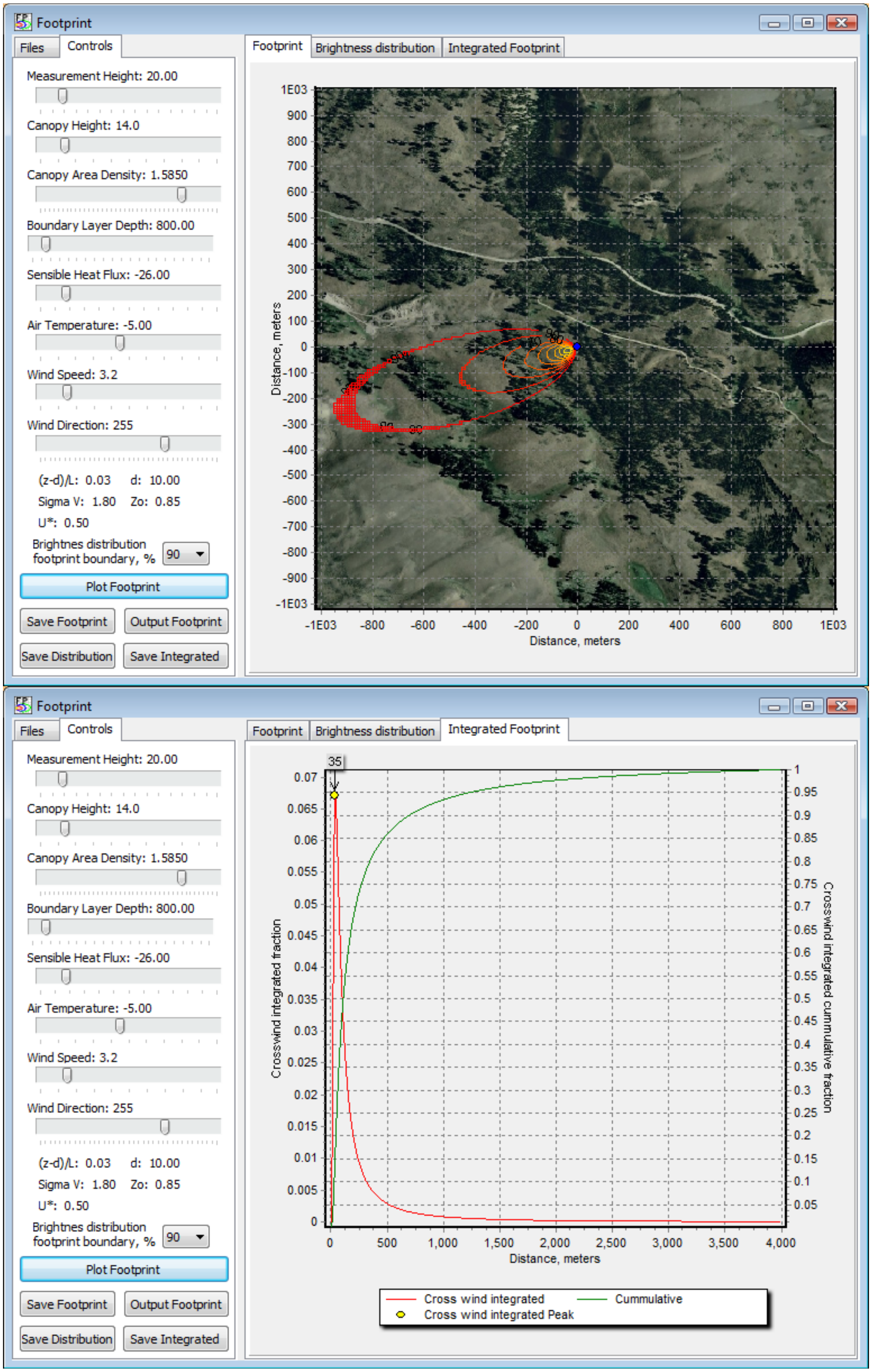


Figure 16. Winter daytime, mean wind speed

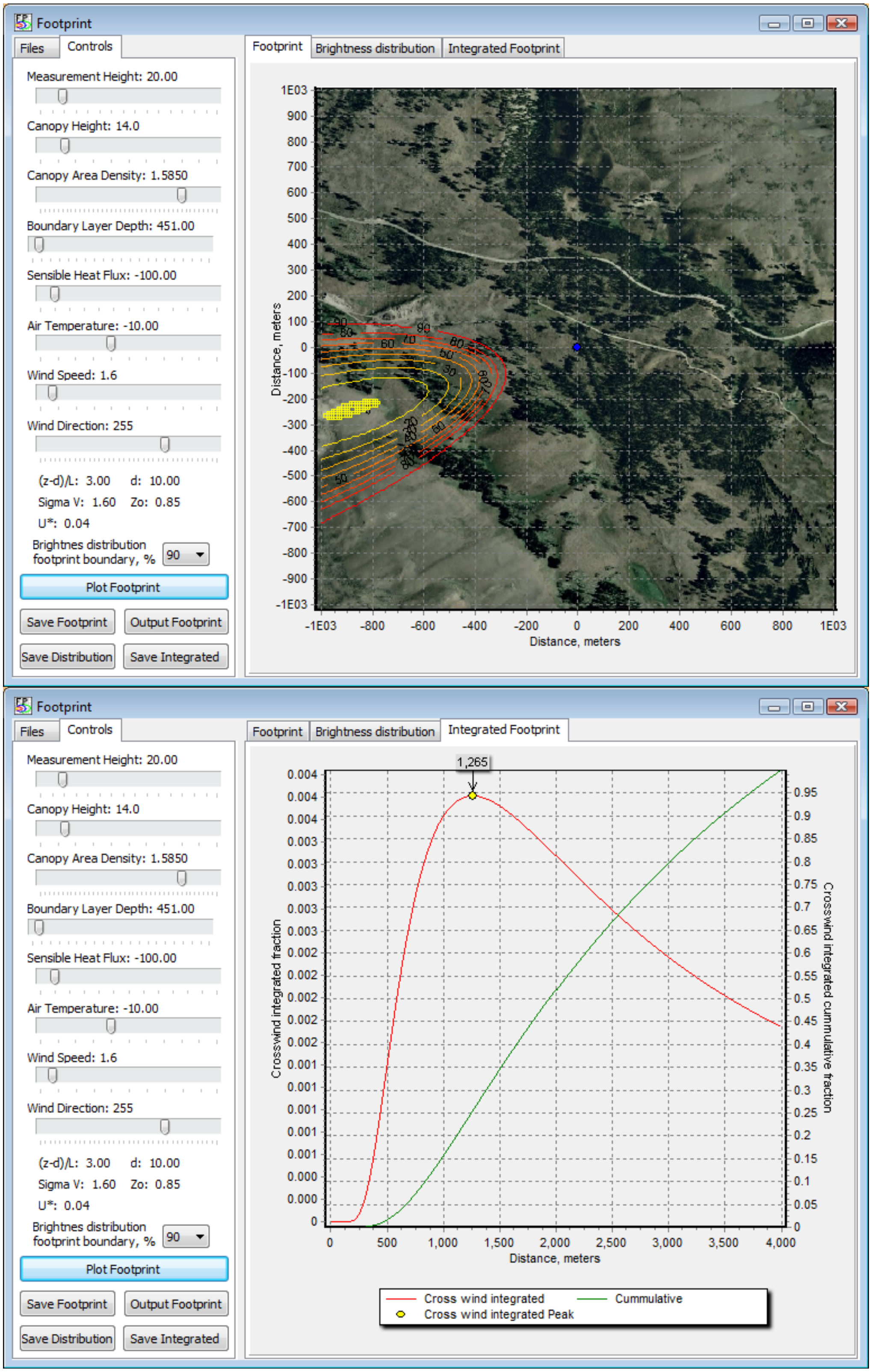


Figure 17. Winter, nighttime, mean wind speed

3.5.1 Site Design and Tower Attributes

The original location of the tower at this site was 44.955, -110.54. However, during the site characterization this location was deemed unacceptable to Yellowstone National Park and the NEON tower was microsited to 44.95348, -110.53914 (~180 m from the original location) and no room for negotiation. Therefore, the new **tower location** is at 44.95348°, -110.53914°.

Based on the local experience and interpretation of the terrain map, we believe that the prevailing wind directions are from south and southeast, and some winds on east-west direction along the local valley. Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the south will be best to capture signals from all wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure.

An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut. However, in this case, Yellowstone National Park assigned a location at 44.95332, -110.53893 for our instrument hut, which is ~24 m away on the southeast to tower. National park picked this location inside the woods to limit the visibility by tourist. It is on the path of the major winds but in a small depression (~2 m lower than tower). The interference of the instrument hut to the wind regime is unknown. Assessment should be done after a few years' weather data are collected and determine from there if instrument hut should be relocated. The instrument hut should be positioned to have the longer side parallel to SE-NW direction. The location of instrument hut is at 44.95332, -110.53893.

The NEON site at Yellowstone is a mosaic of pine-dominated forest and grassland. The mean canopy height for the pine trees is ~ 14 m with lowest branch at ~ 2.5 m. Some small trees form top understory with height around 8 m. Some tree seedlings and shrubs form next understory with height around 1 m. Grasses form the understory at floor level with mean height ~ 0.4 m. We require 6 **measurement layers** on the tower with top measurement height at 20 m, and remaining levels are 17 m, 14 m, 8 m, 1m and 0.3 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile. National park stressed that tower top should not be more than 20 feet above tree canopy. Given the canopy height at ~14 m, 20 m tower height should meet national park's requirement.

DFIR location is at 44.95439, -110.53980, which is ~115 m northwest to tower. This is also a designated opening area by national park for DFIR. The rain gauge is located in the center of this opening. The radius of the opening is ~30 m. Given the tree height is ~ 14 m, this opening is not big enough to meet USCRN class 1 siting criteria (>4 times the height of any obstacle taller in height) for DFIR, but meet the USCRN class 2 siting criteria (>2 times the height of any obstacle taller in height). **Wet deposition collector** will collocate at the top of the tower. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 5. Site design and tower attributes for Yellowstone Advanced site. 0° is true north with declination accounted for. Color of Instrument hut exterior shall be dark brown to best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed area			South and southeast		Do not know exact angles
Tower location	44.95348,	-110.53914	--	--	new site
Instrument hut	44.95332,	-110.53893			
Instrument hut orientation vector	--	--	135° - 315°		
Instrument hut distance z	--	--	--	24	
Anemometer/Temperature boom orientation	--	--	180°	--	
DFIR	44.95439,	-110.53980			
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				1.0	m.a.g.l.
Level 3				8.0	m.a.g.l.
Level 4				14.0	m.a.g.l.
Level 5				17.0	m.a.g.l.
Level 5				20.0	m.a.g.l.
Tower Height				20.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Figure below shows the proposed tower location, instrument hut location, DFIR, airshed area and access road.

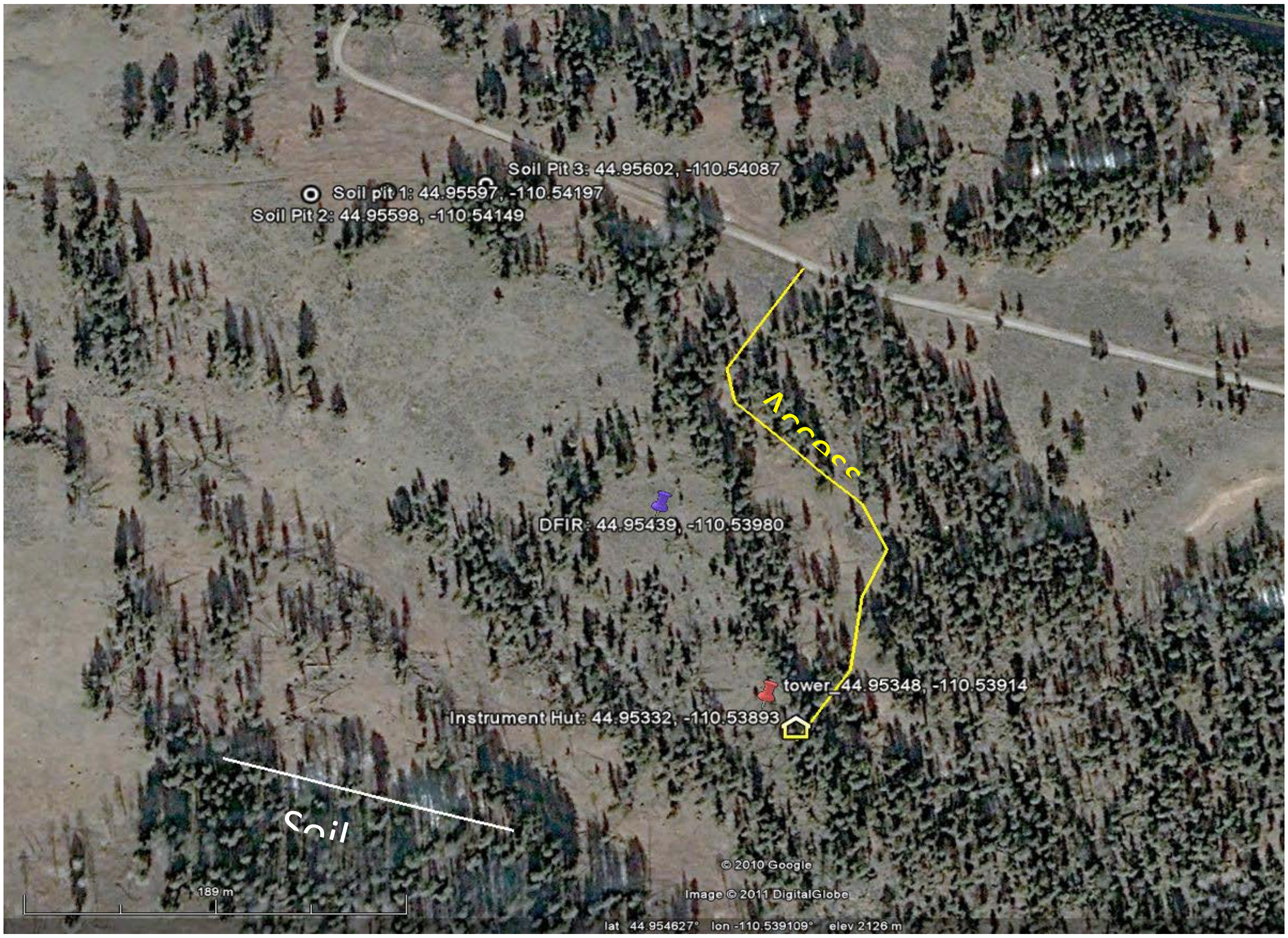


Figure 18. Site layout for Yellowstone Advanced tower site.

i) Tower location is presented (red pin), ii) Airshed boundary lines are not presented. Prevailing winds blow from south and south east. But no local wind data available to define the airshed boundary iii) Yellow line is the suggested access road to instrument hut. iv) Purple pin is DFIR location

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36" (0.914 m). The boardwalk to access the tower is not on any side that has a boom.

Specific Boardwalks at Yellowstone Advance site:

- Marked footpath from the road to instrument hut, pending landowner decision. The first marker should not be visible from the road to minimize the chance of Park visitors seeing it.
- Marked path from the instrument hut to the tower to intersect on north face of the tower

- Marked path to the soil array
- No path from the soil array marked path to the individual soil plots
- No boardwalk or path needed to DFIR site
- Note: FIU would have recommended boardwalks from the access route to the instrument hut, tower, and soil array in order to minimize site disturbance. However, Doug Madsen (Yellowstone National Park) said that boardwalk would not be permitted unless evidence of disturbance appears once Operations have begun at the site.

The relative locations between tower, instrument hut and boardwalk can be found in the Figure below:

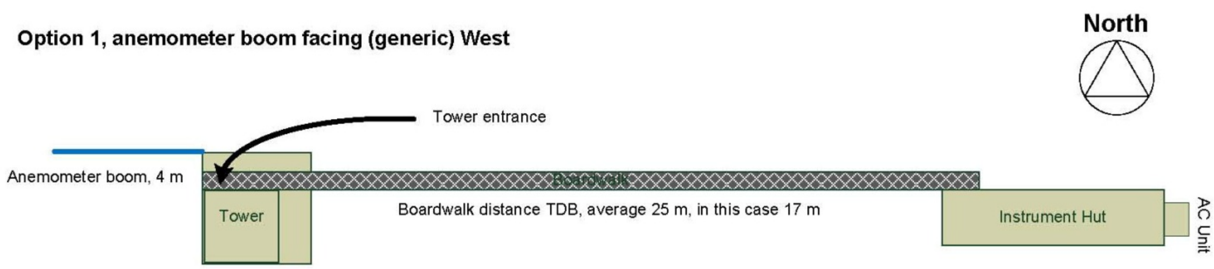


Figure 19. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the east towards the tower.

This is just a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At Yellowstone Advanced site, the boom angle will be 180 degrees, instrument hut will be on the southeast to the tower, the distance between instrument hut and tower is ~24 m. The instrument hut vector will be SE-NW (135º-315º, longwise).

3.5.2 Information for ecosystem productivity plots

The tower at Yellowstone Advanced site was suggested by National park. No local wind data are available to accurately determine airshed area. But according to the local people's experience and by examining the terrain map, we presume prevailing winds blow from south and/or southeast. According to our best knowledge, we would suggest FSU EP plots are placed within the boundary of 135° to 225° from tower. If wind speed at tower site is similar to the windroses above, then 90% signals for flux measurements are within a distance of 600 m from tower during summer, and 80% within 380 m, while 90% signals are within 1100 m and 80% signals within 600 m during winter daytime. Signals collected during winter nighttime can be from few kilometers away.

3.6 Issues and attentions

Yellowstone National Park requests that the effect of the NEON site on visitors should be minimal, and in most cases the site should go unnoticed. Yellowstone National Park placed a number of restrictions on the site design that have altered it from the design that FIU would have requested if science were the only consideration.

The maximum height of the tower was limited to 20 feet (6 m) above tree height by Yellowstone National Park. We required top tower measruement level at 20 m based on our science requirements.

Given the tree height at ~14 m, 20 m is approximately meet park's requirement above. But the actual tower height may go beyond 20 m to provide top measurement level at 20 m. FCC may want to keep this in mind when design a tower and discuss with park.

The preffered location of the DFIR (44.95515, -110.54086) was not permitted by Yellowstone National Park. Instead a less visible location was required, which resulted in the DFIR being closer to obsticles (i.e. trees) than the FIU preference. The radius of the opening is ~30 m. Given the tree height is ~ 14 m, this opening is not big enough to meet USCRN class 1 siting criteria (>4 times the height of any obstacle taller in height) for DFIR, but meet the USCRN class 2 siting criteria (>2 times the height of any obstacle taller in height). As a result, precipitation measurements at this site will be of higher uncertainty (5% error) than at the other NEON sites.

Yellowstone National Park restricted the tower location to a lava tongue surrounded by trees to minimize visibility to Park visitors. However, soil depth on the lava tongue was only a few centimeters, which was not sufficient for the FIU Soil Array. As a result, the suggested location of the soil plots are between 140 m and 275 m from the tower, whereas at most NEON site the soil plots are between 20 m and 200 m from the tower. As a result the soil measurements will not be as relatable to the tower-based measurements as at most other NEON sites.

The data used to make the wind roses are from weather station at 44.544, -110.421, which is on the west of the Yellowstone lake and about 47 km away from the tower location. Because of the complexity of the mountain terrain, the wind pattern at this weather station is like not representative the wind patterns at tower location. But, no other wind data at tower location or within a reasonable distance to tower location is available by the time this report is written. Therefore, we cannot accurately define the airshed. Further wind pattern analysis need to be done after NEON tower is established and collects wind data for a few years. According to the local people's experience and by examining the terrain map, it is likely that wind mainly blows from south and southeast direction. We suggest FSU EP plots are placed within the boundary of 135° to 225° from tower according to our best knowledge.

The instrument hut should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut. However, in this case, Yellowstone National Park assigned a location at 44.95332, -110.53893 for our instrument hut, which is ~24 m away on the southeast to tower. National park picked this location inside the woods to limit the visibility by tourist. It is on the path of the major winds but in a small depression (~2 m lower than tower). The interference of the instrument hut to the wind regime is unknown. Assessment should be done after a few years' weather data are collected and determine from there if instrument hut should be relocated.

FIU would prefer that boardwalks were installed, instead of marked paths, to mimimize the impact of foot traffic on the site. However, Doug Madsen (Yellowstone National Park) said that boardwalks would not be permitted unless the foot traffic is damaging the site. The impact of foot traffic shall be monitored to determine whether boardwalks need to be added once Operations begins.

The access route and power/communication lines should follow the contures of the landscapes to minimize visibility to visitors to the Park. Chris Thompson collected GPS coordinates for an approximate route during the site characterization.

Doug Madsen (Yellowstone National Park) requested that the instrument hut be painted dark green or dark brown to match the color of its surroundings. FIU suggests dark brown.

Doug Madsen (Yellowstone National Park)requested that no trees be cut down for site construction. Tree trunks that are laying on the ground (e.g. at the instrument hut location) can be moved to facilitate construction.

The site commonly is covered in 45-60 cm of snow between early November and mid April. Construction and Operations should be planned accordingly.

4 BOZEMAN, RELOCATEABLE TOWER 1

4.1 Site description

This site is at the southern part of the city of Bozeman. The tower location is in a field owned by Montana State University. This field was previously residential housing and pavement area. The houses on the left edge and north edge of this field have been demolished and foundations have been excavated. The paved road inside the field is now returned to soil surface. These areas will be re-seeded and turned into lawn. There are residential houses to the south, north and west, and some large buildings (~25-35 m in height) to the east and south, but about 300 m away. A footpath runs NW-SE cross the field. Roads are adjacent to the field to the east, north and west. This field is small, approximately 150 m (N-E) × 180 m (W-E)

Figure 20. Property boundary of the Bozeman site and original candidate tower location.

Note that the houses on the west edge and north edge have been demolished and the paved roads inside the field have been returned to soil surface. The red square dot was a previous proposed tower location, not the final location.

4.2 Ecosystem

Vegetation type and land cover information at this relocatable site are presented below:

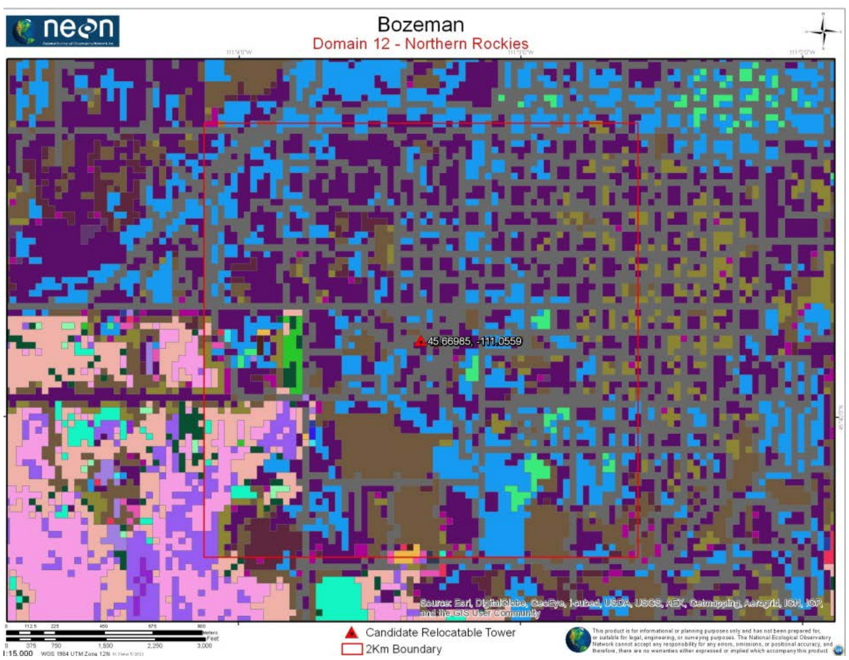


Figure 21. Vegetative cover map of the Bozeman relocatable site and surrounding areas

Table 6. Percent Land cover information at the Bozeman relocatable site (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Veg_Type	Veg_Height	Area_km^2	Percentage
High Intensity Urban	Developed - High Intensity	0.043	1.080
Inter-Mountain Basins Big Sagebrush Steppe	Shrub Height 0.5 to 1.0 meter	0.001	0.024
Inter-Mountain Basins Mixed Salt Desert Scrub	Shrub Height 0.5 to 1.0 meter	0.004	0.091
Inter-Mountain Basins Montane Sagebrush Steppe	Shrub Height 0.5 to 1.0 meter	0.003	0.067
Low Intensity Urban	Developed - Low Intensity	1.095	27.369
Low Intensity Urban	Developed - Open Space	0.003	0.067
Medium Intensity Urban	Developed - Medium Intensity	0.630	15.748
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Herb Height 0 to 0.5 meters	0.003	0.067
Roads	Developed-Roads	1.305	32.627
Rocky Mountain Aspen Forest and Woodland	Forest Height 10 to 25 meters	0.001	0.022
Rocky Mountain Montane Riparian Systems	Forest Height 5 to 10 meters	0.000	0.001
Rocky Mountain Montane Riparian Systems	Forest Height 10 to 25 meters	0.007	0.181
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Shrub Height 0.5 to 1.0 meter	0.004	0.090
Rocky Mountain Subalpine-Montane Mesic Meadow	Herb Height 0 to 0.5 meters	0.002	0.045
Western Cool Temperate Close Grown Crop	Herb Height 0 to 0.5 meters	0.046	1.139
Western Cool Temperate Developed Ruderal Evergreen Forest	Forest Height 10 to 25 meters	0.021	0.517
Western Cool Temperate Developed Ruderal Grassland	Herb Height 0 to 0.5 meters	0.089	2.226
Western Cool Temperate Developed Ruderal Shrubland	Shrub Height 0.5 to 1.0 meter	0.021	0.537
Western Cool Temperate Fallow/Idle Cropland	Herb Height 0 to 0.5 meters	0.004	0.090
Western Cool Temperate Pasture and Hayland	Herb Height 0 to 0.5 meters	0.051	1.275
Western Cool Temperate Urban Deciduous Forest	Developed-Upland Deciduous Forest	0.131	3.268
Western Cool Temperate Urban Evergreen Forest	Developed-Upland Evergreen Forest	0.001	0.022
Western Cool Temperate Urban Herbaceous	Developed-Upland Herbaceous	0.415	10.371
Western Cool Temperate Urban Mixed Forest	Developed-Upland Mixed Forest	0.034	0.840
Western Cool Temperate Urban Shrubland	Developed-Upland Shrubland	0.078	1.940
Western Cool Temperate Wheat	Herb Height 0 to 0.5 meters	0.010	0.247
Xeric Montane Douglas-fir Forest	Forest Height 10 to 25 meters	0.002	0.045
TOTAL		**4.000**	**100.000**

There are many land-use types within a radius of ~500 m surrounding the tower site, including residential areas, parking lot, factories, recreational facilities, open space (mowed grassland), and roads. As a result the measurements at the tower site will be influenced by a number of different ecosystems/land-uses, which will complicate interpretation of the measurements. The height of the buildings nearest the tower ranged from 6 m (residential houses)to 35 m (building). The mean canopy height of the trees in within airshed and in the surrounding residential area is estimated 15 m.

The tower is located in a small patch of grassy field and is surrounded with residential houses. The houses and paved roads inside this piece of land have been demolished and the ground surface of these areas was returned to dirt/sand soil surface, and counts for ~40 – 50% land cover in this piece of land. Soil in this piece of land is well-disturbed and compacted.

Grass and annuals on this piece of land are ~ 0.2 m in height, but average canopy height is ~15 m for the trees in this piece of land, within airshed and in the surrounding residential area. Therefore, we determine tower height based on the trees height in the airshed, and design measurement layers based on the grassland, tree and building heights.

Figure 22. Ecosystem and surrounding environment at the Bozeman relocatable site.

Table 7. Ecosystem and site attributes for Bozeman Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height*	15.0 m
Surface roughness [a]	4 m
Zero place displacement height [a]	10 m
Structural elements	grass and annuals, trees presented at surrounding residential area
Time zone	Mountain time zone
Magnetic declination	12° 48' E changing by 0° 9' W/year

Note, [a] From field survey. * Tree height within airshed and in the surrounding residential area, which will be used to design tower height.

4.3 Soils

4.3.1 Description of Soils

Soil data and soil maps below for the Bozeman tower site were collected from 2.4 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

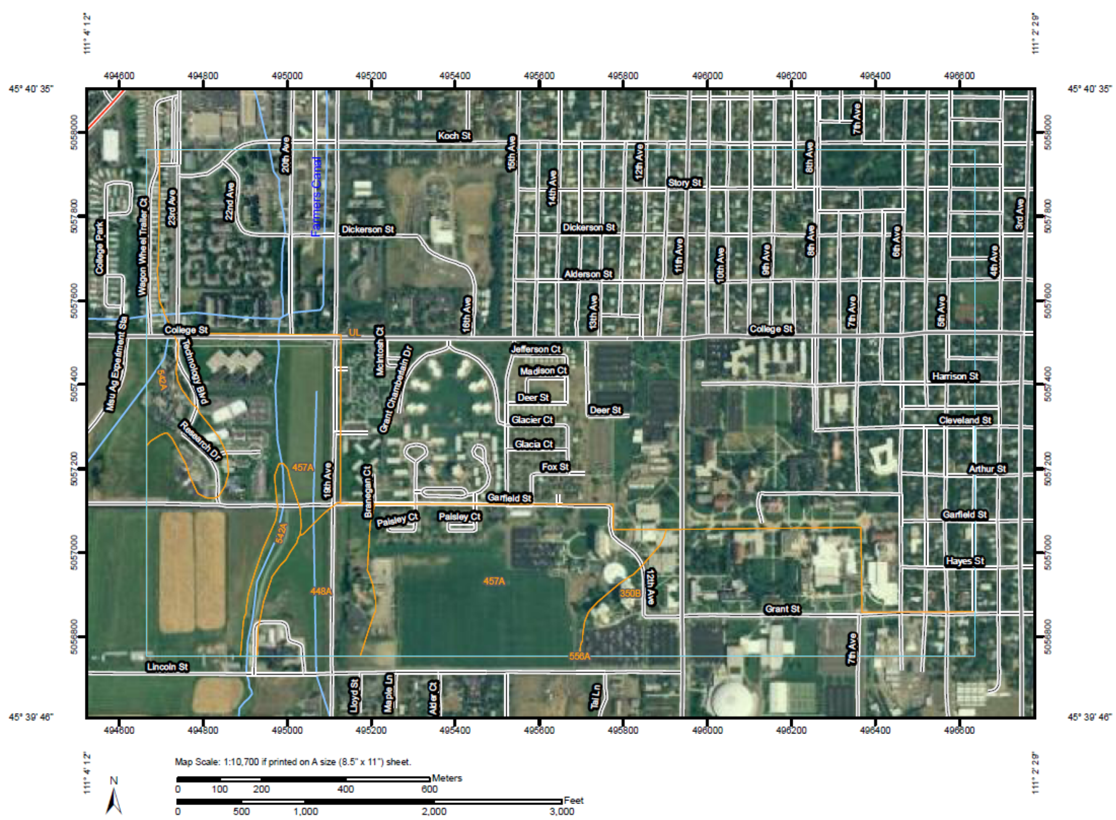


Figure 23. Soil map of the Bozeman site and surrounding areas.

Soil Map Units Description: The map units delineated on the detailed soil maps in a soil survey represents the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils. Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. T he name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series. Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups. A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example. An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-

Beta association, 0 to 2 percent slopes, is an example. An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, are an example. Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example. Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 8. Soil series and percentage of soil series within 2.4 km2 at the Bozeman site

Gallatin County Area, Montana (MT622)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
350B	Blackmore silt loam, 0 to 4 percent slopes	50.9	8.7%
448A	Hyalite-Beaverton complex, moderately wet, 0 to 2 percent slopes	19.2	3.3%
457A	Turner loam, moderately wet, 0 to 2 percent slopes	112.1	19.1%
542A	Blossberg loam, 0 to 2 percent slopes	18.0	3.1%
556A	Threeriv-Bonebasin loams, 0 to 2 percent slopes	0.0	0.0%
UL	Urban land	386.4	65.9%
Totals for Area of Interest		**586.5**	**100.0%**

Gallatin County Area, Montana 350B—Blackmore silt loam, 0 to 4 percent slopes Map Unit Setting Elevation: 4,850 to 5,550 feet Mean annual precipitation: 18 to 22 inches Mean annual air temperature: 37 to 43 degrees F Frost-free period: 80 to 95 days **Map Unit Composition** Blackmore and similar soils: 90 percent Minor components: 10 percent **Description of Blackmore Setting** Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Parent material: Calcareous loess **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 30 percent Available water capacity: High (about 11.4 inches) **Interpretive groups** Land capability classification (irrigated): 4e Land capability (nonirrigated): 4e Ecological site: Silty (Si) 20"+ p.z. (R043BS323MT) **Typical profile** 0 to 10 inches: Silt loam 10 to 27 inches: Silty clay loam 27 to 42 inches: Silt loam 42 to 60 inches: Silt loam **Minor Components Bowery** Percent of map unit: 5 percent Landform: Alluvial fans, stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Silty (Si) 15-19" p.z. (R044XS355MT) **Blackmore** Percent of map unit: 3 percent Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Silty (Si) 20"+ p.z. (R043BS323MT) **Brodyk** Percent of map unit: 2 percent Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Limy (Ly) 15-19" p.z. (R044XS357MT)

Gallatin County Area, Montana 542A—Blossberg loam, 0 to 2 percent slopes Map Unit Setting Elevation: 4,200 to 5,550 feet Mean annual precipitation: 12 to 18 inches Mean annual air temperature: 39 to 45 degrees F Frost-free period: 90 to 110 days **Map Unit Composition** Blossberg and similar soils: 85 percent Minor components: 15 percent **Description of Blossberg Setting** Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr) Depth to water table: About 12 to 24 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/ cm) Available water capacity: Low (about 5.5 inches) **Interpretive groups** Farmland classification: Farmland of local importance Land capability (nonirrigated): 5w Hydrologic Soil Group: B/D Ecological site: Wet Meadow (WM) 15-19" p.z. (R044XS365MT) **Typical profile** 0 to 15 inches: Loam 15 to 24 inches: Sandy clay loam 24 to 60 inches: Extremely gravelly loamy coarse sand **Minor Components Bonebasin** Percent of map unit: 10 percent Landform: Terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Wet Meadow (WM) 15-19" p.z. (R044XS365MT) **Meadowcreek** Percent of map unit: 5 percent Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Subirrigated (Sb) 15-19" p.z. (R044XS359MT)

Gallatin County Area, Montana 448A—Hyalite-Beaverton complex, moderately wet, 0 to 2 percent slopes Map Unit Setting Elevation: 4,450 to 5,300 feet Mean annual precipitation: 15 to 19 inches Mean annual air temperature: 39 to 45 degrees F Frost-free period: 90 to 110 days **Map Unit Composition** Hyalite and similar soils: 70 percent Beaverton and similar soils: 20 percent Minor components: 10 percent **Description of Hyalite Setting** Landform: Alluvial fans, stream terraces Down-slope shape: Linear Across-slope shape: Linear Parent material: Loamy alluvium **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr) Depth to water table: About 48 to 96 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Available water capacity: Low (about 4.4 inches) **Interpretive groups** Farmland classification: Farmland of local importance Land capability classification (irrigated): 3e Land capability (nonirrigated): 4e Hydrologic Soil Group: C Ecological site: Shallow to Gravel (SwGr) 15-19" p.z. (R044XS354MT) **Typical profile** 0 to 5 inches: Loam 5 to 9 inches: Clay loam 9 to 17 inches: Silty clay loam 17 to 26 inches: Very cobbly sandy clay loam 26 to 60 inches: Very cobbly loamy sand **Description of Beaverton Setting** Landform: Alluvial fans, stream terraces Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 48 to 96 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 3.7 inches) **Interpretive groups** Farmland classification: Farmland of local importance Land capability classification (irrigated): 4s Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 15-19" p.z. (R044XS354MT) **Typical profile** 0 to 5 inches: Cobbly loam 5 to 21 inches: Very gravelly clay loam 21 to 25 inches: Very cobbly coarse sandy loam 25 to 60 inches: Extremely cobbly loamy coarse sand **Minor Components Beaverton** Percent of map unit: 5 percent Landform: Alluvial fans, stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Shallow to Gravel (SwGr) 15-19" p.z. (R044XS354MT) **Meadowcreek** Percent of map unit:

5 percent Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Subirrigated (Sb) 15-19" p.z. (R044XS359MT)

Gallatin County Area, Montana 556A—Threeriv-Bonebasin loams, 0 to 2 percent slopes Map Unit Setting Elevation: 4,000 to 6,100 feet Mean annual precipitation: 12 to 18 inches Mean annual air temperature: 39 to 45 degrees F Frost-free period: 90 to 110 days **Map Unit Composition** Bonebasin and similar soils: 45 percent Threeriv and similar soils: 45 percent Minor components: 10 percent **Description of Threeriv Setting** Landform: Flood plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Very poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr) Depth to water table: About 0 to 12 inches Frequency of flooding: Rare Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/ cm) Available water capacity: Moderate (about 7.1 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 5w Hydrologic Soil Group: C/D Ecological site: Wet Meadow (WM) 15-19" p.z. (R044XS365MT) **Typical profile** 0 to 4 inches: Moderately decomposed plant material 4 to 9 inches: Loam 9 to 29 inches: Stratified sandy loam to silty clay loam 29 to 60 inches: Extremely gravelly loamy sand **Description of Bonebasin Setting** Landform: Flood plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Very poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 0 to 12 inches Frequency of flooding: Rare Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/ cm) Available water capacity: Moderate (about 7.6 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 5w Hydrologic Soil Group: B/D Ecological site: Wet Meadow (WM) 15-19" p.z. (R044XS365MT) **Typical profile** 0 to 4 inches: Muck 4 to 15 inches: Loam 15 to 25 inches: Stratified sandy loam to silty clay loam 25 to 60 inches: Very gravelly coarse sand **Minor Components Threeriv** Percent of map unit: 5 percent Landform: Flood plains Down-slope shape: Linear Across-slope shape: Linear Ecological site: Wet Meadow (WM) 15-19" p.z. (R044XS365MT) **Blossberg** Percent of map unit: 5 percent Landform: Marshes Down-slope shape: Linear Across-slope shape: Linear Ecological site: Wet Meadow (WM) 15-19" p.z. (R044XS365MT) **Data Source Information** Soil Survey Area: Gallatin County Area, Montana Survey Area Data: Version 16, Apr 18, 2012

Gallatin County Area, Montana 457A—Turner loam, moderately wet, 0 to 2 percent slopes Map Unit Setting Elevation: 4,300 to 5,200 feet Mean annual precipitation: 15 to 19 inches Mean annual air temperature: 39 to 45 degrees F Frost-free period: 90 to 110 days **Map Unit Composition** Turner and similar soils: 85 percent Minor components: 15 percent **Description of Turner Setting** Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 48 to 96 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm) Available water capacity: Low (about 5.4 inches) **Interpretive groups** Farmland classification: Prime farmland if irrigated Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 15-19" p.z. (R044XS355MT) **Typical profile** 0 to 6 inches: Loam 6 to 12 inches: Clay loam 12 to 26 inches: Clay loam 26 to 60 inches: Very gravelly loamy sand **Minor Components Beaverton** Percent of map unit: 5 percent Landform: Alluvial fans, stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Shallow to Gravel (SwGr) 15-19" p.z. (R044XS354MT) **Meadowcreek** Percent of map unit: 5 percent Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Subirrigated (Sb) 15-19" p.z. (R044XS359MT) **Turner** Percent of map unit: 5 percent Landform: Stream terraces Down-slope shape: Linear Across-slope shape: Linear Ecological site: Silty (Si) 15-19" p.z. (R044XS355MT) **Data Source Information** Soil Survey Area: Gallatin County Area, Montana Survey Area Data: Version 16, Apr 18, 2012

Gallatin County Area, Montana UL—Urban land Map Unit Composition Urban land: 100 percent **Data Source Information** Soil Survey Area: Gallatin County Area, Montana Survey Area Data: Version 16, Apr 18, 2012

4.3.2 Soil Semi-variogram Description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g.*, soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 24). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 24).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 24), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

The variogram analysis will be used, to determine the spatial scales at which we can consider soil measurements spatially independent. This characterization will directly inform the minimum distance between *i*) soil plots within each soil array, *ii*) the soil profile measurements, *iii*) EP plots, and *iv*) the microbial sampling locations. These data will directly inform NEON construction and site design activities.

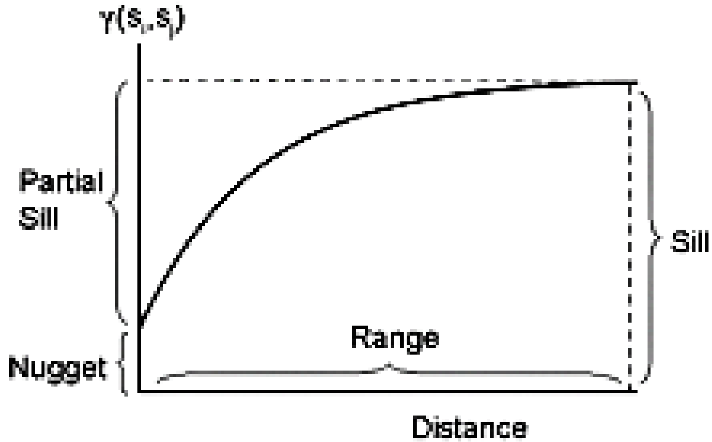


Figure 24. Example semivariogram, depicting range, sill, and nugget.

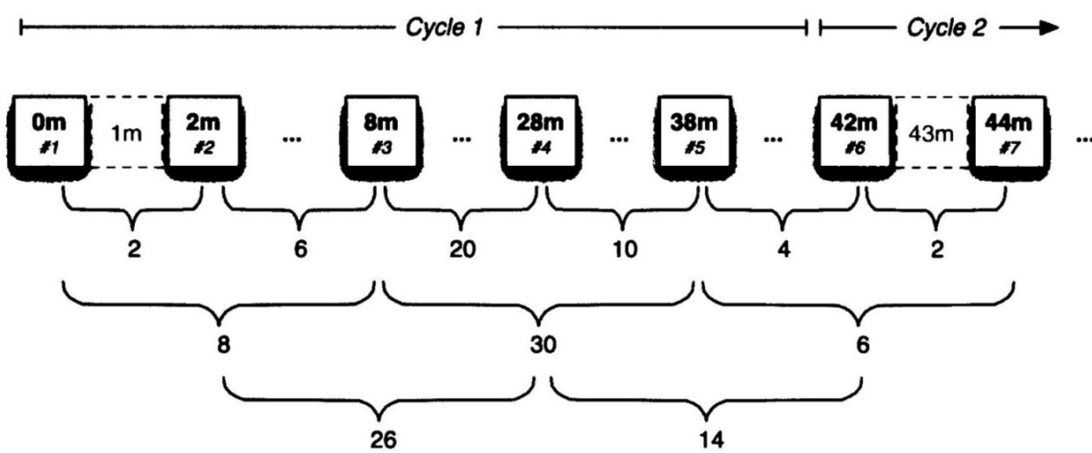


Figure 25. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 17 July 2013 at the Bozeman site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 25). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Bozeman. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 25, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Trangmar *et al.* 1986; Webster & Oliver 1989; Goovaerts 1997; Riberiro & Diggle 2001) and estimate the distance necessary for independence among soil plots in the soil array. To correct for changes in temperature and moisture over the sampling period, the stationary data was subtracted from the mobile data. In many instances a time of day trend was still apparent in the data even after subtracting the stationary data from the mobile data. This time of day trend was corrected for by fitting a linear regression and using the residuals for the semivariogram analysis. Soil temperature and moisture data, R code, graphs, and R output can be found at: P:\FIU\FIU_Site_Characterization\DXX\YYYYYYY_Characterization\Soil Measurements\Soil Data Analysis (where XX = domain number and YYYYYYY = site name).

4.3.3 Results and Interpretation

4.3.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data, any remaining time of day trend, and elevation, aspect and slope, were used for the semivariogram analysis (Figure 26). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 27, left graph) and directional semivariograms do not show anisotropy (Figure 27, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 27, right graph). The model indicates a distance of effective independence of 4 m for soil temperature.

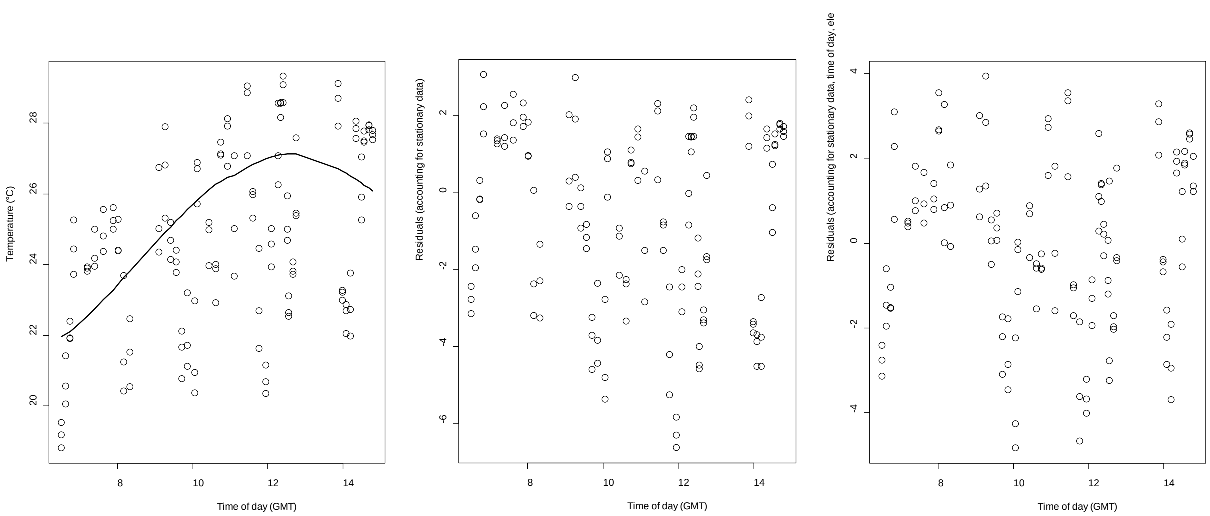


Figure 26. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

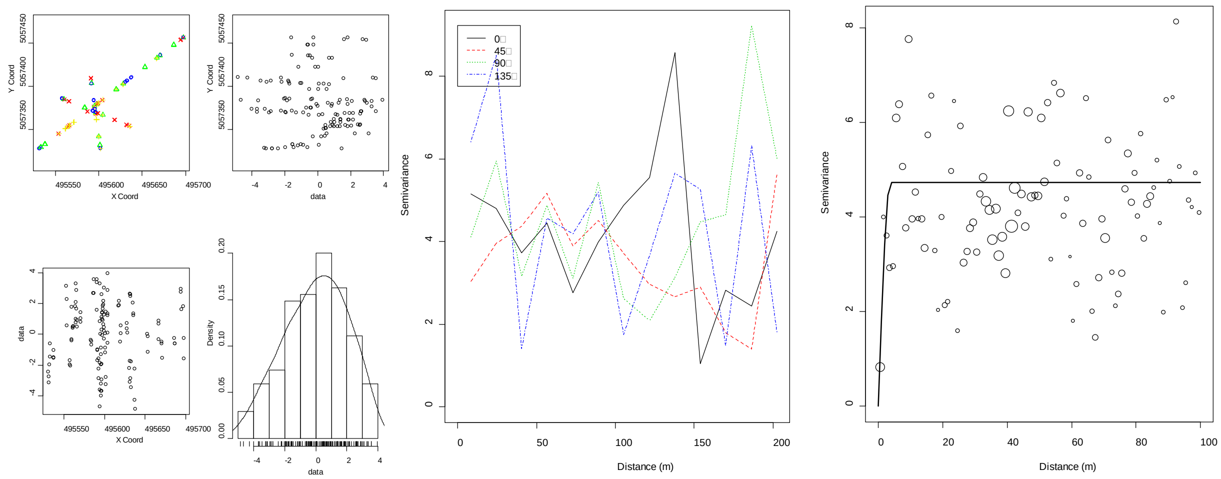


Figure 27. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

4.3.3.2 Soil Water Content

Soil water content data residuals, after accounting for changes in water content in the stationary data, any remaining time of day trend, and elevation, were used for the semivariogram analysis (Figure 28). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 29, left graph) and directional semivariograms do not show anisotropy (Figure 29, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 29, right graph). The model indicates a distance of effective independence of 33 m for soil water content.

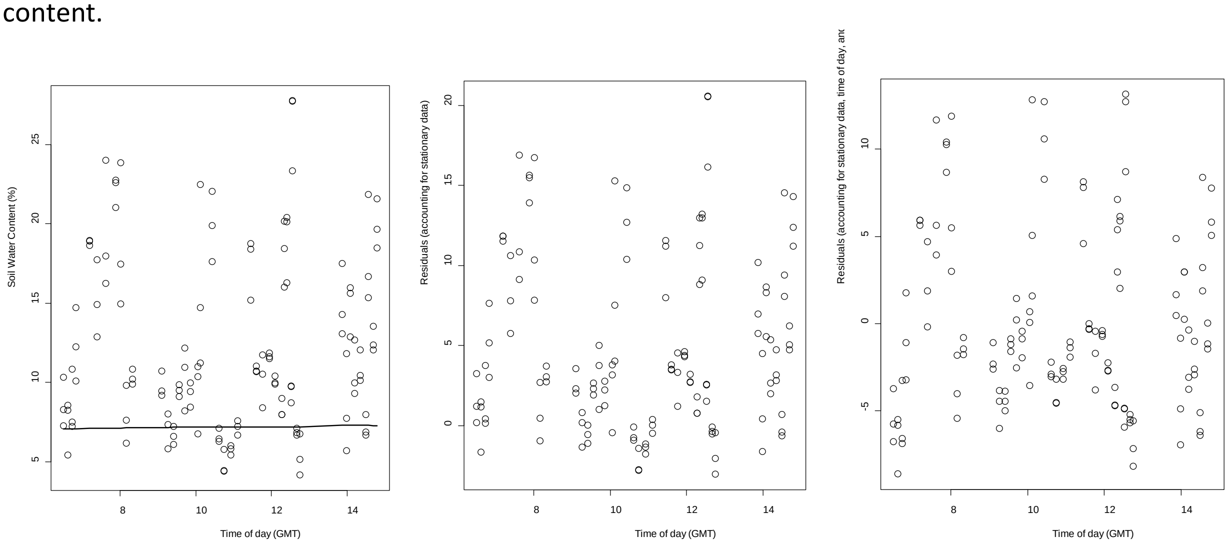


Figure 28. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting for changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

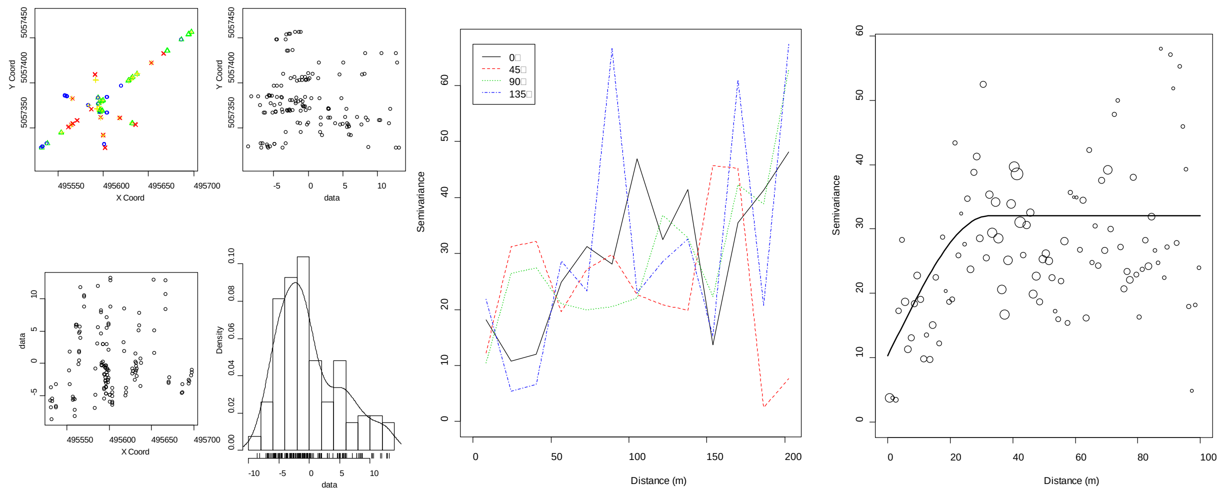


Figure 29. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

4.3.3.3 Soil array layout and soil pit location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 4 m for soil temperature and 33 m for soil moisture. Based on these results and the site design guidelines the soil plots at Bozeman shall be placed 33 m apart. The soil array shall follow the compact soil array design (Soil Array Pattern C) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 0° from the soil plot nearest the tower (i.e., first soil plot, Fig. 30). The location of the first soil plot will be approximately 45.67020°, -111.05646°. The exact location of each soil plot may be microsited to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 45.67019, -111.05521 (primary location); or 45.67042, -111.05521 (alternate location 1 if primary location is unsuitable); or 45.67064, -111.05521 (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 9 and site layout can be seen in Figure 31.

Dominant soil series at the site: Urban land. The taxonomy of this soil is shown below:
Order: Not applicable
Suborder: Not applicable
Great group: Not applicable
Subgroup: Not applicable
Family: Not applicable
Series: Not applicable

Table 9. Summary of soil array and soil pit information at Bozeman. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	C
Distance between soil plots: x	33 m
Distance from tower to closest soil plot: y	29 m
Latitude and longitude of 1st soil plot OR direction from tower	45.67020°, -111.05646°
Direction of soil array	0°
Latitude and longitude of FIU soil pit 1	45.67019, -111.05521 (primary location)
Latitude and longitude of FIU soil pit 2	45.67042, -111.05521 (alternate 1)
Latitude and longitude of FIU soil pit 3	45.67064, -111.05521 (alternate 2)
Dominant soil type	Not applicable
Expected soil depth	>2 m
Depth to water table	>1.22 m

Expected depth of soil horizons	**Expected measurement depths***
Unknown	

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.

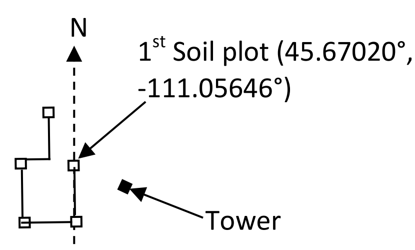


Figure 30. Schematic diagram of soil array layout in relation to tower. Soil plot positions are approximate.

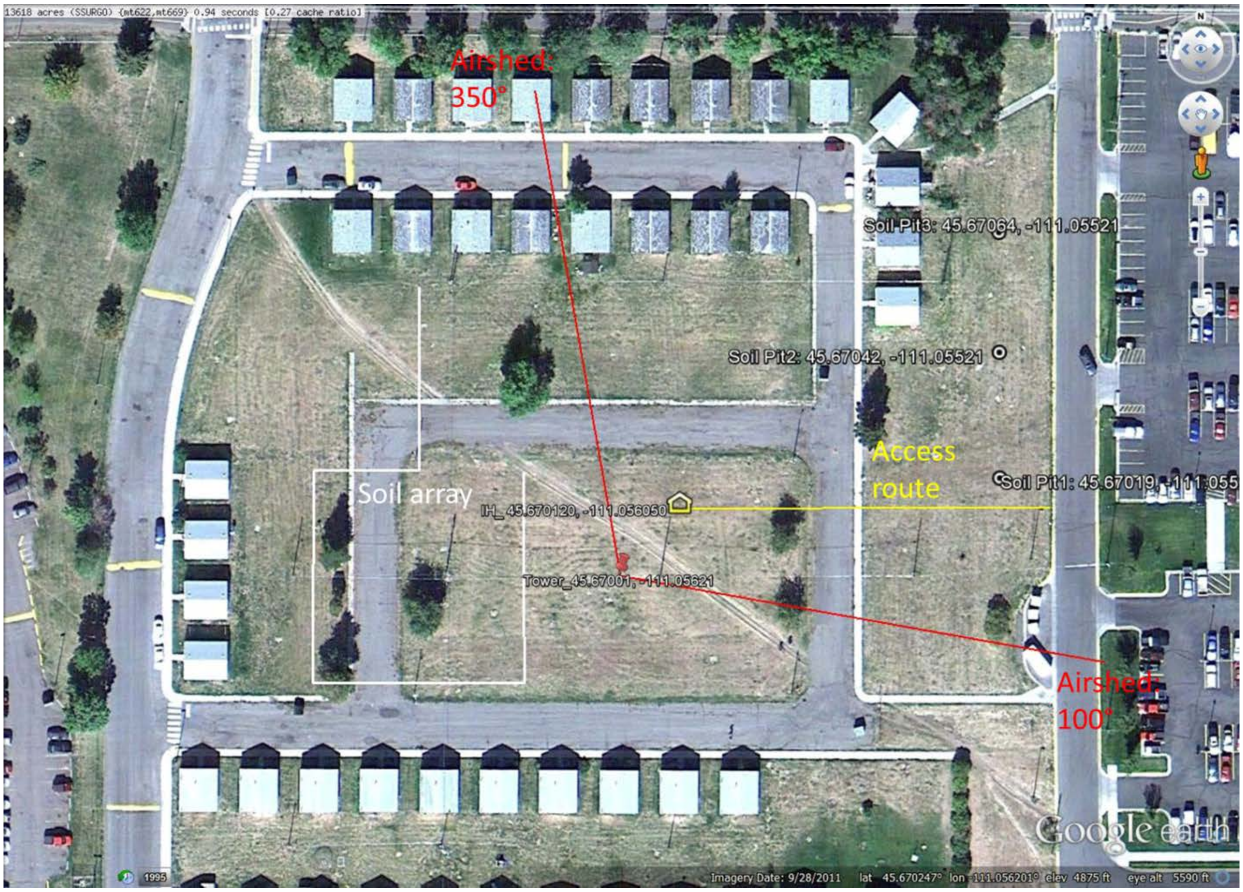


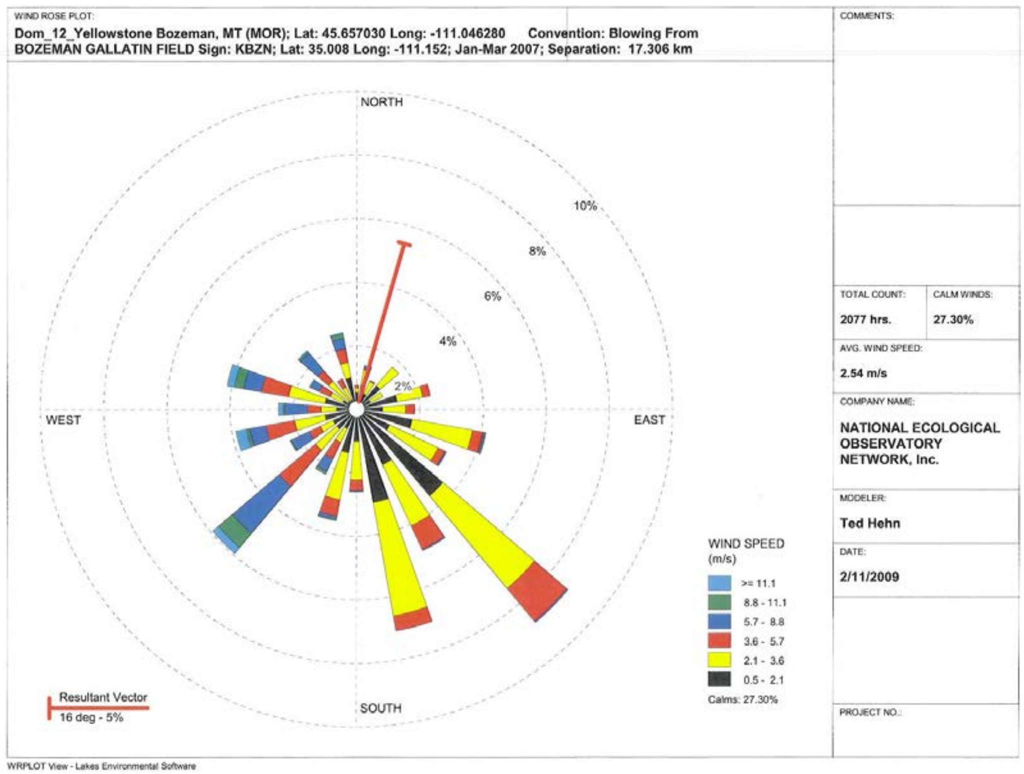
Figure 31. Site layout at Bozeman showing soil array and location of the FIU soil pit.

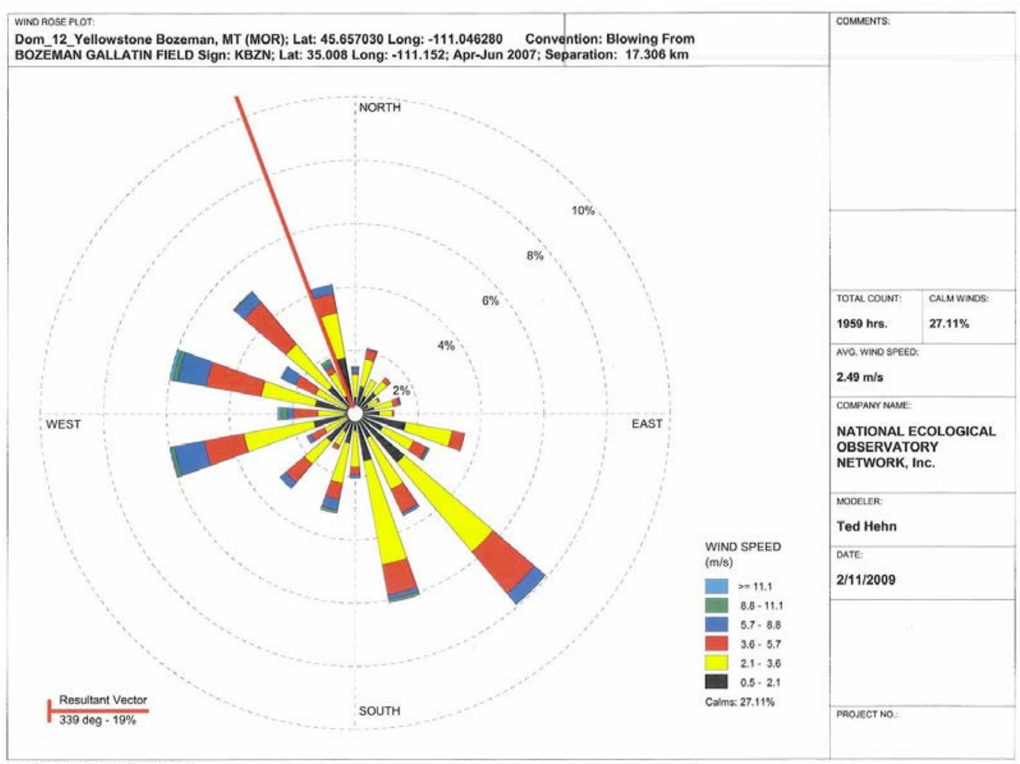
4.4 Airshed

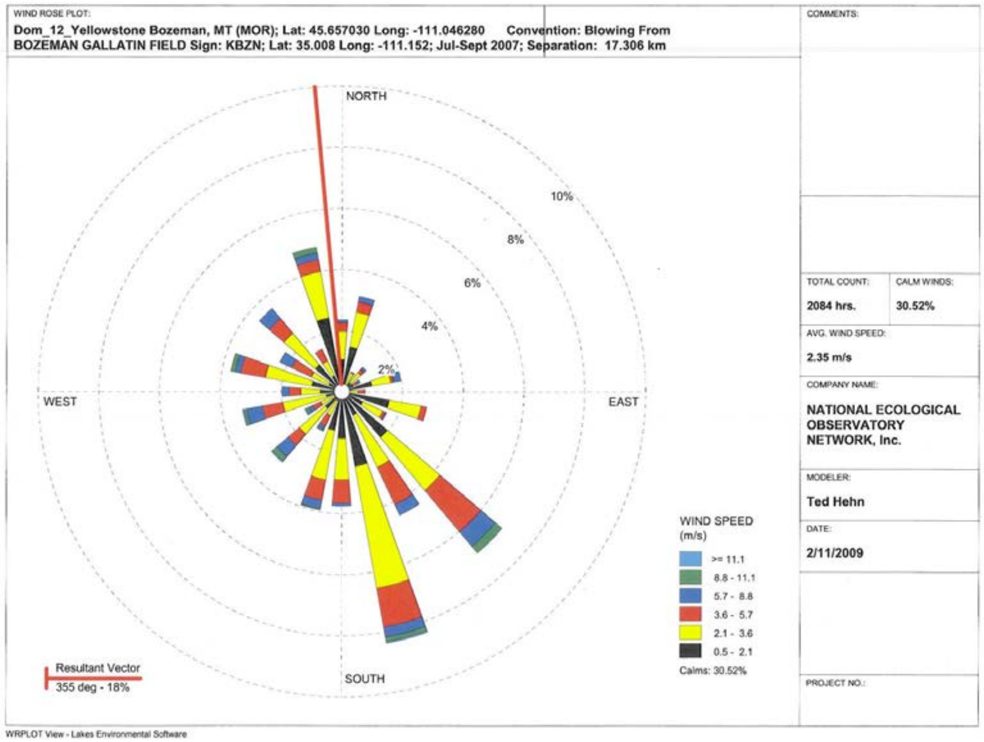
4.4.1 Seasonal Windroses

Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given time series. The weather data used to generate the following wind roses are from Gallatin Field airport (45.776, -111.152), which is ~17 km northwest to tower site. Terrain is flat in this region. We assume that the wind patterns at Hobart Municipal airport are similar to the ones at our site. The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

4.4.2 Results (graphs for wind roses)







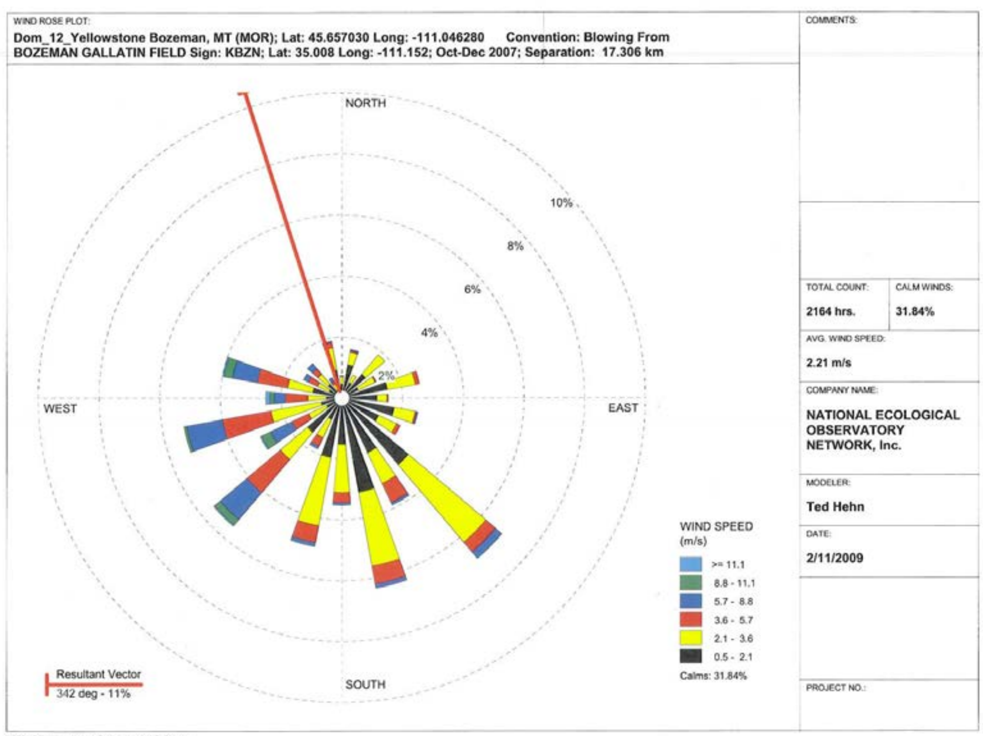


Figure 32. Windroses from Gallatin Field Airport for Bozeman Relocatable site.

Data used here are 2007 data from Gallatin Field Airport, which is ~17 km from tower site. Terrain is flat in this region. We assume that the wind patterns at Gallatin Field Airport are similar to the ones at our site. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

4.4.3 Resultant vectors

Table 10. The resultant wind vectors from Klemme using hourly data in 2007.

Quarterly (seasonal) timeperiod	Resultant vector	% duration
January to March	16°	5
April to June	339°	19
July to September	335°	18
October to December	342°	11
Annual mean	348°	na.

4.4.4 Expected environmental controls on source area

Two types of models were commonly used to determine the shape and extent of the source area under different and contrasting atmospheric stability classes. An inverted plume dispersion model with modeled cross wind solutions were used for convective conditions (Horst and Weil 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann and Meixner 2001). The source area models where bounded by the expected conditions depict the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically have long source area and associated waveforms. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime wind speeds, *e.g.,* 1-4 m s^{-2}. Higher wind speeds, like those experienced over the Rockies, are often the product of mechanical turbulence with long waveforms. Because thermal stratification is very efficient in suppressing vertical mixing, stable conditions also have typically very long waveforms.

As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (e.g., Harvard Forest, Bartlett Experimental Forest, and Burlington Conservation Area). The type of turbulence (mechanical verse convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

Here, we use a web-based footprint model to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature and energy information were either from the RFI document, previous site visit report, available data files or best estimated from experienced expert. Measurement height was determined from the Tower Height Info document provided by ENG group, then verify according to the real ecosystem structure after FIU site characterization at site. Runs 1-3 and 4-6 represent the expected conditions for summer and winter conditions, respectively, with maximum and mean windspeeds (daytime convective) and nighttime (stable atmospheres) conditions. The wind vector for each run was estimated from wind roses and is placed as a centerline in the site map included in the graphics. The width of the footprint was also estimated using the length between the isopleth of 80% cumulative flux and center line to calculate the angle from centerline. This information, along with distance of the cumulative flux isopleths and wind direction, will define the source area for the flux measurements on the top of the tower.

Table 11. Expected environmental controls to parameterize the source area model and associated results from Bozeman Relocatable tower site.

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height‡	30	30	30	30	30	30	m
Canopy Height	15	15	15	15	15	15	m
Canopy area density	2.0	2.0	2.0	1	1	1	m
Boundary layer depth	2800	2800	851	801	801	450	m
Expected sensible heat flux	550	550	175	-25	-25	-100	W m^{-2}
Air Temperature	28	28	14	-5	-5	-10	°C
Max. windspeed	11	2.8	2.4	13	6.2	2.8	m s^{-1}
Resultant wind vector	165	165	344	255	225	135	degrees
Results							
(z-d)/L	-0.04	-0.51	-0.44	0	0.01	3	m
d	11	11	11	9.9	9.9	9.9	m
Sigma v	3.6	2.4	1.3	1.8	1.8	1.6	m^2 s^{-2}
Z0	0.82	0.82	0.82	1.1	1.1	1.10	m
u*	1.5	0.6	0.44	1.8	0.84	0.06	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	1100	300	400	1300	1400	3700	m
Distance of 80% cumulative flux	650	250	250	750	750	3400	m
Distance of 70% cumulative flux	450	150	200	500	500	3200	m
Peak contribution	105	35	55	95	95	2675	m

‡: measurement height is design based on the tree height (15 m) in the residential area within airshed.

4.4.5 Results (source area graphs)

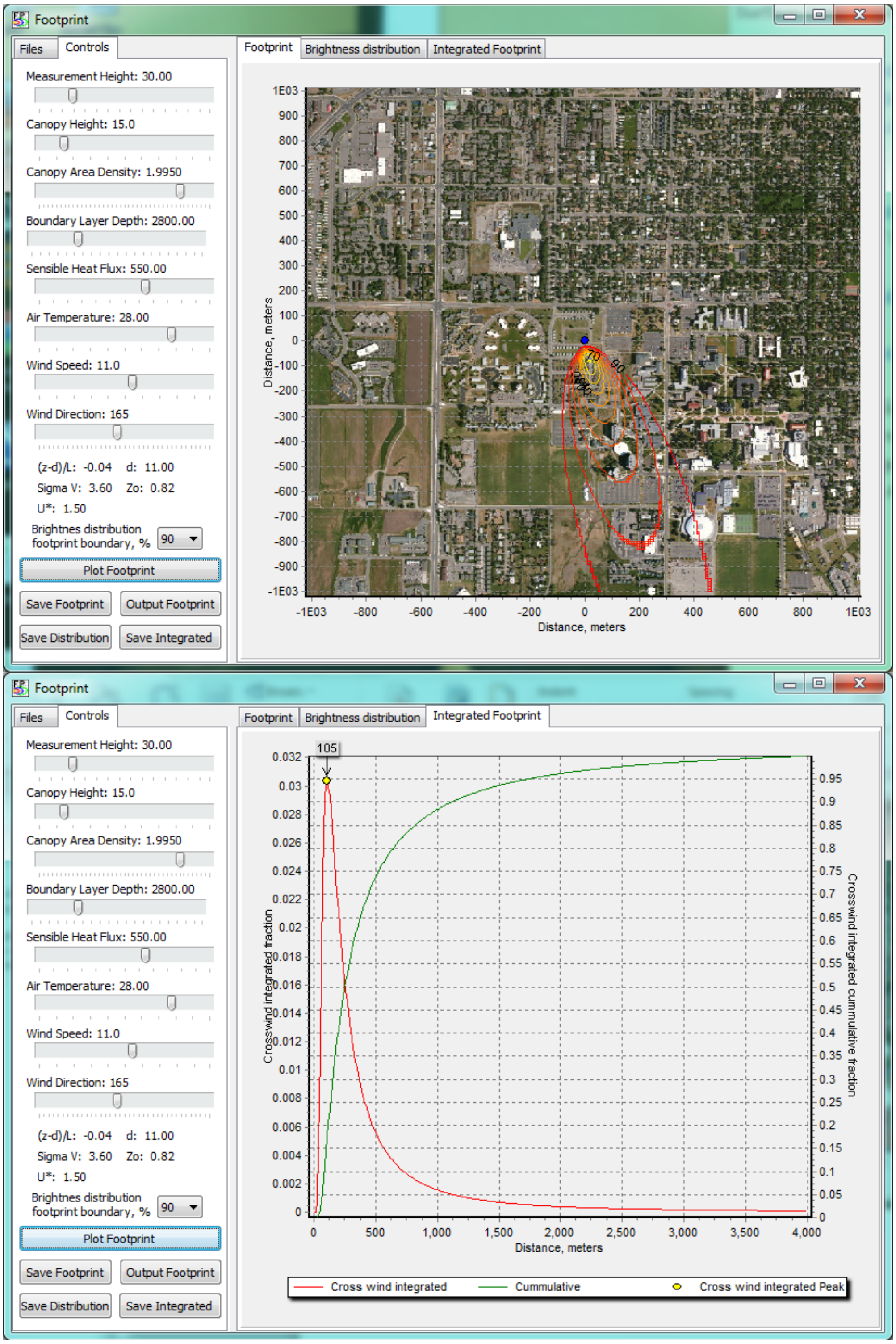


Figure 33. Bozeman Relocatable site summer daytime (convective) footprint output with max wind speed

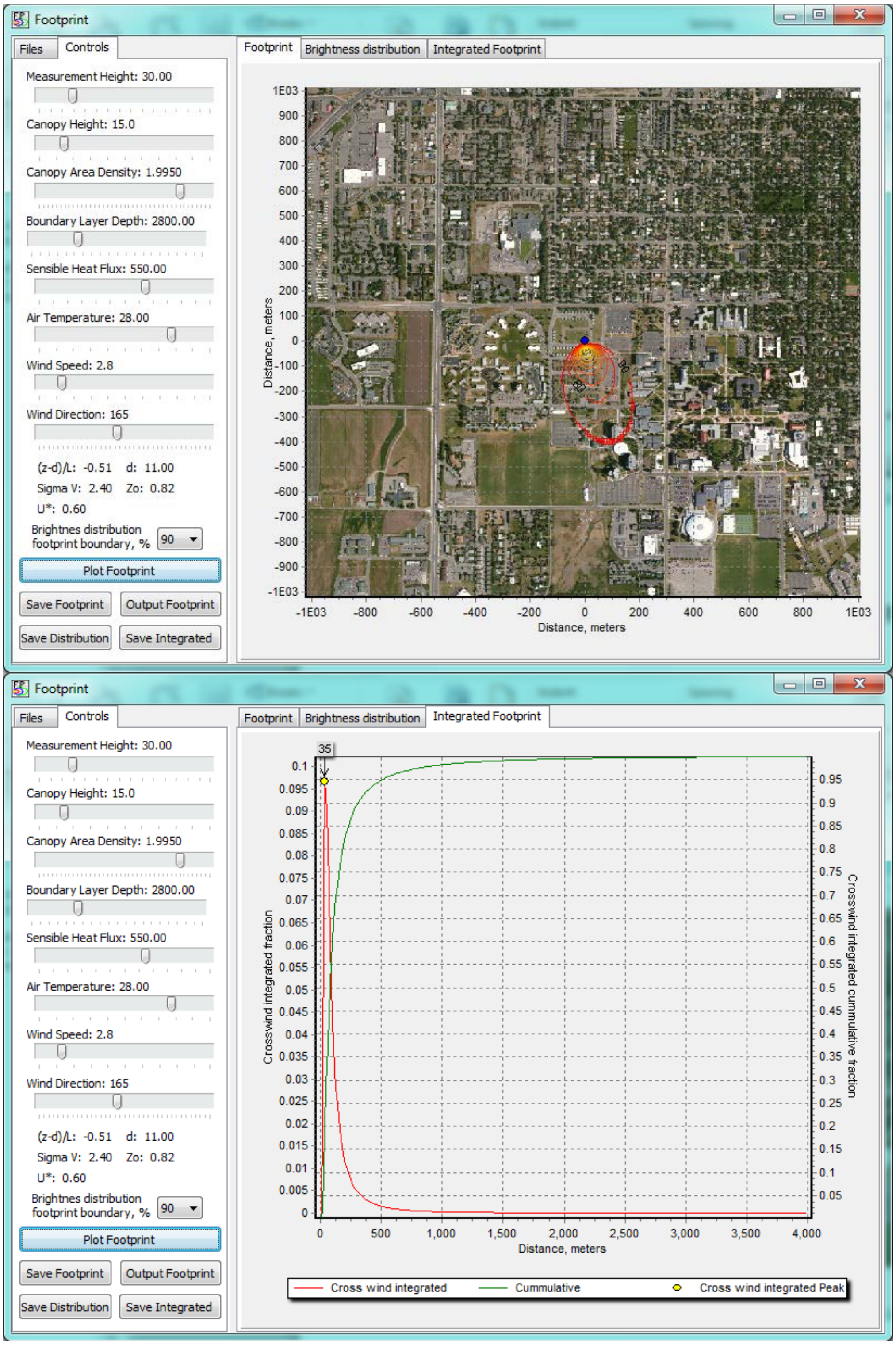


Figure 34. Bozeman Relocatable site summer daytime (convective) footprint output with mean wind speed

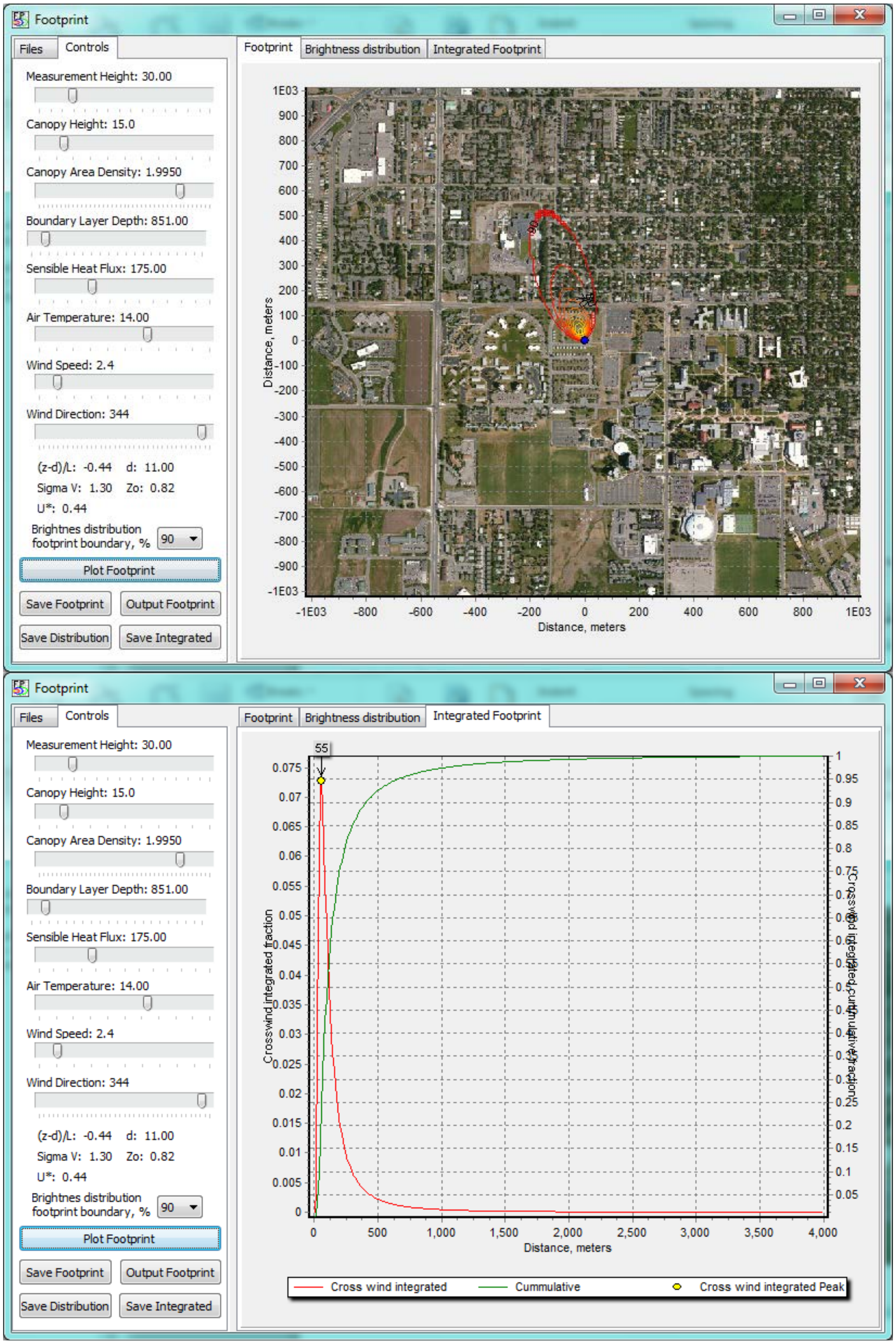


Figure 35. Bozeman Relocatable site summer nighttime (stable) footprint output with mean wind speed.

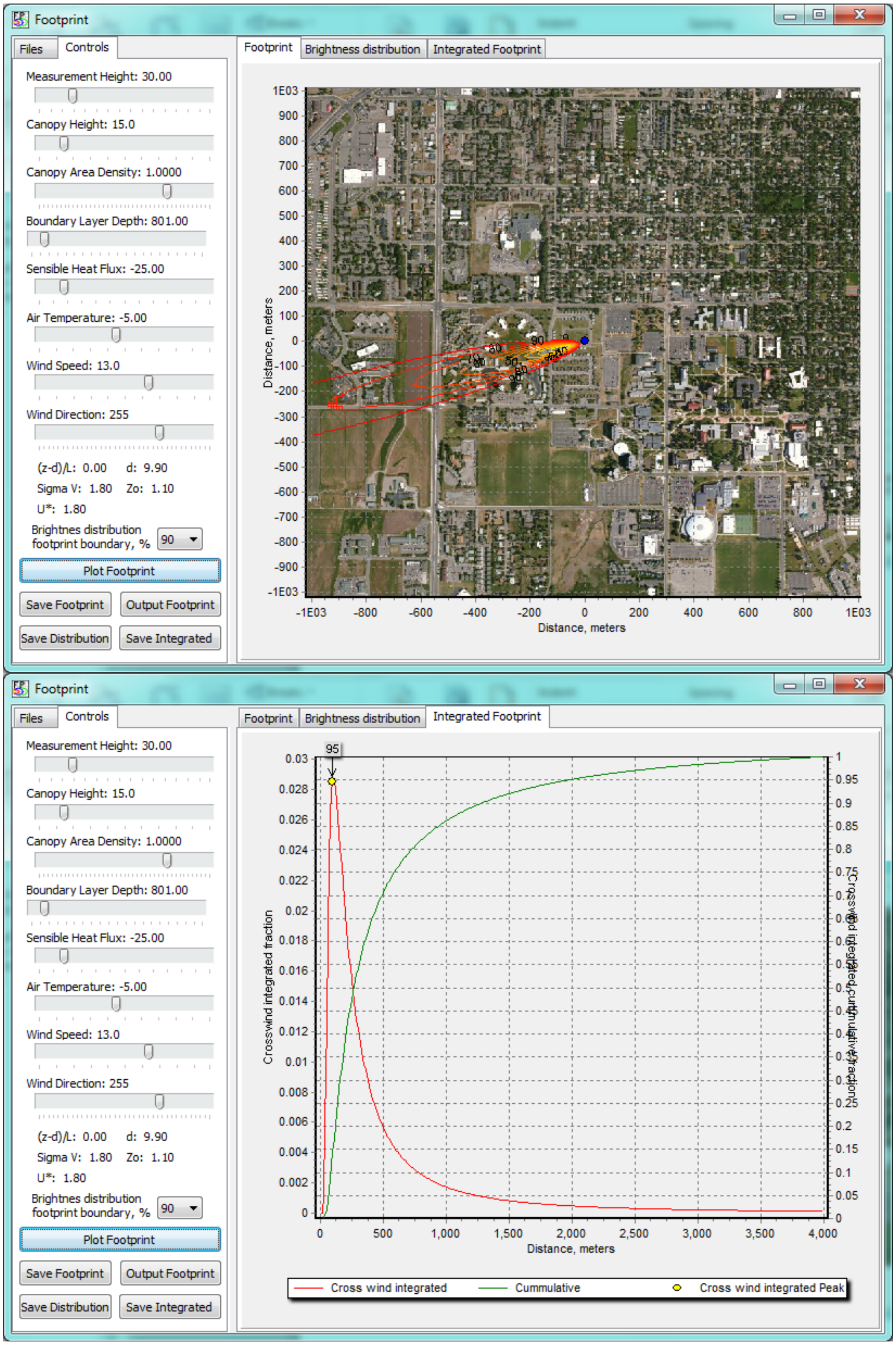


Figure 36. Bozeman Relocatable site winter daytime (convective) footprint output with max wind speed

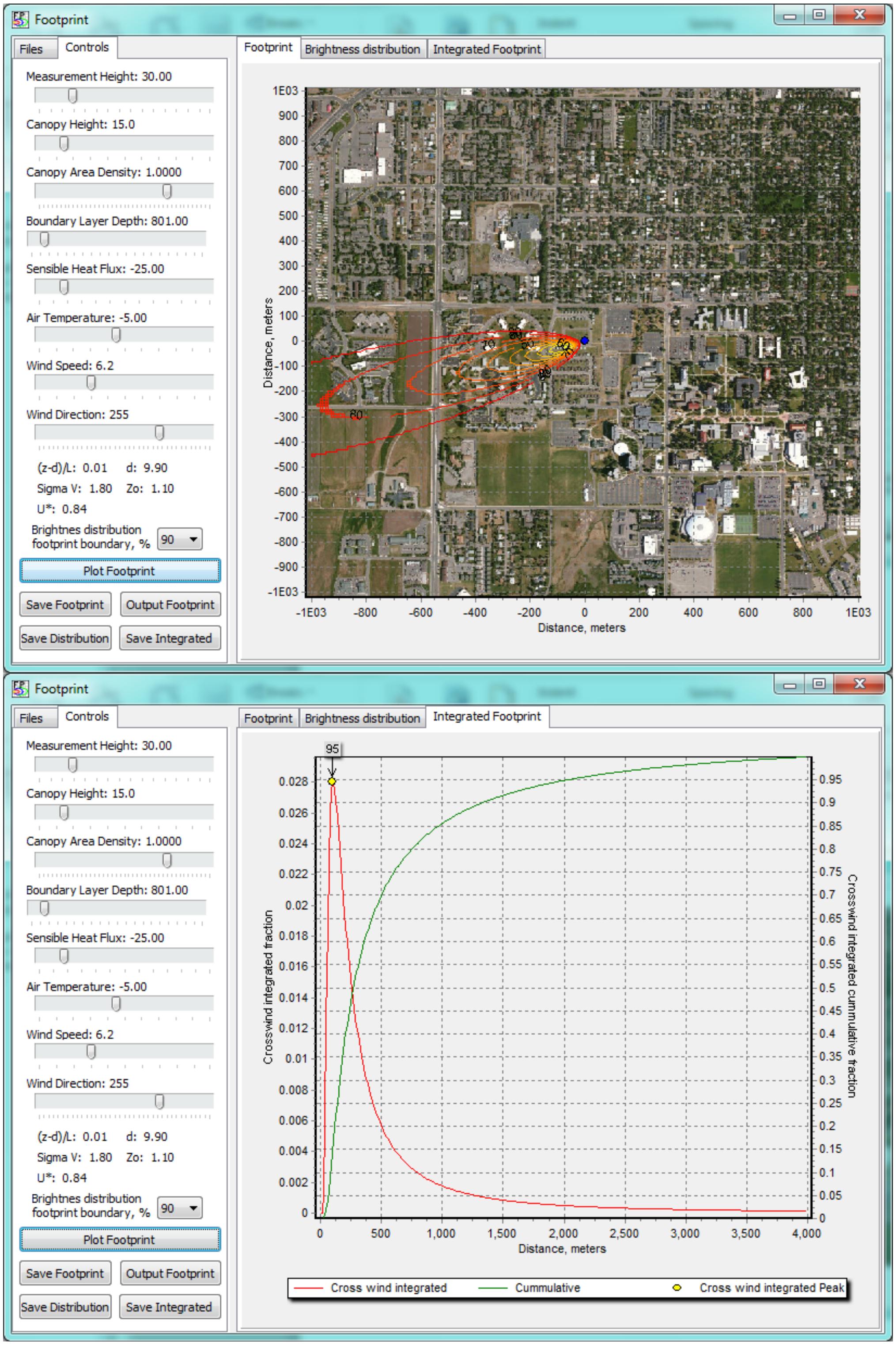


Figure 37. Bozeman Relocatable site winter daytime (convective) footprint output with mean wind speed.

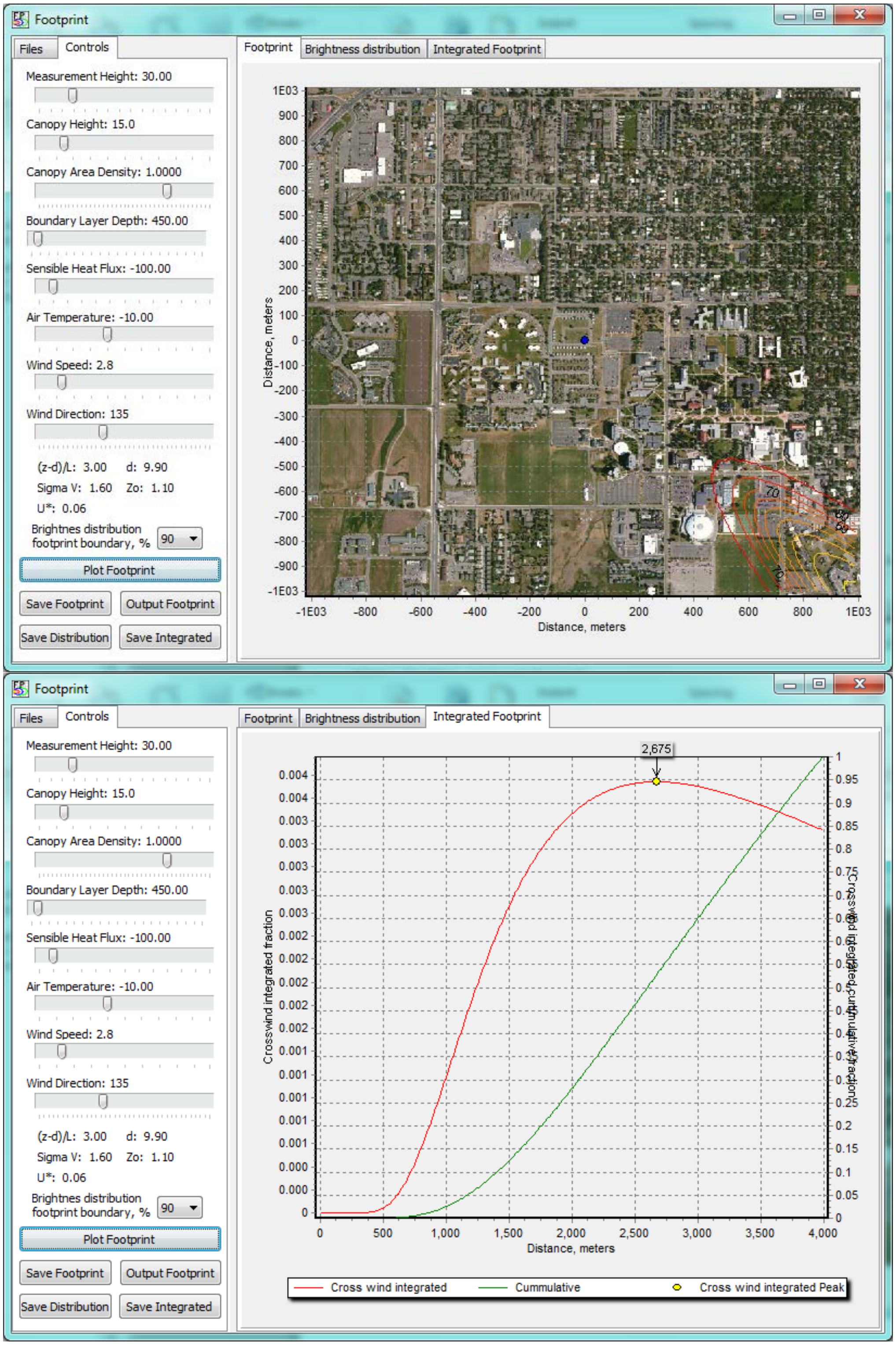


Figure 38. Bozeman Relocatable site winter nighttime (stable) footprint output with mean wind speed.

4.4.6 Site design and tower attributes

According to wind roses, prevailing wind blows between south (100^o to 350^o, clockwise from 100^o), but has higher frequency between 100° and 180° (clockwise from 100°). **Tower** should be placed to a location to best catch the signals from the airshed of the ecosystem in interest, which is the grass field and surrounding urban area at this site. We propose to place the tower in the center of the piece of land, so that it is at least one tower-height distance away from surrounding buildings, streets, the power line across S-N of this land, as well as all trees in this piece of land. The proposed tower location is at 45.67001, -111.05621 degrees.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the southwest will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the northeast toward tower and have the longer side parallel to SE-NW direction. Therefore, we decide the placement of instrument hut at 45.67012, -111.05605 degrees.

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Grass and annuals on this piece of land are ~ 0.2-0.3 m in height, but average canopy height is ~15 m for the trees in this piece of land, within airshed and in the surrounding residential area. Therefore, we determine tower height based on the trees height in the airshed, and design measurement layers based on the grassland, tree and building heights. Therefore, we require 6 **measurement layers** on the tower with top measurement height at 30 m, and the remaining levels are 19 m, 15 m, 9 m, 4 m and 0.3 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. No **wet deposition collector** will be deployed at this site. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 12. Site design and tower attributes for Bozeman Relocatable site. 0° is true north with declination accounted for. Color of instrument hut exterior shall be tan or best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed area			100° to 350° but has higher frequency from 100° to 180°		Clockwise from first angle
Tower location	45.67001	-111.05621	--	--	new site
Instrument hut	45.67012	-111.05605			
Instrument hut orientation vector	--	--	135° - 315°		
Instrument hut distance z	--	--	--	18	
Anemometer/Temperature boom orientation	--	--	225°	--	
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				4.0	m.a.g.l.
Level 3				9.0	m.a.g.l.
Level 4				15.0	m.a.g.l.
Level 5				19.0	m.a.g.l.
Level 6				30.0	m.a.g.l.
Tower Height				30.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Figure below shows the proposed tower location, instrument hut location, airshed area and access road.

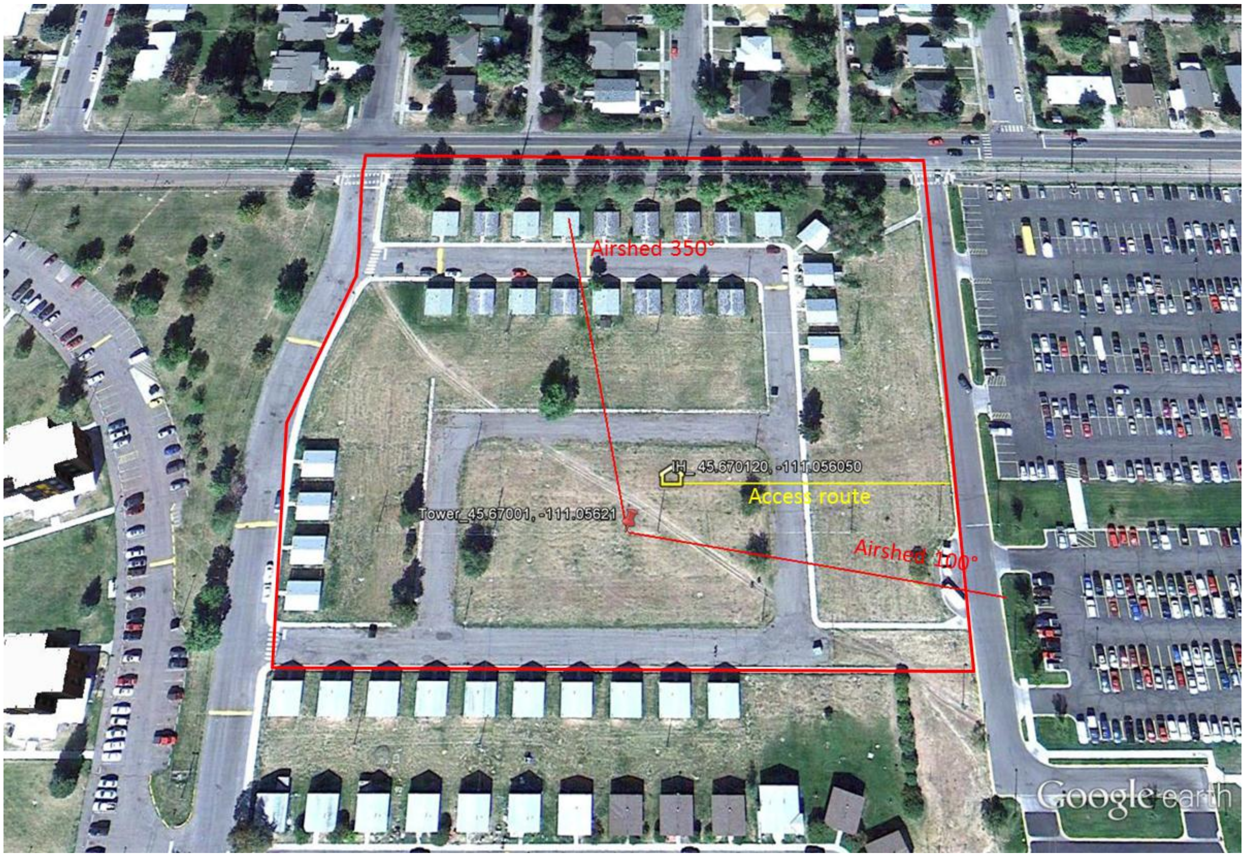


Figure 39. Site layout for Bozeman Relocatable site.

i) New tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 100^{o} to 350^{o} (clockwise from 100^{o}) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. Here FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36' wide footprint. While the final design is not yet known, there are some general criteria that can be outlined. We assume that the boardwalk width is 36" (0.914 m). Material is not known, but must be fire proof, and in some locations the site is seasonally flooded and inundated with water. Boardwalks may also provide a scratching structure for grazing animals that in turn, would wear and unduly impact the site. Site by site evaluations must be done.

Specific boardwalks at the Bozeman Relocatable site

- Gravel path from the access point to the instrument hut, pending landowner decision.
- Boardwalk from the instrument hut to the tower
- Gravel path to the soil array
- No gravel path or boardwalk to individual soil plots

The relative locations between tower, instrument hut and boardwalk can be found in the diagram below:

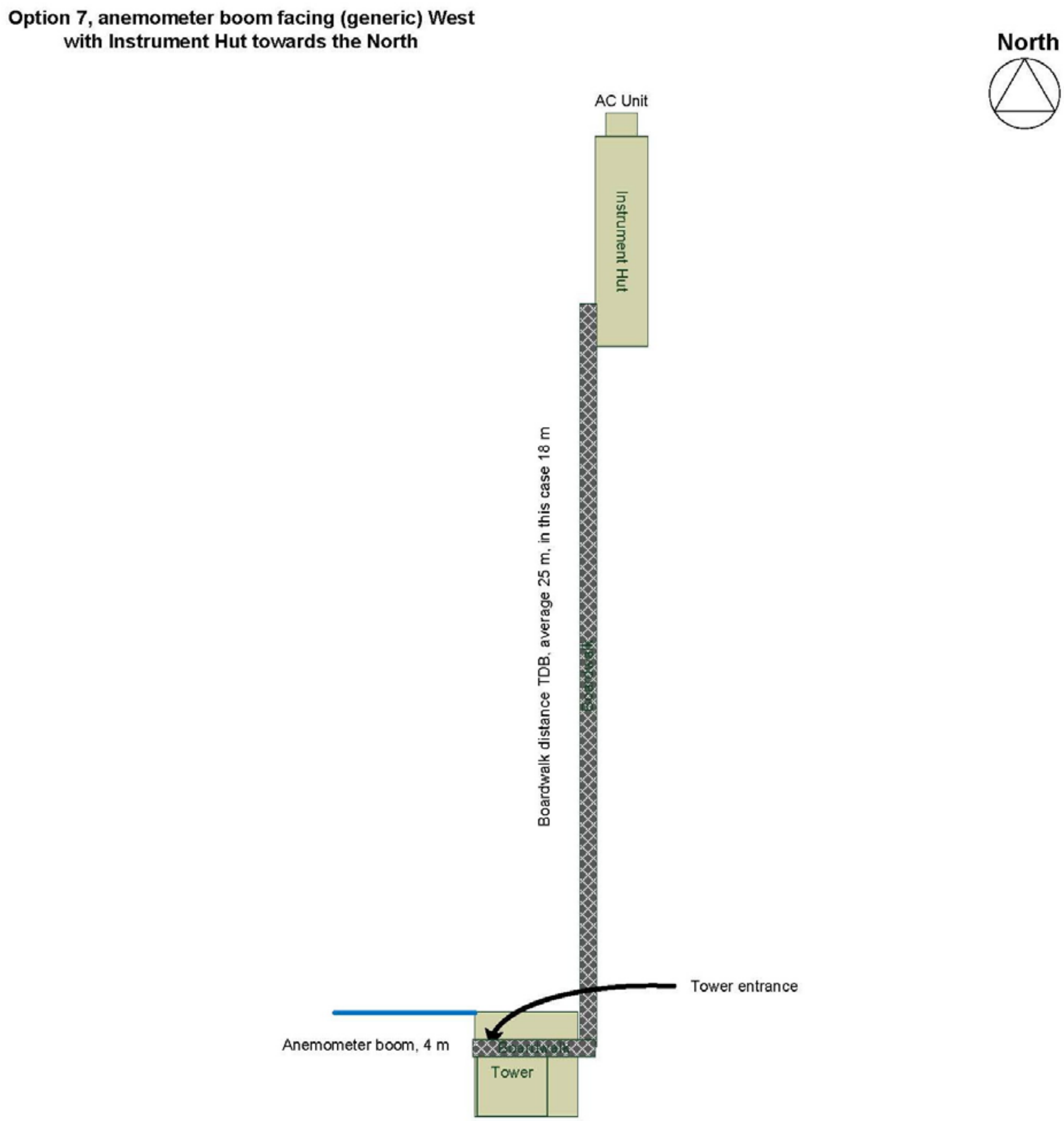


Figure 40. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the north towards the tower.

This is just a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At Bozeman Relocatable site, the boom angle will be 225º, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~18 m. The instrument hut vector will be SE-NE (135º-315º, longwise).

4.4.7 Information for Ecosystem Productivity Plots

The tower at Bozeman relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (grass field and surrounding urban area). Prevailing wind blows from 100º to 350º, clockwise from 100º, but has higher frequency from 100° to 180° (clockwise from 100°). 90% signals for flux measurements are within a distance of 1100 m from tower during summer, and 80% within 650 m, while during winter, the signals collected at tower can be far beyond 1 km, especially at nighttime. But during winter daytime, 80% signals are within 750 m from tower. We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 100º to 180º (clockwise from 100°) from tower.

4.5 Issues and Attentions

This field is small, approximately 150 m (N-E) × 180 m (W-E). It will not be big enough to meet the needs for FSU science activities.

There are many different land-use types surrounding the site, which will complicate the interpretation of the data from this site. However, this is somewhat enevitable in an urban site, since urban areas often have many different land-uses in close proximity to one another. In particular, relating tower-based flux measurements, which have a footprint covering hundreds of meters (i.e. extending beyond the field boundary), will be difficult to relate to point based measurements made from the tower or soil array.

There are residential houses to the south, north and west, and some large buildings (~25-35 m in height) to the east and south, but about 300 m away. A footpath runs NW-SE cross the field. Roads are adjacent to the field to the east, north and west. The nearby residential areas and adjacent footpath result in a lot of foot traffic near this NEON candidate site. Signage and fencing may be required to deter tampering with NEON equipment.

This field was previously residential housing and pavement area. The houses on the left edge and north edge of this field have been demolished and foundations have been excavated. The paved road inside the field is now returned to soil surface. These areas will be re-seeded and turned into lawn. Irrigation system will be installed soon. Both re-seeding and installation of irrigation system likely occur in August or September 2013. Tower sensors could be under the risk of being watered, so do the soil radiation sensors and throughfall collector. Soil moisture will be heavily impacted by the irrigation frequency and the distance between the soil moisture sensors and irrigation system.

There is a power line running S-N direction across this land (see the purple line in the map below) and providing power supply to the houses on the south outside this land. There is no immediate plan to demolish these houses and take down the power line.

The north part of this land (see orange box below in the map) is currently used as fenced construction staging area, concrete truck washing area and soil deposition site. It likely remains as it is untill construction of Engineering building is done, which is 2-3 years.

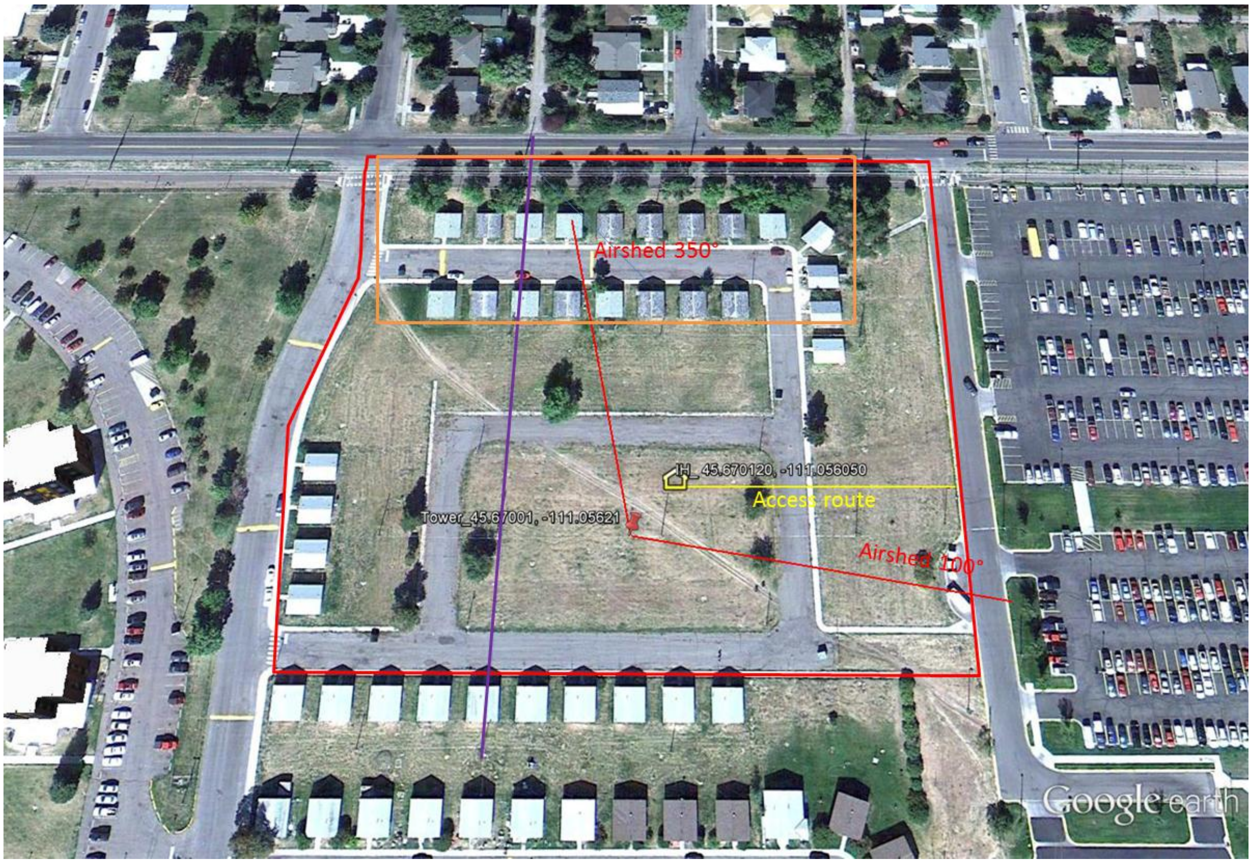


Figure 41. Map to indicate the power line (purple line) and the MSU construction staging area (orange box).

Figure 42. A picture to show the power line in the background, which runs S-N across this land

5 PARADISE VALLEY, RELOCATEABLE TOWER 2

5.1 Site Description

The Paradise Valley tower site is located in a property of Department of Natural Resources (DNR) and is ~ 25 miles southeast of Bozeman, and 33 miles north of Yellowstone national park. This site is just west of the N Old Yellowstone Trail. This is a short grassland site and open for active grazing from June to October every year. The terrain within the tower airshed (areas south and north of tower) is generally flat and gentle rolling hills with less than 2-3 m changes in height. The hill ridge, ~ 370 m away to the west of tower location, runs NE-SW direction and rises up for 20-30 m. About 150 m to the east of the tower location, the terrain drops steeply for ~10 – 20 m along the N Old Yellowstone trail. Flood is not a concern at this site. A power line runs NE-SW across site ~ 120 m west of tower location.

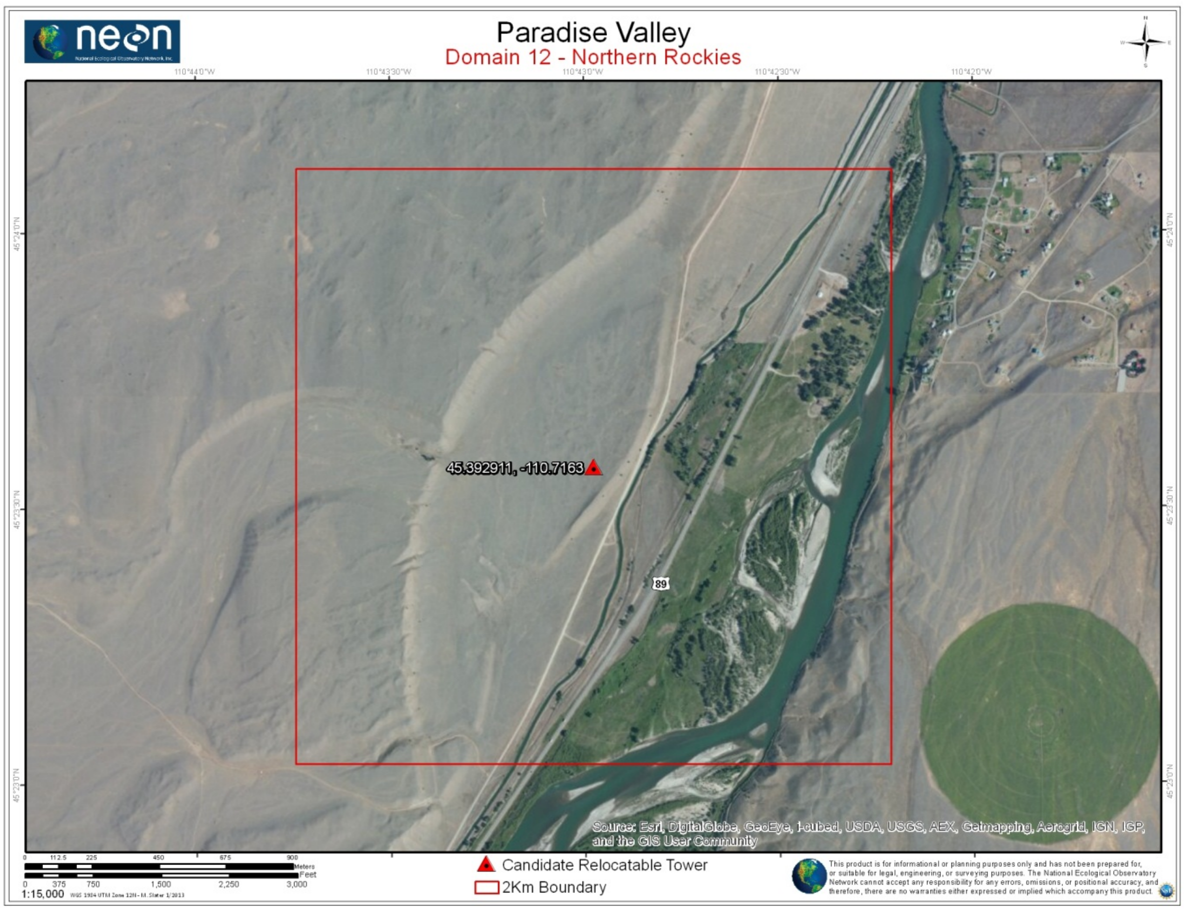


Figure 43. Paradise Valley 2 km map and original tower location.

5.2 Ecosystem

Vegetation and land cover around tower site and surrounding area are presented below:

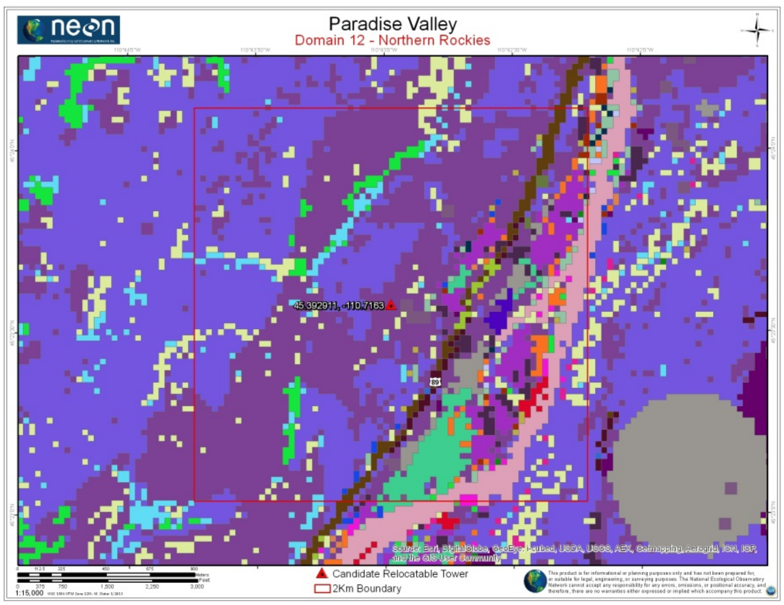


Figure 44. Vegetative cover map of the Paradise Valley relocatable site and surrounding areas (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Table 13. Percent Land cover information at the Pradise Valley relocatable site (from USGS, http://landfire.cr.usgs.gov/viewer/viewer.htm)

Veg_Type	**Veg_Height**	**Area_km2**	**Percentage**
Agriculture-Cultivated Crops and Irrigated Agriculture	Developed - Open Space	0.005	0.11
Agriculture-Cultivated Crops and Irrigated Agriculture	Herb Height 0 to 0.5 meters	0.034	0.85
Agriculture-Cultivated Crops and Irrigated Agriculture	Shrub Height 0.5 to 1.0 meter	0.023	0.56
Agriculture-Pasture and Hay	Herb Height 0 to 0.5 meters	0.005	0.13

Agriculture-Pasture and Hay	Shrub Height 0.5 to 1.0 meter	0.011	0.27
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Herb Height 0 to 0.5 meters	0.008	0.20
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Open Water	0.002	0.04
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Shrub Height 0 to 0.5 meters	0.042	1.06
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Shrub Height 0.5 to 1.0 meter	0.007	0.18
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Shrub Height 1.0 to 3.0 meters	0.001	0.02
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Sparse Vegetation Height	0.004	0.09
Barren	Barren	0.007	0.18
Barren	Sparse Vegetation Height	0.001	0.02
Barren	Open Water	0.005	0.11
Developed-Roads	Developed-Roads	0.022	0.54
Developed-Roads	Developed-Upland Shrubland	0.005	0.11
Developed-Roads	Herb Height 0 to 0.5 meters	0.001	0.02
Developed-Upland Herbaceous	Developed-Upland Herbaceous	0.001	0.02
Developed-Upland Mixed Forest	Developed-Upland Mixed Forest	0.011	0.27
Developed-Upland Mixed Forest	Developed-Upland Shrubland	0.001	0.02
Developed-Upland Mixed Forest	Herb Height 0 to 0.5 meters	0.002	0.04
Developed-Upland Shrubland	Developed - Low Intensity	0.005	0.13
Developed-Upland Shrubland	Developed-Roads	0.002	0.04
Developed-Upland Shrubland	Developed-Upland Mixed Forest	0.001	0.02
Developed-Upland Shrubland	Developed-Upland Shrubland	0.054	1.35
Developed-Upland Shrubland	Forest Height 10 to 25 meters	0.002	0.04
Developed-Upland Shrubland	Herb Height 0 to 0.5 meters	0.010	0.26
Developed-Upland Shrubland	Shrub Height 0 to 0.5 meters	0.001	0.02
Herbaceous Wetlands	Forest Height 10 to 25 meters	0.047	1.18
Herbaceous Wetlands	Forest Height 5 to 10 meters	0.001	0.02
Herbaceous Wetlands	Herb Height 0 to 0.5 meters	0.065	1.64
Herbaceous Wetlands	Shrub Height 0.5 to 1.0 meter	0.017	0.43
Herbaceous Wetlands	Shrub Height 1.0 to 3.0 meters	0.001	0.02
Herbaceous Wetlands	Sparse Vegetation Height	0.001	0.02
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Forest Height 10 to 25 meters	0.002	0.06

Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Herb Height 0 to 0.5 meters	0.001	0.02
Inter-Mountain Basins Big Sagebrush Steppe	Herb Height 0 to 0.5 meters	0.011	0.27
Inter-Mountain Basins Big Sagebrush Steppe	Shrub Height 0 to 0.5 meters	0.034	0.85
Inter-Mountain Basins Big Sagebrush Steppe	Shrub Height 0.5 to 1.0 meter	0.019	0.46
Inter-Mountain Basins Big Sagebrush Steppe	Shrub Height 1.0 to 3.0 meters	0.012	0.29
Inter-Mountain Basins Mixed Salt Desert Scrub	Shrub Height 0.5 to 1.0 meter	0.004	0.09
Inter-Mountain Basins Montane Sagebrush Steppe	Developed-Roads	0.001	0.02
Inter-Mountain Basins Montane Sagebrush Steppe	Developed-Upland Shrubland	0.001	0.02
Inter-Mountain Basins Montane Sagebrush Steppe	Forest Height 10 to 25 meters	0.002	0.04
Inter-Mountain Basins Montane Sagebrush Steppe	Herb Height 0 to 0.5 meters	0.036	0.90
Inter-Mountain Basins Montane Sagebrush Steppe	Open Water	0.010	0.26
Inter-Mountain Basins Montane Sagebrush Steppe	Shrub Height 0 to 0.5 meters	0.109	2.73
Inter-Mountain Basins Montane Sagebrush Steppe	Shrub Height 0.5 to 1.0 meter	0.013	0.31
Inter-Mountain Basins Montane Sagebrush Steppe	Shrub Height 1.0 to 3.0 meters	0.004	0.10
Introduced Upland Vegetation-Perennial Grassland and Forbland	Herb Height 0 to 0.5 meters	0.001	0.02
Introduced Upland Vegetation-Perennial Grassland and Forbland	Shrub Height 0.5 to 1.0 meter	0.001	0.02
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Forest Height 0 to 5 meters	0.001	0.02
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Forest Height 10 to 25 meters	0.002	0.04
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Herb Height 0 to 0.5 meters	0.006	0.14
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Open Water	0.005	0.12

NASS-Close Grown Crop	Developed - Open Space	0.002	0.04
NASS-Close Grown Crop	Forest Height 0 to 5 meters	0.001	0.02
NASS-Close Grown Crop	Herb Height 0 to 0.5 meters	0.018	0.45
NASS-Row Crop	Developed - Open Space	0.001	0.02
NASS-Row Crop	Developed-Upland Shrubland	0.001	0.02
NASS-Row Crop	Herb Height 0 to 0.5 meters	0.004	0.09
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Developed - Low Intensity	0.001	0.02
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Developed-Upland Shrubland	0.002	0.04
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Forest Height 0 to 5 meters	0.001	0.02
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Forest Height 10 to 25 meters	0.004	0.09
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Herb Height 0 to 0.5 meters	1.146	28.65
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Herb Height 0.5 to 1.0 meters	0.002	0.04
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Open Water	0.016	0.41
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Shrub Height 0 to 0.5 meters	0.025	0.63
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Shrub Height 0.5 to 1.0 meter	0.003	0.07
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Shrub Height 1.0 to 3.0 meters	0.002	0.04
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Sparse Vegetation Height	0.005	0.12
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	Herb Height 0 to 0.5 meters	0.002	0.04

Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	Shrub Height 0 to 0.5 meters	0.005	0.11
Northern Rocky Mountain Subalpine Woodland and Parkland	Forest Height 10 to 25 meters	0.003	0.07
Open Water	Forest Height 10 to 25 meters	0.003	0.07
Open Water	Herb Height 0 to 0.5 meters	0.001	0.03
Open Water	Open Water	0.161	4.02
Open Water	Sparse Vegetation Height	0.003	0.07
Pseudotsuga menziesii Forest Alliance	Forest Height 10 to 25 meters	0.002	0.04
Rocky Mountain Aspen Forest and Woodland	Forest Height 10 to 25 meters	0.003	0.08
Rocky Mountain Aspen Forest and Woodland	Forest Height 5 to 10 meters	0.001	0.01
Rocky Mountain Aspen Forest and Woodland	Herb Height 0 to 0.5 meters	0.001	0.02
Rocky Mountain Aspen Forest and Woodland	Open Water	0.002	0.06
Rocky Mountain Aspen Forest and Woodland	Shrub Height 0.5 to 1.0 meter	0.001	0.02
Rocky Mountain Foothill Limber Pine-Juniper Woodland	Forest Height 10 to 25 meters	0.005	0.13
Rocky Mountain Foothill Limber Pine-Juniper Woodland	Herb Height 0 to 0.5 meters	0.003	0.07
Rocky Mountain Foothill Limber Pine-Juniper Woodland	Open Water	0.001	0.02
Rocky Mountain Foothill Limber Pine-Juniper Woodland	Shrub Height 0.5 to 1.0 meter	0.001	0.02
Rocky Mountain Lodgepole Pine Forest	Forest Height 0 to 5 meters	0.001	0.02
Rocky Mountain Lodgepole Pine Forest	Forest Height 10 to 25 meters	0.020	0.51
Rocky Mountain Lodgepole Pine Forest	Herb Height 0 to 0.5 meters	0.002	0.04
Rocky Mountain Lodgepole Pine Forest	Open Water	0.008	0.19
Rocky Mountain Montane Riparian Systems	Barren	0.001	0.02
Rocky Mountain Montane Riparian Systems	Developed-Upland Mixed Forest	0.001	0.02

Rocky Mountain Montane Riparian Systems	Developed-Upland Shrubland	0.001	0.02
Rocky Mountain Montane Riparian Systems	Forest Height 10 to 25 meters	0.129	3.23
Rocky Mountain Montane Riparian Systems	Forest Height 5 to 10 meters	0.001	0.02
Rocky Mountain Montane Riparian Systems	Herb Height 0 to 0.5 meters	0.006	0.14
Rocky Mountain Montane Riparian Systems	Open Water	0.010	0.25
Rocky Mountain Montane Riparian Systems	Shrub Height 0.5 to 1.0 meter	0.024	0.59
Rocky Mountain Montane Riparian Systems	Shrub Height 1.0 to 3.0 meters	0.001	0.02
Rocky Mountain Poor-Site Lodgepole Pine Forest	Open Water	0.000	0.00
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 0 to 5 meters	0.013	0.31
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 10 to 25 meters	0.023	0.58
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest Height 5 to 10 meters	0.002	0.04
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Herb Height 0 to 0.5 meters	0.007	0.18
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Open Water	0.004	0.09
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Shrub Height 0.5 to 1.0 meter	0.001	0.02
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Sparse Vegetation Height	0.001	0.02
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Forest Height 10 to 25 meters	0.005	0.13

Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Herb Height 0 to 0.5 meters	0.003	0.07
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Forest Height 10 to 25 meters	0.004	0.09
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Herb Height 0 to 0.5 meters	0.008	0.20
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Open Water	0.001	0.02
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Shrub Height 0 to 0.5 meters	0.005	0.11
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Shrub Height 0.5 to 1.0 meter	0.039	0.98
Rocky Mountain Subalpine/Upper Montane Riparian Systems	Shrub Height 1.0 to 3.0 meters	0.006	0.15
Rocky Mountain Subalpine-Montane Mesic Meadow	Developed-Roads	0.004	0.09
Rocky Mountain Subalpine-Montane Mesic Meadow	Developed-Upland Mixed Forest	0.002	0.04
Rocky Mountain Subalpine-Montane Mesic Meadow	Developed-Upland Shrubland	0.004	0.09
Rocky Mountain Subalpine-Montane Mesic Meadow	Forest Height 0 to 5 meters	0.002	0.04
Rocky Mountain Subalpine-Montane Mesic Meadow	Forest Height 10 to 25 meters	0.010	0.24
Rocky Mountain Subalpine-Montane Mesic Meadow	Herb Height 0 to 0.5 meters	1.504	37.60
Rocky Mountain Subalpine-Montane Mesic Meadow	Open Water	0.005	0.11
Rocky Mountain Subalpine-Montane Mesic Meadow	Shrub Height 0 to 0.5 meters	0.026	0.65
Rocky Mountain Subalpine-Montane Mesic Meadow	Shrub Height 0.5 to 1.0 meter	0.013	0.31
Rocky Mountain Subalpine-Montane Mesic Meadow	Shrub Height 1.0 to 3.0 meters	0.003	0.07
Rocky Mountain Subalpine-Montane Mesic Meadow	Sparse Vegetation Height	0.001	0.03
TOTAL		**4.000**	**100.00**

The ecosystems inside the tower airshed are mainly Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland and Rocky Mountain Subalpine-Montane Mesic Meadow. Due to the heavy grazing, the soil is compacted, and the grasses are sparse and short. . The soil is very stony. Vegetation cover at this site is ~80-90% The canopy height for grassland is ~ 0.2-0.3 m.

Table 14. Ecosystem and site attributes for the Paradise Valley Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height [a]	0.3 m
Surface roughness [a]	0.05 m
Zero place displacement height [a]	0.05 m
Structural elements	Grassland, uniform
Time zone	Mountain time zone
Magnetic declination	12° 34' E changing by 0° 9' W/year

Note, [a] From field survey

Figure 45. Grassland is the dominated ecosystem at Paradise Valley Relocatable site.

5.3 Soils

5.3.1 Description of soils

Soil data and soil maps below for the Paradise Valley tower site were collected from 16.6 km^2 NRCS soil maps (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to determine the dominant soil types in the larger tower foot print. This was done to assure that the soil array is in the dominant (or in the co-dominant) soil type present in the tower footprint.

Figure 46. Soil map of the Paradise Valley Relocatable site and surrounding areas.

Soil Map Units Description: The map units delineated on the detailed soil maps in a soil survey represents the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils. Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas. An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series. Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups. A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example. An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example. An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, are an example. Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example. Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Table 15. Soil series and percentage of soil series within 16.6 km2 at the Paradise Valley site

Park County Area, Montana (MT669)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
25B	Cozdome-Cozberg complex, O to 4 percent slopes	17.1	0.4%
220F	Sixbeacon, cobbly-Vendome complex, 35 to 60 percent slopes	282.3	6.9%
302A	Glendive-Meadowcreek-Clunton complex, 0 to 4 percent slopes, occasionally flooded	170.8	4.2%
321B	Beaverell, stony-Attewan complex, 0 to 4 percent slopes	98.3	2.4%
421A	Beaverell cobbly loam, 0 to 2 percent slopes	11.6	0.3%
425B	Cozberg-Beaverell, cobbly complex, 0 to 4 percent slopes	116.0	2.8%
428B	Attewan-Vendome, stony complex, 0 to 4 percent slopes	13.1	0.3%
429C	Kremlin-Beavwan-Vendome, very stony complex, 2 to 8 percent slopes	44.0	1.1%
602A	Glendive-McCabe-Ryell complex, 0 to 2 percent slopes, occasionally flooded	74.6	1.8%
724D	Beavwan, cobbly-Nebies, very stony-Chinook complex, 2 to 15 percent slopes	1,247.8	30.4%
725C	Cozdome-Beaverell, cobbly complex, 0 to 8 percent slopes	758.8	18.5%
745E	Sixbeacon, cobbly-Kremlin-Cozberg complex, 0 to 25 percent slopes	20.8	0.5%
824E	Notter-Kremlin-Chinook complex, 2 to 25 percent slopes	160.4	3.9%
1216	Riverwash-Rivra complex, 0 to 4 percent slopes	105.3	2.6%
1218	Vendome-Meadowcreek complex, 0 to 4 percent slopes	81.4	2.0%
2303	Beaverell-Vendome-Cozdome complex, 2 to 8 percent slopes	224.0	5.5%
3402	Beaverell, extremely stony-Attewan-Beaverell, very stony complex, 0 to 8 percent slopes	554.1	13.5%
3501	Varney, very bouldery-Gnojek, bouldery-Chinook, bouldery complex, 2 to 45 percent slopes	10.1	0.2%
W	Water	112.5	2.7%
Totals for Area of Interest		**4,103.3**	**100.0%**

Park County Area, Montana 428B—Attewan-Vendome, stony complex, 0 to 4 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,700 to 5,100 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Attewan and similar soils: 50 percent Vendome, stony, and similar soils: 30 percent **Description of Attewan Setting** Landform: Glacial drainage channels Down-slope shape: Concave Across-slope shape: Concave Parent material: Calcareous fine-loamy alluvium over calcareous sandy and gravelly glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 6.1 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 9 inches: Silt loam 9 to 15 inches: Clay loam 15 to 28 inches: Clay loam 28 to 60 inches: Very gravelly loamy sand **Description of Vendome, Stony Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Convex Across-slope shape: Convex Parent material: Sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock and/or sandy and gravelly glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 4 percent Surface area covered with cobbles, stones or boulders: 0.1 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 4.6 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 8 inches: Stony loam 8 to 15 inches: Very cobbly loam 15 to 26 inches: Very cobbly loam 26 to 60 inches: Very cobbly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 421A—Beaverell cobbly loam, 0 to 2 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,300 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Beaverell and similar soils: 85 percent **Description of Beaverell Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 3.4 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6e Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 6 inches: Cobbly loam 6 to 11 inches: Very gravelly sandy clay loam 11 to 60 inches: Extremely gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 3402—Beaverell, extremely stony-Attewan-Beaverell, very stony complex, 0 to 8 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Beaverell, extremely stony, and similar soils: 38 percent Attewan and similar soils: 30 percent Beaverell, very stony, and similar soils: 12 percent **Description of Beaverell,**

Extremely Stony Setting Landform: Knolls on ground moraines Landform position (two-dimensional): Backslope, shoulder, summit Landform position (three-dimensional): Side slope Down-slope shape: Convex Across-slope shape: Linear Parent material: Loamy till over sandy and gravelly till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Surface area covered with cobbles, stones or boulders: 9.0 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 3.2 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6e Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 5 inches: Very cobbly loam 5 to 13 inches: Very gravelly sandy clay loam 13 to 60 inches: Extremely gravelly loamy sand **Description of Attewan Setting** Landform: Glacial drainage channels on ground moraines Down-slope shape: Linear Across-slope shape: Linear Parent material: Fine-loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 5.1 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 5 inches: Loam 5 to 11 inches: Clay loam 11 to 19 inches: Clay loam 19 to 60 inches: Very gravelly loamy sand **Description of Beaverell, Very Stony Setting** Landform: Glacial drainage channels on ground moraines Down-slope shape: Linear Across-slope shape: Linear Parent material: Loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 20 to 30 percent Surface area covered with cobbles, stones or boulders: 1.5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 3.2 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6e Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 5 inches: Very cobbly loam 5 to 13 inches: Very gravelly sandy clay loam 13 to 60 inches: Extremely gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 321B—Beaverell, stony-Attewan complex, 0 to 4 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,700 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Beaverell, stony, and similar soils: 60 percent Attewan and similar soils: 20 percent **Description of Beaverell, Stony Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Surface area covered with cobbles, stones or boulders: 0.1 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 3.0 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 4 inches: Very cobbly sandy clay loam 4 to 12 inches: Very gravelly sandy clay loam 12 to 60 inches: Extremely gravelly loamy sand **Description of Attewan Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Concave Across-slope shape: Concave Parent material: Fine-loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 5.3 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 5 inches: Sandy loam 5 to 14 inches: Gravelly loam 14 to 20 inches: Gravelly loam 20 to 60 inches: Very gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 2303—Beaverell-Vendome-Cozdome complex, 2 to 8 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Beaverell and similar soils: 50 percent Vendome and similar soils: 25 percent Cozdome and similar soils: 15 percent **Description of Beaverell Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Loamy alluvium over sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Very low (about 3.0 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6s Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 4 inches: Very cobbly loam 4 to 10 inches: Very gravelly sandy clay loam 10 to 60 inches: Extremely gravelly loamy sand **Description of Vendome Setting** Landform: Stream terraces Landform position (three-dimensional): Riser Down-slope shape: Convex Across-slope shape: Linear Parent material: Sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 3.8 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 4s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 5 inches: Gravelly sandy loam 5 to 12 inches: Sandy loam 12 to 18 inches: Sandy loam 18 to 60 inches: Very cobbly loamy sand **Description of Cozdome Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Convex Across-slope shape: Concave Parent material: Coarse-loamy alluvium over sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 15 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 30 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 4.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 4e Land capability (nonirrigated): 4e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 6 inches: Sandy loam 6 to 13 inches: Sandy loam 13 to 22 inches: Gravelly sandy loam 22 to 60 inches: Extremely gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 724D—Beavwan, cobbly-Nebies, very stony-Chinook complex, 2 to 15 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Beavwan and similar soils: 30 percent Nebies, very stony, and similar soils: 30 percent Chinook and similar soils: 20 percent **Description of Nebies, Very Stony Setting** Landform: Knolls on ground moraines Landform position (two-dimensional): Backslope, footslope, summit, shoulder Down-slope shape: Convex Across-slope shape: Convex Parent material: Loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 15 percent Surface area covered with cobbles, stones or boulders: 1.5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 30 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 4.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7s Hydrologic Soil Group: B Ecological site: Silty-Droughty-Steep (SiDrStp) 9-14" p.z. (R044XS340MT) **Typical profile** 0 to 5 inches: Very cobbly sandy loam 5 to 10 inches: Very cobbly sandy clay loam 10 to 60 inches: Very cobbly sandy loam **Description of Beavwan Setting** Landform: Glacial drainage channels on ground moraines, swales on ground moraines, potholes on ground moraines Landform position (two-dimensional): Footslope, toeslope, backslope Landform position (three-dimensional): Side slope Down-slope shape: Concave Across-slope shape: Concave Parent material: Fine-loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 15 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 5.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 4e Land capability (nonirrigated): 4e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 4 inches: Cobbly sandy loam 4 to 14 inches: Clay loam 14 to 18 inches: Very gravelly sandy clay loam 18 to 60 inches: Very gravelly sandy loam **Description of Chinook Setting** Landform: Glacial drainage channels on ground moraines, swales on ground moraines Landform position (two-dimensional): Footslope, toeslope, backslope Landform position (three-dimensional): Side slope Down-slope shape: Linear, concave Across-slope shape: Concave Parent material: Coarse-loamy eolian deposits derived from igneous, metamorphic and sedimentary rock and/or coarse-loamy glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 15 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Moderate (about 7.4 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 4e Land capability (nonirrigated): 4e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 6 inches: Sandy loam 6 to 13 inches: Sandy loam 13 to 18 inches: Sandy loam 18 to 33 inches: Fine sandy loam 33 to 60 inches: Sandy loam **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 425B—Cozberg-Beaverell, cobbly complex, 0 to 4 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,000 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Cozberg and similar soils: 45 percent Beaverell and similar soils: 35 percent **Description of Cozberg Setting** Landform: Channels on stream terraces Landform position (three-dimensional): Tread Down-slope shape: Concave Across-slope shape: Concave Parent material: Coarse-loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 35 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 5.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 7 inches: Sandy loam 7 to 20 inches: Sandy loam 20 to 26 inches: Sandy loam 26 to 30 inches: Gravelly loamy sand 30 to 60 inches: Loamy sand **Description of Beaverell Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Convex Across-slope shape: Linear Parent material: Loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 3.2 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6e Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 4 inches: Cobbly sandy loam 4 to 10 inches: Very gravelly sandy clay loam 10 to 60 inches: Extremely gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 725C—Cozdome-Beaverell, cobbly complex, 0 to 8 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Cozdome and similar soils: 50 percent Beaverell and similar soils: 35 percent **Description of Cozdome Setting** Landform: Channels on stream terraces Landform position (three-dimensional): Tread Down-slope shape: Concave Across-slope shape: Concave Parent material: Coarse-loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 30 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Low (about 3.9 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 3 inches: Sandy loam 3 to 8 inches: Sandy loam 8 to 16 inches: Gravelly sandy loam 16 to 60 inches: Extremely gravelly loamy sand **Description of Beaverell Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Convex Across-slope shape: Linear Parent material: Loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.8 mmhos/cm) Available water capacity: Low (about 3.6 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6e Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 7 inches: Cobbly sandy loam 7 to 15 inches: Very gravelly sandy clay loam 15 to 60 inches: Extremely gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 25B—Cozdome-Cozberg complex, O to 4 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Cozdome and similar soils: 55 percent Cozberg and similar soils: 28 percent **Description of Cozdome Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Coarse-loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 30 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Low (about 4.7 inches) **Interpretive groups** Farmland classification: Farmland of statewide importance Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 6 inches: Sandy loam 6 to 18 inches: Sandy loam 18 to 23 inches: Sandy loam 23 to 60 inches: Very gravelly loamy sand **Description of Cozberg Setting** Landform: Swales on stream terraces Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Coarse-loamy alluvium derived from mixed **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High

(1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 35 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Low (about 5.5 inches) **Interpretive groups** Farmland classification: Farmland of statewide importance Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 7 inches: Sandy loam 7 to 20 inches: Sandy loam 20 to 26 inches: Sandy loam 26 to 30 inches: Gravelly loamy sand 30 to 60 inches: Loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 602A—Glendive-McCabe-Ryell complex, 0 to 2 percent slopes, occasionally flooded Map Unit Setting Landscape: Valleys Elevation: 4,180 to 5,020 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Glendive and similar soils: 40 percent Mccabe and similar soils: 25 percent Ryell and similar soils: 20 percent **Description of Glendive Setting** Landform: Flood-plain steps Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Coarse-loamy alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Occasional Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 8.7 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 4 inches: Loam 4 to 42 inches: Loam 42 to 60 inches: Stratified loam to loamy fine sand **Description of Mccabe Setting** Landform: Channels on flood-plain steps Down-slope shape: Concave Across-slope shape: Linear Parent material: Sandy alluvium over sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 12 to 24 inches Frequency of flooding: Occasional Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Maximum salinity: Nonsaline (0.8 to 1.5 mmhos/cm) Available water capacity: Low (about 3.8 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 5w Hydrologic Soil Group: D Ecological site: Subirrigated (Sb) 9-14" p.z. (R044XS343MT) **Typical profile** 0 to 5 inches: Loam 5 to 18 inches: Stratified sandy loam to fine sandy loam 18 to 60 inches: Extremely cobbly loamy coarse sand **Description of Ryell Setting** Landform: Flood plains Down-slope shape: Linear Across-slope shape: Linear Parent material: Sandy alluvium over sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Occasional Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 4.1 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 4s Land capability (nonirrigated): 4s Hydrologic Soil Group: B Ecological site: Overflow (Ov) 9-14" p.z. (R044XS332MT) **Typical profile** 0 to 7 inches: Sandy loam 7 to 25 inches: Sandy loam 25 to 60 inches: Very gravelly sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 302A—Glendive-Meadowcreek-Clunton complex, 0 to 4 percent slopes, occasionally flooded Map Unit Setting Landscape: Valleys Elevation: 4,180 to 5,020 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Meadowcreek and similar soils: 30 percent Glendive and similar soils: 30 percent Clunton and similar soils: 15 percent **Description of Glendive Setting** Landform: Flood-plain steps Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Coarse-loamy alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: Occasional Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 8.7 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 10 inches: Fine sandy loam 10 to 32 inches: Loam 32 to 60 inches: Stratified loam to loamy fine sand **Description of Meadowcreek Setting** Landform: Flood-plain steps Landform position (three-dimensional): Tread Down-slope shape: Concave Across-slope shape: Linear Parent material: Fine-loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 24 to 42 inches Frequency of flooding: Occasional Frequency of ponding: None Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 7.9 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3w Land capability (nonirrigated): 3w Hydrologic Soil Group: C Ecological site: Subirrigated (Sb) 9-14" p.z. (R044XS343MT) **Typical profile** 0 to 5 inches: Loam 5 to 15 inches: Loam 15 to 38 inches: Sandy clay loam 38 to 60 inches: Very gravelly loamy sand **Description of Clunton Setting** Landform: Backswamps on flood-plain steps Down-slope shape: Concave Across-slope shape: Linear Parent material: Fine-loamy alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 2 percent Depth to restrictive feature: More than 80 inches Drainage class: Very poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 0 to 12 inches Frequency of flooding: Occasional Frequency of ponding: Rare Calcium carbonate, maximum content: 5 percent Maximum salinity: Nonsaline (0.8 to 1.5 mmhos/cm) Available water capacity: Moderate (about 7.9 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 5w Land capability (nonirrigated): 5w Hydrologic Soil Group: D Ecological site: Wet Meadow (WM) 9-14" p.z. (R044XS349MT) **Typical profile** 0 to 4 inches: Mucky peat 4 to 14 inches: Loam 14 to 30 inches: Clay loam 30 to 40 inches: Stratified gravelly loamy sand to silt loam 40 to 60 inches: Stratified very cobbly sand to very gravelly sandy loam **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 429C—Kremlin-Beavwan-Vendome, very stony complex, 2 to 8 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,900 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Kremlin and similar soils: 45 percent Beavwan and similar soils: 25 percent Vendome, very stony, and similar soils: 20 percent **Description of Kremlin Setting** Landform: Glacial drainage channels on ground moraines Down-slope shape: Linear Across-slope shape: Concave Parent material: Fine-loamy alluvium over fine-loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.38 to 1.28 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.8 mmhos/cm) Available water capacity: High (about 10.4 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 3 inches: Silt loam 3 to 18 inches: Silt loam 18 to 29 inches: Silt loam 29 to 60 inches: Stratified loam to silt loam **Description of Beavwan Setting** Landform: Ground moraines Landform position (two-dimensional): Backslope Landform position (three-dimensional): Side slope Down-slope shape: Convex Across-slope shape: Linear Parent material: Fine-loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 7.2 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6s Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 6 inches: Silt loam 6 to 26 inches: Silty clay loam 26 to 39 inches: Very gravelly loam 39 to 60 inches: Very gravelly sandy loam **Description of Vendome, Very Stony Setting** Landform: Stream terraces, ground moraines Landform position (two-dimensional): Toeslope Landform position (three-dimensional): Base slope, tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Sandy and gravelly alluvium over sandy and gravelly till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Surface area covered with cobbles, stones or boulders: 1.5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 3.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 6s Land capability (nonirrigated): 6s Hydrologic Soil Group: B Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 4 inches: Very cobbly loam 4 to 9 inches: Very cobbly loam 9 to 15 inches: Very cobbly loam 15 to 60 inches: Very cobbly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 824E—Notter-Kremlin-Chinook complex, 2 to 25 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,900 to 5,300 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Notter and similar soils: 40 percent Kremlin and similar soils: 20 percent Sixbeacon and similar soils: 15 percent Chinook and similar soils: 15 percent **Description of Notter Setting** Landform: Ground moraines Landform position (two-dimensional): Backslope, footslope Down-slope shape: Concave, convex Across-slope shape: Concave, convex Parent material: Till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 4 to 25 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 25 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 8.3 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 6e Hydrologic Soil Group: B Ecological site: Silty-Steep (SiStp) 9-14" p.z. (R044XS347MT) **Typical profile** 0 to 3 inches: Cobbly loam 3 to 10 inches: Gravelly clay loam 10 to 21 inches: Gravelly loam 21 to 60 inches: Very gravelly loam **Description of Kremlin Setting** Landform: Glacial drainage channels on ground moraines Landform position (two-dimensional): Backslope, footslope, toeslope Landform position (three-dimensional): Side slope Down-slope shape: Linear Across-slope shape: Concave Parent material: Fine-loamy alluvium over fine-loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 8 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.38 to 1.28 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: High (about 10.4 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 3 inches: Silt loam 3 to 14 inches: Silt loam 14 to 21 inches: Silt loam 21 to 60 inches: Stratified loam to silt loam **Description of Sixbeacon Setting** Landform: Hills on ground moraines Landform position (two-dimensional): Backslope, summit, shoulder, footslope Landform position (three-dimensional): Side slope, crest Down-slope shape: Convex Across-slope shape: Convex Parent material: Loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 4 to 25 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 35 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 4.7 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 6e Hydrologic Soil Group: B Ecological site: Silty-Droughty-Steep (SiDrStp) 9-14" p.z. (R044XS340MT) **Typical profile** 0 to 8 inches: Very cobbly loam 8 to 15 inches: Very cobbly sandy loam 15 to 29 inches: Very cobbly sandy loam 29 to 60 inches: Extremely cobbly loamy sand **Description of Chinook Setting** Landform: Hills on ground moraines Landform position (two-dimensional): Backslope, footslope, shoulder Landform position (three-dimensional): Side slope Down-slope shape: Convex Across-slope shape: Convex Parent material: Coarse-loamy alluvium derived from igneous, metamorphic and sedimentary rock and/or coarse-loamy eolian sands derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 25 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Moderate (about 7.3 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 6e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 3 inches: Sandy loam 3 to 11 inches: Sandy loam 11 to 18 inches: Sandy loam 18 to 32 inches: Fine sandy loam 32 to 60 inches: Sandy loam **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 1216—Riverwash-Rivra complex, 0 to 4 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,180 to 5,020 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Riverwash: 60 percent Rivra and similar soils: 40 percent **Description of Rivra Setting** Landform: Flood-plain steps Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Over sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Moderately well drained Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 99.90 in/hr) Depth to water table: About 42 to 60 inches Frequency of flooding: Frequent Frequency of ponding: None Calcium carbonate, maximum content: 10 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Very low (about 2.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 6s Hydrologic Soil Group: C Ecological site: Overflow (Ov) 9-14" p.z. (R044XS332MT) **Typical profile** 0 to 4 inches: Sand 4 to 22 inches: Loamy fine sand 22 to 28 inches: Gravelly loamy sand 28 to 60 inches: Extremely cobbly sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 745E—Sixbeacon, cobbly-Kremlin-Cozberg complex, 0 to 25 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,200 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Sixbeacon and similar soils: 30 percent Kremlin and similar soils: 25 percent Cozberg and similar soils: 20 percent **Description of Sixbeacon Setting** Landform: Stream terraces, knolls on moraines Landform position (two-dimensional): Shoulder, summit Landform position (three-dimensional): Side slope, tread Down-slope shape: Linear, convex Across-slope shape: Linear, convex Parent material: Loamy alluvium over sandy and gravelly till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 25 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 35 percent Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm) Available water capacity: Low (about 4.4 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty-Droughty-Steep (SiDrStp) 9-14" p.z. (R044XS340MT) **Typical profile** 0 to 7 inches: Cobbly sandy loam 7 to 15 inches: Very cobbly sandy loam 15 to 22 inches: Very cobbly sandy loam 22 to 60 inches: Extremely cobbly loamy sand **Description of Kremlin Setting** Landform: Swales on moraines, stream terraces Landform position (two-dimensional): Footslope, toeslope Landform position (three-dimensional): Tread Down-slope shape: Concave Across-slope shape: Concave Parent material: Fine-loamy alluvium over fine-loamy till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.38 to 1.28 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.8 mmhos/cm) Available water capacity: High (about 10.3 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Silty (Si) 9-14" p.z. (R044XS339MT) **Typical profile** 0 to 5 inches: Silt loam 5 to 19 inches: Silt loam 19 to 21 inches: Silt loam 21 to 60 inches: Stratified loam to silt loam **Description of Cozberg Setting** Landform: Swales on moraines, stream terraces Landform position (two-dimensional): Backslope, footslope Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Concave Parent material: Coarse-loamy alluvium over sandy and gravelly till derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Low (about 5.4 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 9 inches: Sandy loam 9 to 14 inches: Sandy loam 14 to 24 inches: Sandy loam 24 to 60 inches: Loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 220F—Sixbeacon, cobbly-Vendome complex, 35 to 60 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,700 to 5,300 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Sixbeacon and similar soils: 55 percent Vendome and similar soils: 28 percent **Description of Sixbeacon Setting** Landform: Escarpments Landform position (two-dimensional): Backslope Down-slope shape: Convex Across-slope shape: Linear Parent material: Loamy alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 35 to 60 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (1.28 to 3.97 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 35 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Low (about 4.6 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7e Hydrologic Soil Group: B Ecological site: Silty-Droughty-Steep (SiDrStp) 9-14" p.z. (R044XS340MT) **Typical profile** 0 to 8 inches: Cobbly sandy loam 8 to 15 inches: Very cobbly sandy loam 15 to 30 inches: Very cobbly sandy loam 30 to 60 inches: Extremely cobbly loamy sand **Description of Vendome Setting** Landform: Escarpments Landform position (two-dimensional): Backslope Landform position (three-dimensional): Side slope Down-slope shape: Convex Across-slope shape: Convex Parent material: Sandy and gravelly alluvium derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 35 to 60 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Low (about 4.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7s Hydrologic Soil Group: B Ecological site: Silty-Droughty-Steep (SiDrStp) 9-14" p.z. (R044XS340MT) **Typical profile** 0 to 9 inches: Very gravelly sandy loam 9 to 31 inches: Gravelly sandy loam 31 to 60 inches: Very cobbly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 3501—Varney, very bouldery-Gnojek, bouldery-Chinook, bouldery complex, 2 to 45 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,800 to 5,300 feet Mean annual precipitation: 12 to 15 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Varney, very bouldery, and similar soils: 40 percent

Gnojek, bouldery, and similar soils: 25 percent Chinook, bouldery, and similar soils: 15 percent **Description of Varney, Very Bouldery Setting** Landform: Knolls on moraines Landform position (two-dimensional): Backslope, toeslope Down-slope shape: Convex Across-slope shape: Concave Parent material: Fine-loamy slope alluvium derived from volcanic rock **Properties and qualities** Slope: 4 to 45 percent Surface area covered with cobbles, stones or boulders: 1.5 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 25 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 6.8 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7s Hydrologic Soil Group: B Ecological site: Silty-Steep (SiStp) 9-14" p.z. (R044XS347MT) **Typical profile** 0 to 5 inches: Cobbly clay loam 5 to 12 inches: Gravelly clay loam 12 to 16 inches: Gravelly sandy clay loam 16 to 22 inches: Gravelly sandy loam 22 to 60 inches: Gravelly sandy loam **Description of Gnojek, Bouldery Setting** Landform: Knolls on moraines Landform position (two-dimensional): Backslope, summit, shoulder Down-slope shape: Convex Across-slope shape: Convex Parent material: Loamy colluvium over loamy residuum weathered from basalt **Properties and qualities** Slope: 15 to 45 percent Depth to restrictive feature: 10 to 20 inches to bedrock (lithic) Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 25 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Very low (about 1.7 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7e Hydrologic Soil Group: D Ecological site: Shallow (Sw) 9-14" p.z. (R044XS336MT) **Typical profile** 0 to 5 inches: Very cobbly clay loam 5 to 11 inches: Very cobbly clay loam 11 to 16 inches: Very cobbly clay loam 16 to 26 inches: Bedrock **Description of Chinook, Bouldery Setting** Landform: Glacial drainage channels on moraines Down-slope shape: Concave Across-slope shape: Concave Parent material: Coarse-loamy alluvium over coarse-loamy glaciofluvial deposits derived from igneous, metamorphic and sedimentary rock **Properties and qualities** Slope: 2 to 15 percent Surface area covered with cobbles, stones or boulders: 0.1 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 15 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 7.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability (nonirrigated): 7s Hydrologic Soil Group: B Ecological site: Sandy (Sy) 9-14" p.z. (R044XS335MT) **Typical profile** 0 to 5 inches: Sandy clay loam 5 to 8 inches: Sandy loam 8 to 20 inches: Sandy loam 20 to 32 inches: Fine sandy loam 32 to 60 inches: Sandy loam **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana 1218—Vendome-Meadowcreek complex, 0 to 4 percent slopes Map Unit Setting Landscape: Valleys Elevation: 4,300 to 5,100 feet Mean annual precipitation: 12 to 14 inches Mean annual air temperature: 43 to 45 degrees F Frost-free period: 90 to 120 days **Map Unit Composition** Vendome and similar soils: 55 percent Meadowcreek and similar soils: 30 percent **Description of Vendome Setting** Landform: Stream terraces Landform position (three-dimensional): Tread Down-slope shape: Convex Across-slope shape: Linear Parent material: Sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Well drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: More than 80 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 20 percent Maximum salinity: Nonsaline (0.0 to 0.3 mmhos/cm) Available water capacity: Low (about 3.2 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 4e Land capability (nonirrigated): 6e Hydrologic Soil Group: A Ecological site: Shallow to Gravel (SwGr) 9-14" p.z. (R044XS338MT) **Typical profile** 0 to 4 inches: Cobbly loam 4 to 9 inches: Sandy loam 9 to 60 inches: Very cobbly loamy sand **Description of Meadowcreek Setting** Landform: Channels on stream terraces Landform position (three-dimensional): Tread Down-slope shape: Linear Across-slope shape: Linear Parent material: Fine-loamy alluvium over sandy and gravelly alluvium derived from igneous and metamorphic rock **Properties and qualities** Slope: 0 to 4 percent Depth to restrictive feature: More than 80 inches Drainage class: Somewhat poorly drained Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr) Depth to water table: About 24 to 42 inches Frequency of flooding: None Frequency of ponding: None Calcium carbonate, maximum content: 5 percent Maximum salinity: Nonsaline (0.3 to 0.7 mmhos/cm) Available water capacity: Moderate (about 7.5 inches) **Interpretive groups** Farmland classification: Not prime farmland Land capability classification (irrigated): 3e Land capability (nonirrigated): 3e Hydrologic Soil Group: C Ecological site: Subirrigated (Sb) 9-14" p.z. (R044XS343MT) **Typical profile** 0 to 5 inches: Loam 5 to 12 inches: Loam 12 to 36 inches: Sandy clay loam 36 to 60 inches: Very gravelly loamy sand **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

Park County Area, Montana W—Water Map Unit Composition Water: 100 percent **Data Source Information** Soil Survey Area: Park County Area, Montana Survey Area Data: Version 6, Jul 10, 2006

5.3.2 Soil semi-variogram description

The goal of this aspect of the site characterization is to determine the minimum distance between the soil plots in the soil array such that data farther apart can be considered spatially independent. The collected field data will be used to produce semivariograms, which is a geostatistical technique to characterize spatial autocorrelation between mapped samples of a quantitative variable (*e.g*., soil property data in our case). In an empirical semivariogram, the average of the squared differences of a response variable is computed for all pairs of points within specified distance intervals (lag classes). The output is presented graphically as a plot of the average semi-variance versus distance class (Figure 47). For the theoretical variogram models considered here, the semivariance will converge on the total variance at distances for which values are no longer spatially auto-correlated (this is referred to as the range, Figure 47).

For the theoretical variograms considered here, three parameters estimated from the data are used to fit a semivariogram model to the empirical semivariogram. This model is then assumed to quantitatively represent the correlation as a function of distance (Figure 47), the range, the sill (the sill is the asymptotic value of semi-variance at the range), and the nugget (which describes sampling error or variation at distances below those separating the closest pairs of samples). The range, sill and nugget are estimated from theoretical models that are fitted to the empirical variograms using non-linear least squares methods.

The variogram analysis will be used, to determine the spatial scales at which we can consider soil measurements spatially independent. This characterization will directly inform the minimum distance between *i*) soil plots within each soil array, *ii*) the soil profile measurements, *iii*) EP plots, and *iv*) the microbial sampling locations. These data will directly inform NEON construction and site design activities.

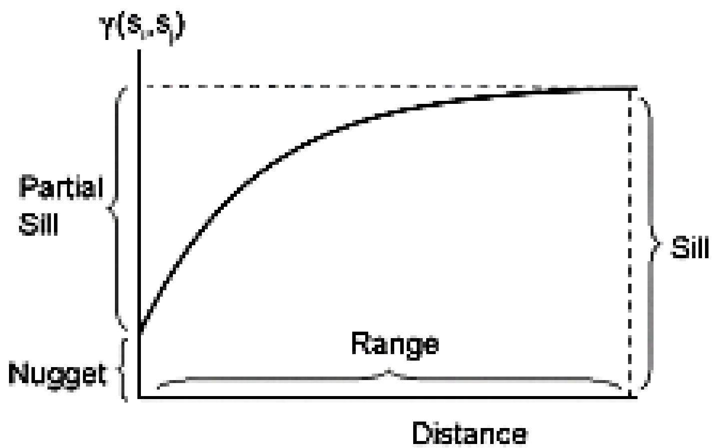


Figure 47. Example semivariogram, depicting range, sill, and nugget.

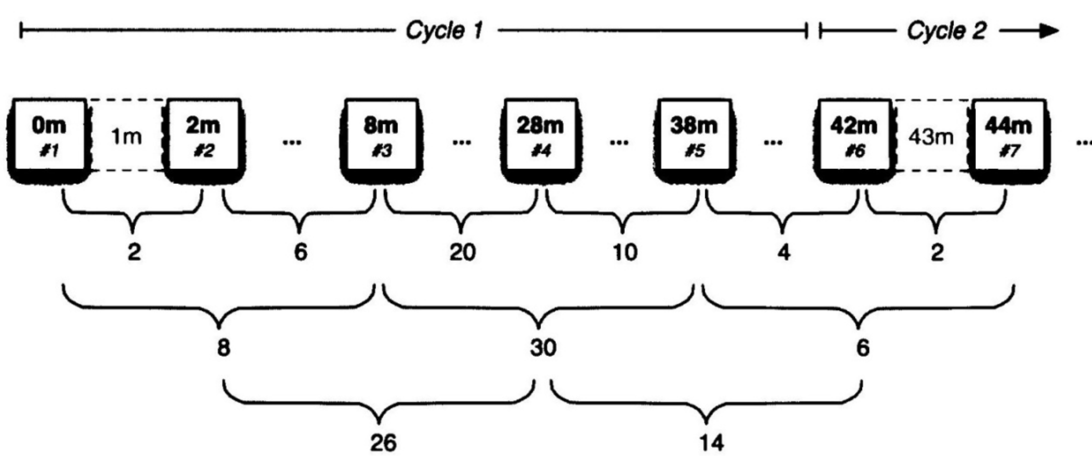


Figure 48. Spatially cyclic sampling design for the measurements of soil temperature and soil water content.

Field measurements of soil temperature (0-12 cm) and moisture (0-15 cm) were taken on 16 July 2013 at the Paradise Valley site. The sampling points followed the spatially cyclic sampling design by Bond-Lamberty et al. (2006) (Figure 48). Soil temperature and moisture measurements were collected along three transects (210 m, 84 m, and 84 m) located in the expected airshed at Paradise Valley. Details of how the airshed was determined are provided below. Soil temperature was measured with platinum resistance temperature sensors (RTD 810, Omega Engineering Inc., Stamford CT) and soil moisture was measured with time domain diaelectric sensors (CS616, Campbell Scientific Inc., Logan UT).

As well as measuring soil temperature and moisture at each sample point in Figure 48, measurements were also taken 30 cm in front and behind the sampling point along the axis of the transect. For example, at the 2 m sampling point, soil temperature and moisture was measured at 1.7 m, 2 m, and 2.3 m; this data is referred to as mobile data, since the measurements were taken at many different locations. In addition, soil temperature and moisture were continuously recorded at a single fixed location (stationary data) throughout the sampling time to correct for changes in temperature and moisture throughout the day.

Data collected were used for geospatial analyses of variograms in the R statistical computing language with the geoR package to test for spatial autocorrelation (Trangmar *et al.* 1986; Webster & Oliver 1989; Goovaerts 1997; Riberiro & Diggle 2001) and estimate the distance necessary for independence among soil plots in the soil array. To correct for changes in temperature and moisture over the sampling period, the stationary data was subtracted from the mobile data. In many instances a time of day trend was still apparent in the data even after subtracting the stationary data from the mobile data. This time of day trend was corrected for by fitting a linear regression and using the residuals for the semivariogram analysis. Soil temperature and moisture data, R code, graphs, and R output can be found at: P:\FIU\FIU_Site_Characterization\DXX\YYYYYYY_Characterization\Soil Measurements\Soil Data Analysis (where XX = domain number and YYYYYYY = site name).

5.3.3 Results and interpretation

5.3.3.1 Soil Temperature

Soil temperature data residuals, after accounting for changes in temperature in the stationary data, any remaining time of day trend, and elevation, were used for the semivariogram analysis (Figure 49). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 50, left graph) and directional semivariograms do not show anisotropy (Figure 50, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 50, right graph). The model indicates a distance of effective independence of 20 m for soil temperature.

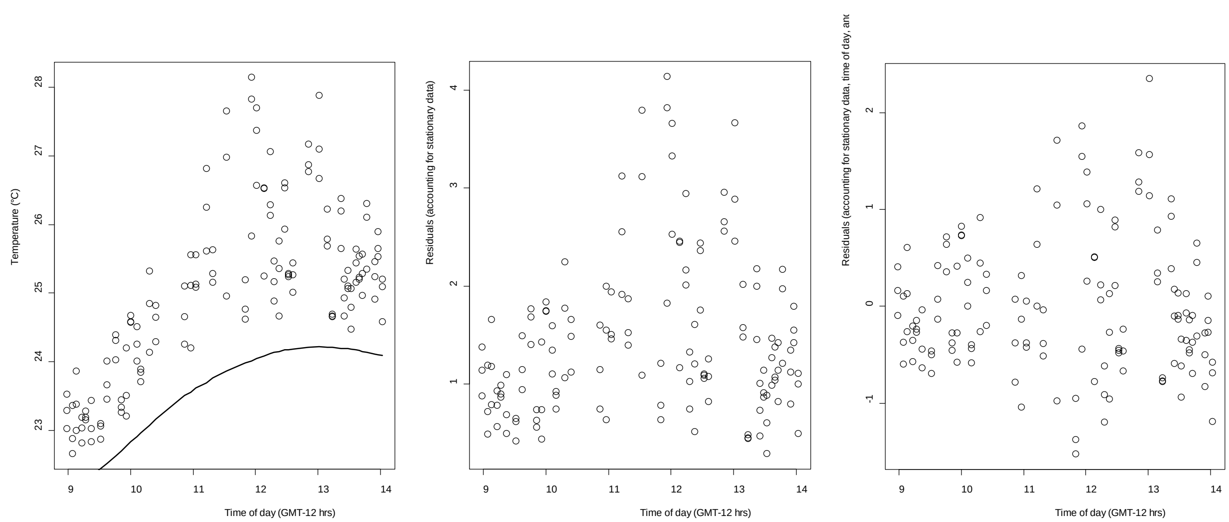


Figure 49. Left graph: mobile (circles) and stationary (line) soil temperature data. Center graph: temperature data after correcting for changes in temperature in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual temperature data after correcting for changes temperature in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

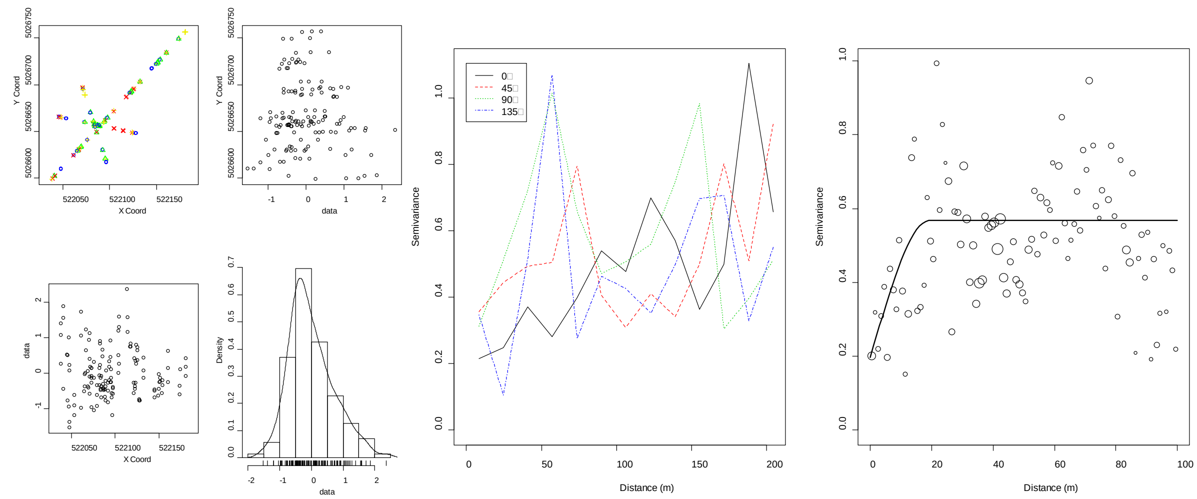


Figure 50. Left graphs: exploratory data analysis plots for residuals of temperature. Center graph: directional semivariograms for residuals of temperature. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of temperature.

5.3.3.2 Soil Water Content

Soil water content data residuals, after accounting for changes in water content in the stationary data, any remaining time of day trend, and elevation, were used for the semivariogram analysis (Figure 51). Exploratory data analysis plots show that there was no distinct patterning of the residuals (Figure 52, left graph) and directional semivariograms do not show anisotropy (Figure 53, center graph). An isotropic empirical semivariogram was produced and a spherical model was fitted using Cressie weights (Figure 54, right graph). The model indicates a distance of effective independence of 16 m for soil water content.

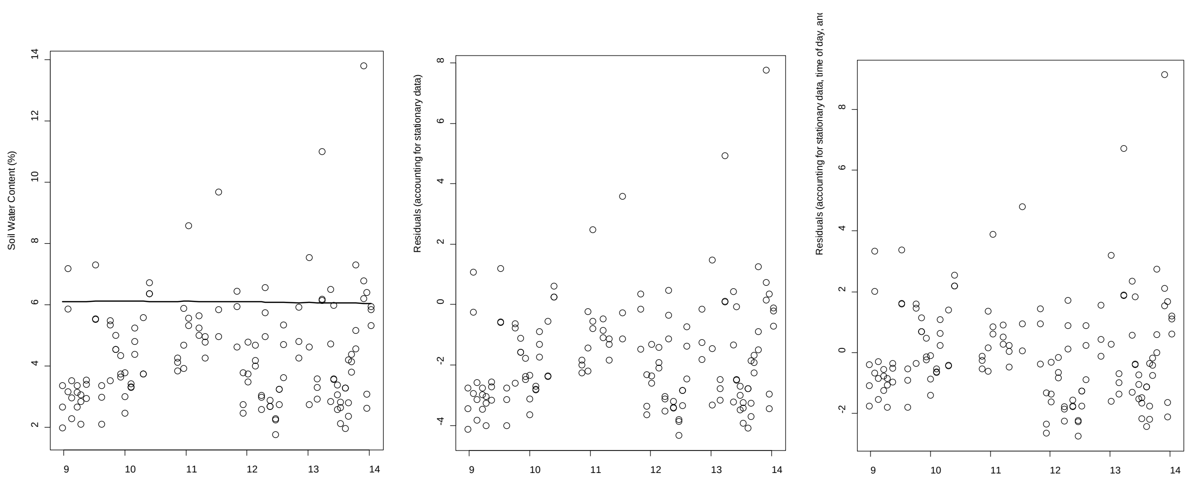


Figure 51. Left graph: mobile (circles) and stationary (line) soil water content data. Center graph: water content data after correcting for changes in water content in the stationary data (circles) and a linear regression based on time of day (line). Right graph: residual water content data after correcting for changes water content in the stationary data and the time of day regression. Data in the right graph were used for the semivariogram analysis.

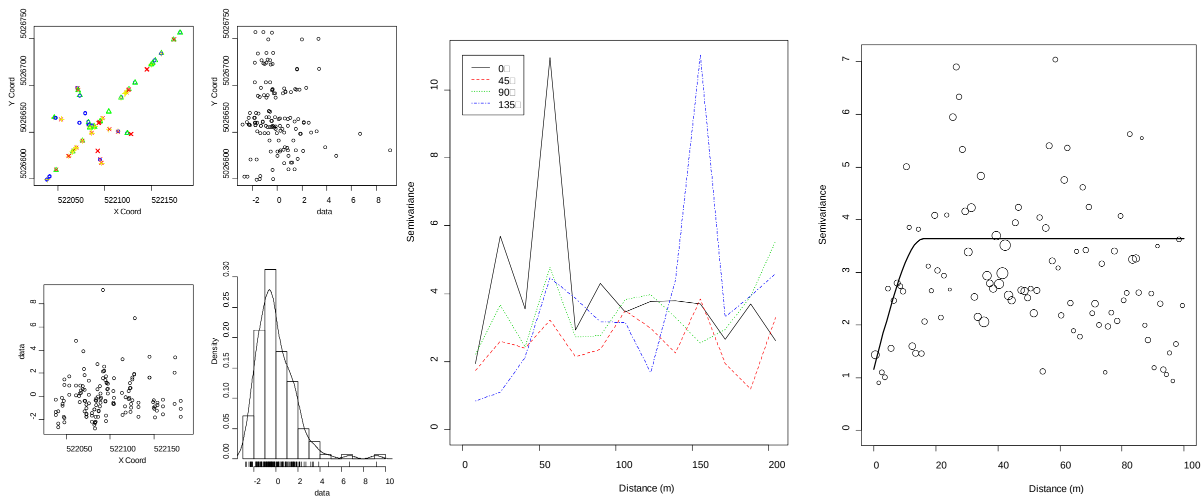


Figure 52. Left graphs: exploratory data analysis plots for residuals of soil water content. Center graph: directional semivariograms for residuals of water content. Right graph: empirical semivariogram (circles) and model (line) fit to residuals of water content.

5.3.3.3 Soil array Layout and Soil Pit Location

The minimum distance allowable between soil plots is 25 m to ensure a degree of spatial independence in non-measured soil parameters (i.e., other than temperature and water content) and the maximum distance allowable between soil plots is 40 m due to cost constraints. The estimated distance of effective independence was 20 m for soil temperature and 16 m for soil moisture. Based on these results and the site design guidelines the soil plots at Paradise Valley shall be placed 25 m apart. The soil array shall follow the linear soil array design (Soil Array Pattern B) with the soil plots being 5 m x 5 m. The direction of the soil array shall be 180° from the soil plot nearest the tower (i.e., first soil plot). The location of the first soil plot will be approximately 45.39372, -110.71651. The exact location of each soil plot may be microsited to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc). The FIU soil pit for characterizing soil horizon depths, collecting soil for site-specific sensor calibration, and collecting soil for the FIU soil archive will be located at 45.39158, -110.71835 (primary location); or 45.391190, -110.718610 (alternate location 1 if primary location is unsuitable); or 45.390730, -110.718820 (alternate location 2 if primary location is unsuitable). A summary of the soil information is shown in Table 16 and site layout can be seen in Figure 53.

Dominant soil series at the site: Beaverell, stony-Attewan complex, 0 to 4 percent slopes. The taxonomy of this soil is shown below:
Order: Mollisols
Suborder: Ustolls
Great group: Argiustolls
Subgroup: Calcidic Argiustolls- Aridic Argiustolls
Family: Loamy-skeletal over sandy or sandy-skeletal, mixed, superactive, frigid Calcidic Argiustolls- Fine-loamy over sandy or sandy-skeletal, mixed, superactive, frigid Aridic Argiustolls
Series: Beaverell, stony-Attewan complex, 0 to 4 percent slopes

Table 16. Summary of soil array and soil pit information at Paradise Valley. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	27 m
Latitude and longitude of 1st soil plot OR direction from tower	45.39372, -110.71651
Direction of soil array	180°
Latitude and longitude of FIU soil pit 1	45.39158, -110.71835 (primary location)
Latitude and longitude of FIU soil pit 2	45.391190, -110.718610 (alternate 1)
Latitude and longitude of FIU soil pit 3	45.390730, -110.718820 (alternate 2)
Dominant soil type	Beaverell, stony-Attewan complex, 0 to 4 percent slopes
Expected soil depth	>2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.10 m (Very cobbly sandy clay loam)	0.05 m
0.10-0.30 m (Very gravelly sandy clay loam)	0.20 m
0.30-2 m (Extremely gravelly loamy sand)	1.15 m

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.

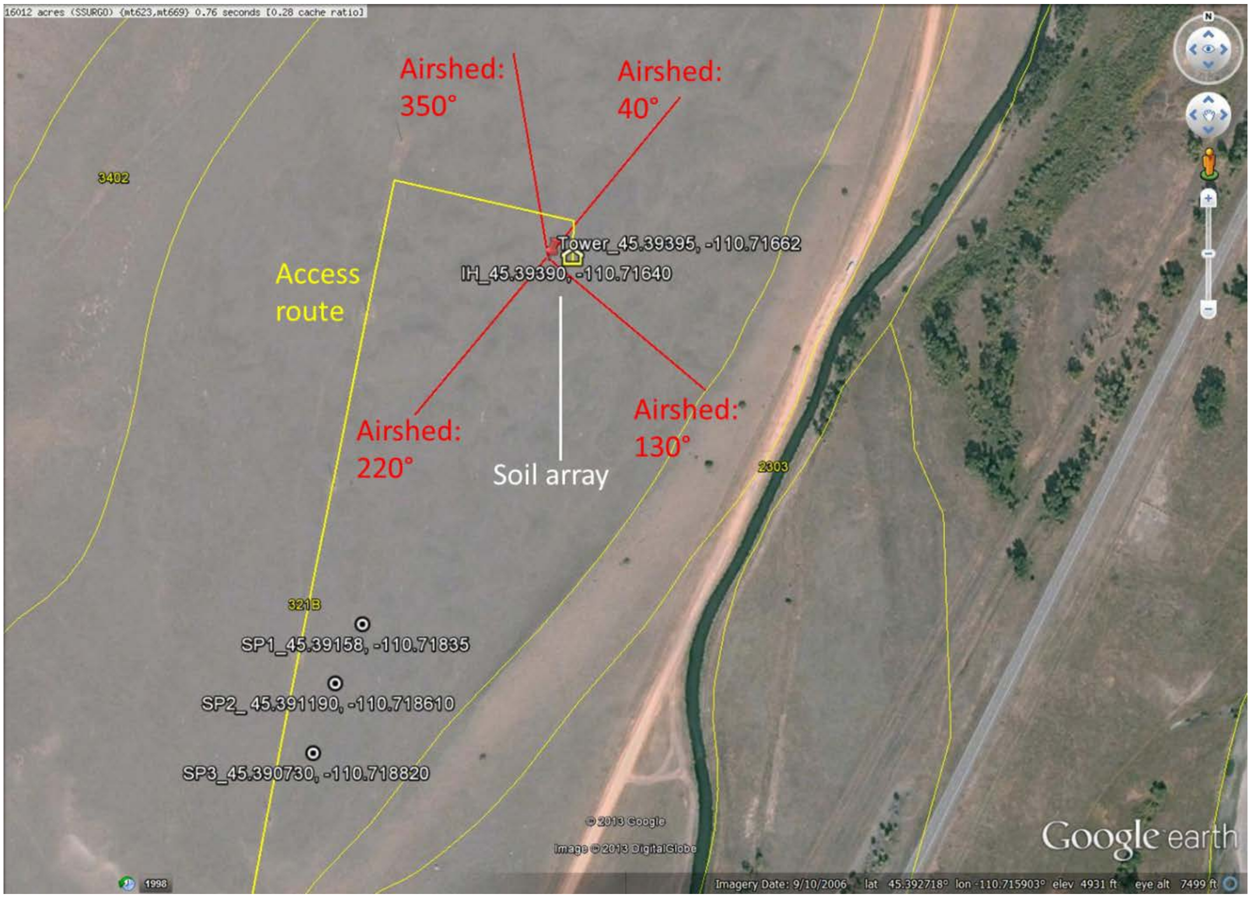


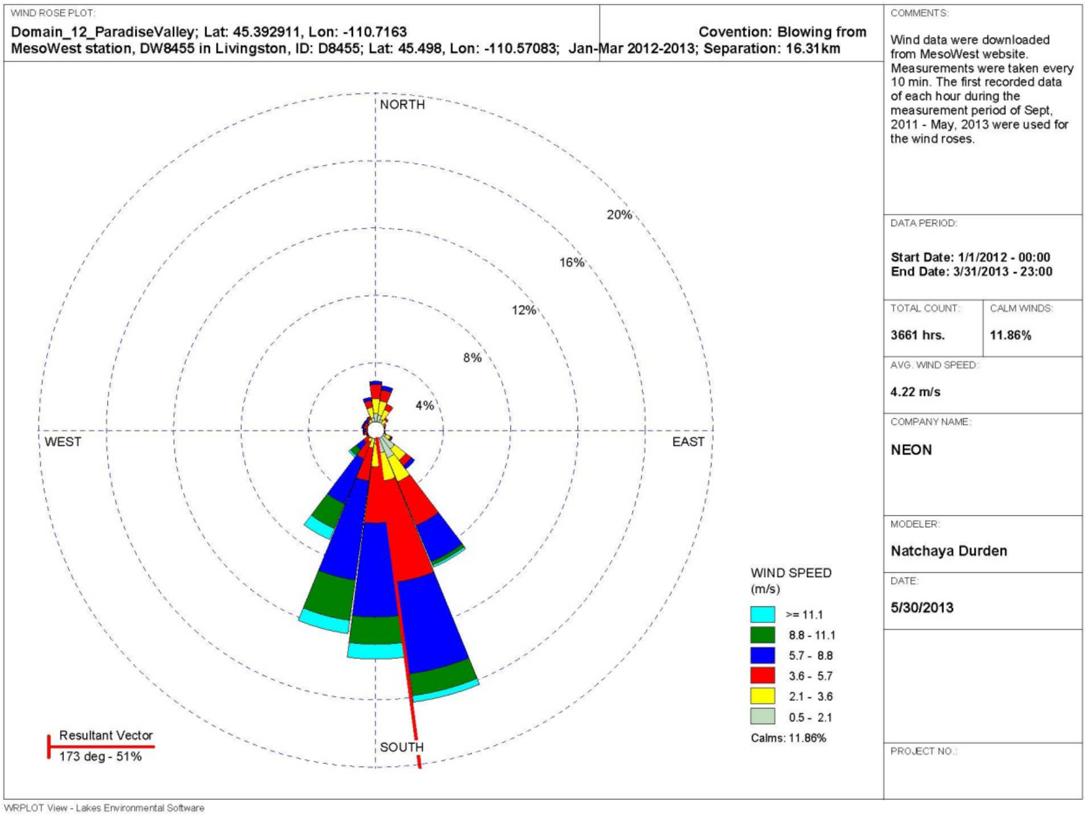
Figure 53. Site layout at Paradise Valley showing soil array and location of the FIU soil pit.

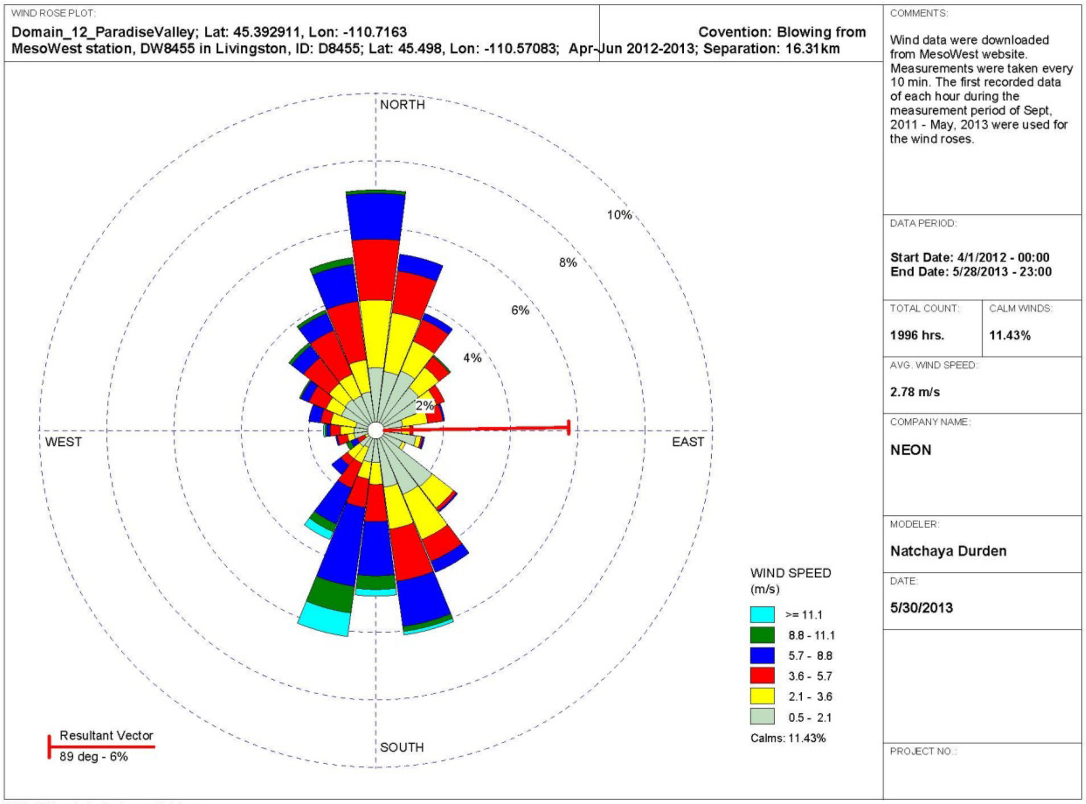
5.4 Airshed

5.4.1 Seasonal Windroses

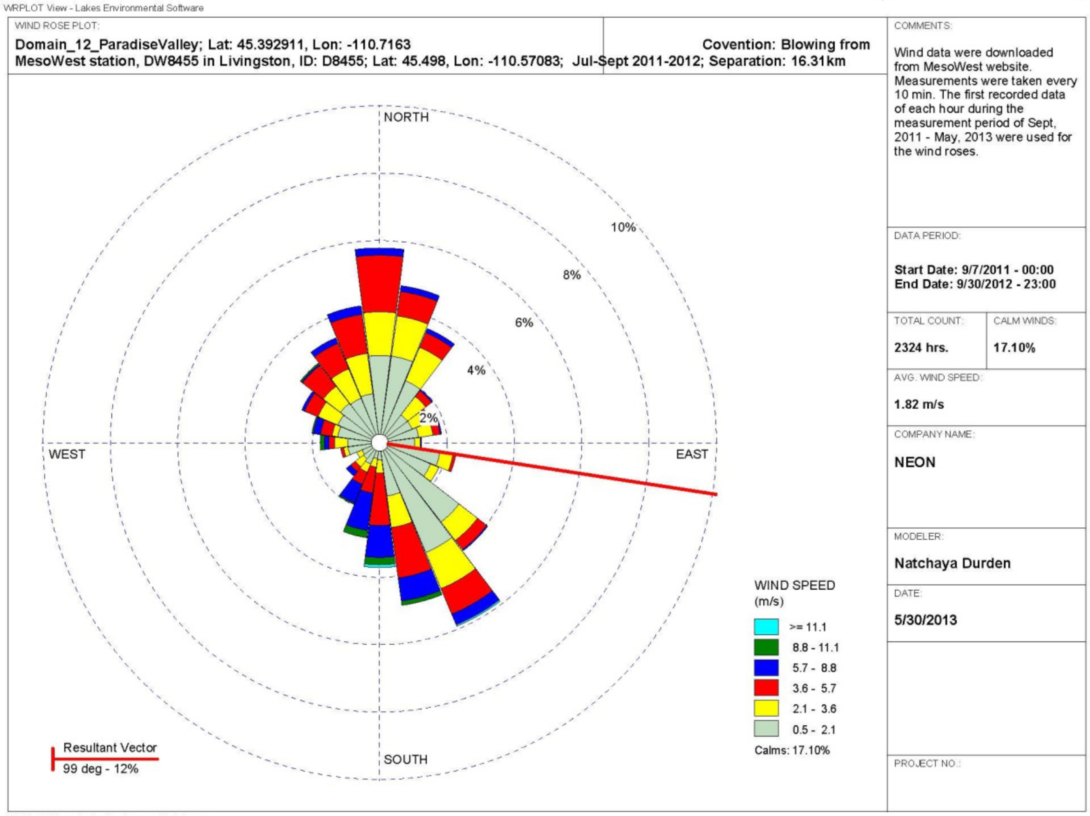
Wind roses analytically determine and graphically represent the frequencies of wind direction and wind speed over a given time series. The weather data used to generate the following wind roses are from MesoWest station DW8455 in Livingston (ID: D8455; Lat: 45.498, Lon: -110.57083), which is16 km away from tower location and in the same valley The orientation of the wind rose follows that of a compass (assume declination applied). When we describe the wind directions it should be noted that they are the cardinal direction that wind blows from. The directions of the rose with the longest spoke show wind directions with the largest frequency. These wind roses are subdivided into as 24 cardinal directions.

5.4.2 Results (graphs for wind roses)





WRPLOT View - Lakes Environmental Software



WRPLOT View - Lakes Environmental Software

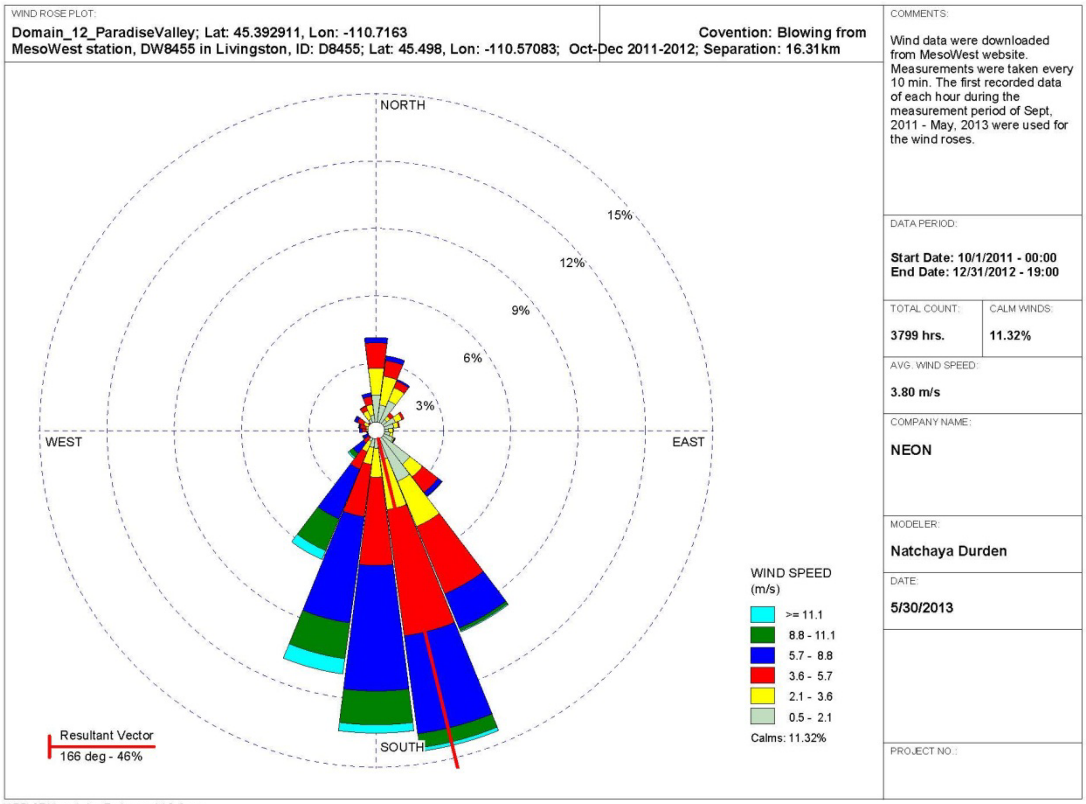


Figure 54. Windroses for Paradise Valley relocatable site.

The data used to make these wind roses are from MesoWest station DW8455 in Livingston (ID: D8455; Lat: 45.498, Lon: -110.57083), which is16 km away from tower location and in the same valley. It is assumed that the wind data was corrected for declination. Panels are (from top to bottom) Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec.

5.4.3 Expected environmental Controls on Source Area

Two types of models were commonly used to determine the shape and extent of the source area under different and contrasting atmospheric stability classes. An inverted plume dispersion model with modeled cross wind solutions were used for convective conditions (Horst and Weil 1994). For strongly stable conditions, and Lagrangian solution was used (Kormann and Meixner 2001). The source area models where bounded by the expected conditions depict the extreme conditions. Convective conditions typically have strong vertical mixing between the ecosystem and atmosphere (surface layer). Stable conditions typically have long source area and associated waveforms. Convective turbulence is often characterized by short mixing scales (scalar) and moderate daytime wind speeds, *e.g.,* 1-4 m s^{-2}. Higher wind speeds, like those experienced over the Rockies, are often the product of mechanical turbulence with long waveforms. Because thermal stratification is very efficient in suppressing vertical mixing, stable conditions also have typically very long waveforms.

As a general rule, shorter and less structurally complex ecosystems have good vertical mixing during all atmospheric stabilities. Taller and more structurally complex ecosystems have well mixed upper canopies during the daytime, and can be decoupled below the canopy under neutral and stable conditions (e.g., Harvard Forest, Bartlett Experimental Forest, and Burlington Conservation Area). The type of turbulence (mechanical verse convective) and the physical attributes of the ecosystem control the degree of mixing, and the length and size of the source area.

Here, we use a web-based footprint model to determine the footprint area under various conditions (model info: http://www.geos.ed.ac.uk/abs/research/micromet/EdiTools/). Winds used to run the model and generate following model results are extracted from the wind roses. Vegetation information, temperature and energy information were either from the RFI document, previous site visit report, available data files or best estimated from experienced expert. Measurement height was determined from the Tower Height Info document provided by ENG group, then verify according to the real ecosystem structure after FIU site characterization at site. Runs 1-3 and 4-6 represent the expected conditions for summer and winter conditions, respectively, with maximum and mean windspeeds (daytime convective) and nighttime (stable atmospheres) conditions. The wind vector for each run was estimated from wind roses and is placed as a centerline in the site map included in the graphics. The width of the footprint was also estimated using the length between the isopleth of 80% cumulative flux and center line to calculate the angle from centerline. This information, along with distance of the cumulative flux isopleths and wind direction, will define the source area for the flux measurements on the top of the tower.

Table 17. Expected environmental controls to parameterize the source area model based on the wind roses from Livingston Mission Field airport, and associated results for Paradise Valley Relocatable tower site.

Parameters	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	
Approximate season	summer			winter			Units
	Day (max WS)	Day (mean WS)	Night	Day (max WS)	Day (mean WS)	night	qualitative
Atmospheric stability	Convective	convective	Stable	Convective	convective	Stable	qualitative
Measurement height	6	6	6	6	6	6	m
Canopy Height	0.5	0.5	0.5	0.3	0.3	0.3	m
Canopy area density	2	2	2	1	1	1	m
Boundary layer depth	2000	2000	650	800	800	450	m
Expected sensible heat flux	450	450	160	-25	-25	-100	W m^{-2}
Air Temperature	28	28	14	-5	-5	-11	°C
Max. windspeed	11	2	1	15	4.4	4	m s^{-1}
Resultant wind vector	355	355	150	180	180	165	degrees
Results							
(z-d)/L	-0.40	-2.60	-3.00	0	0.07	2.60	m
d	0.37	0.37	0.37	0.20	0.20	0.20	m
Sigma v	2.40	1.80	0.88	1.80	1.80	1.60	m^2 s^{-2}
Z0	0.03	0.03	0.03	0.02	0.02	0.02	m
u*	0.85	0.22	0.11	1.10	0.30	0.14	m s^{-1}
Distance source area begins	0	0	0	0	0	0	m
Distance of 90% cumulative flux	750	160	100	1000	1230	2740	m
Distance of 80% cumulative flux	410	70	50	550	660	1970	m
Distance of 70% cumulative flux	280	50	40	370	430	1460	m
Peak contribution	65	15	15	75	75	335	m

Note: Model was run based on the wind info extracted from wind roses above. The actual model outputs may be different at the tower location. But currently no wind data from tower location are available for actual assessment. Actual tower height will be 8 m due to NEON tower design.

5.4.4 Results (source area graphs)

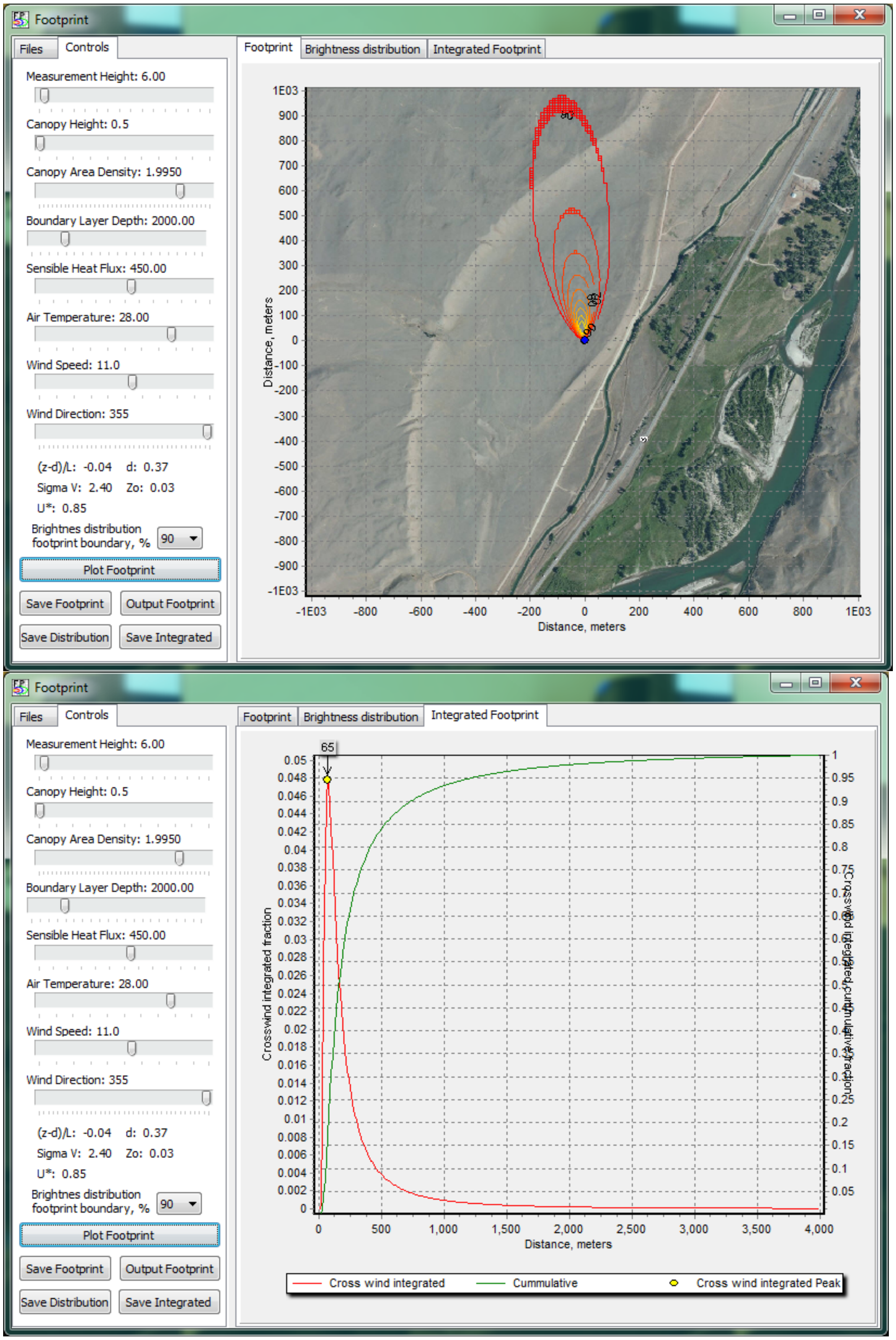


Figure 55. Paradise Valley Relocatable site summer daytime (convective) footprint output with max wind speed

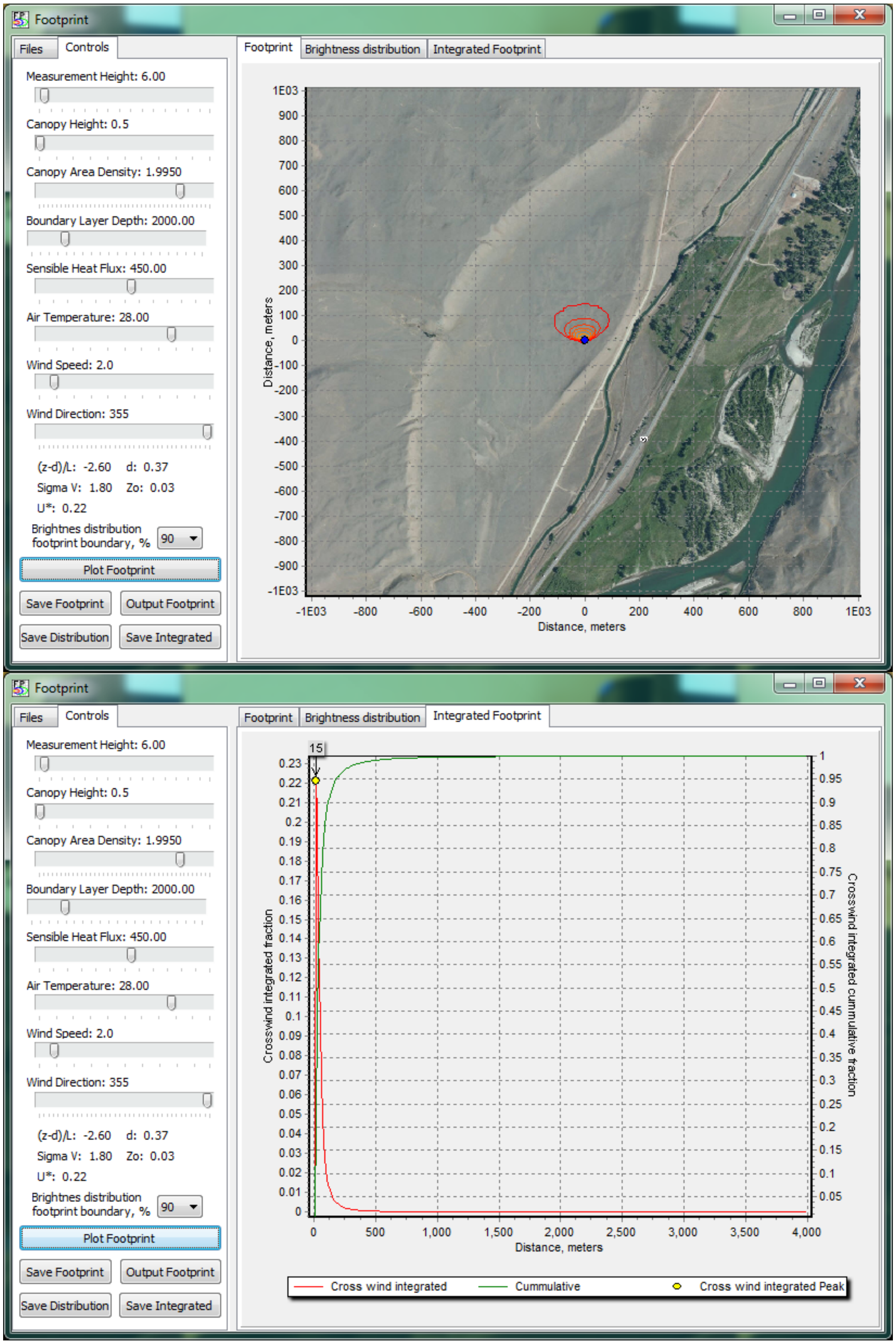


Figure 56. Paradise Valley Relocatable site summer daytime (convective) footprint output with mean wind speed (primary wind direction)

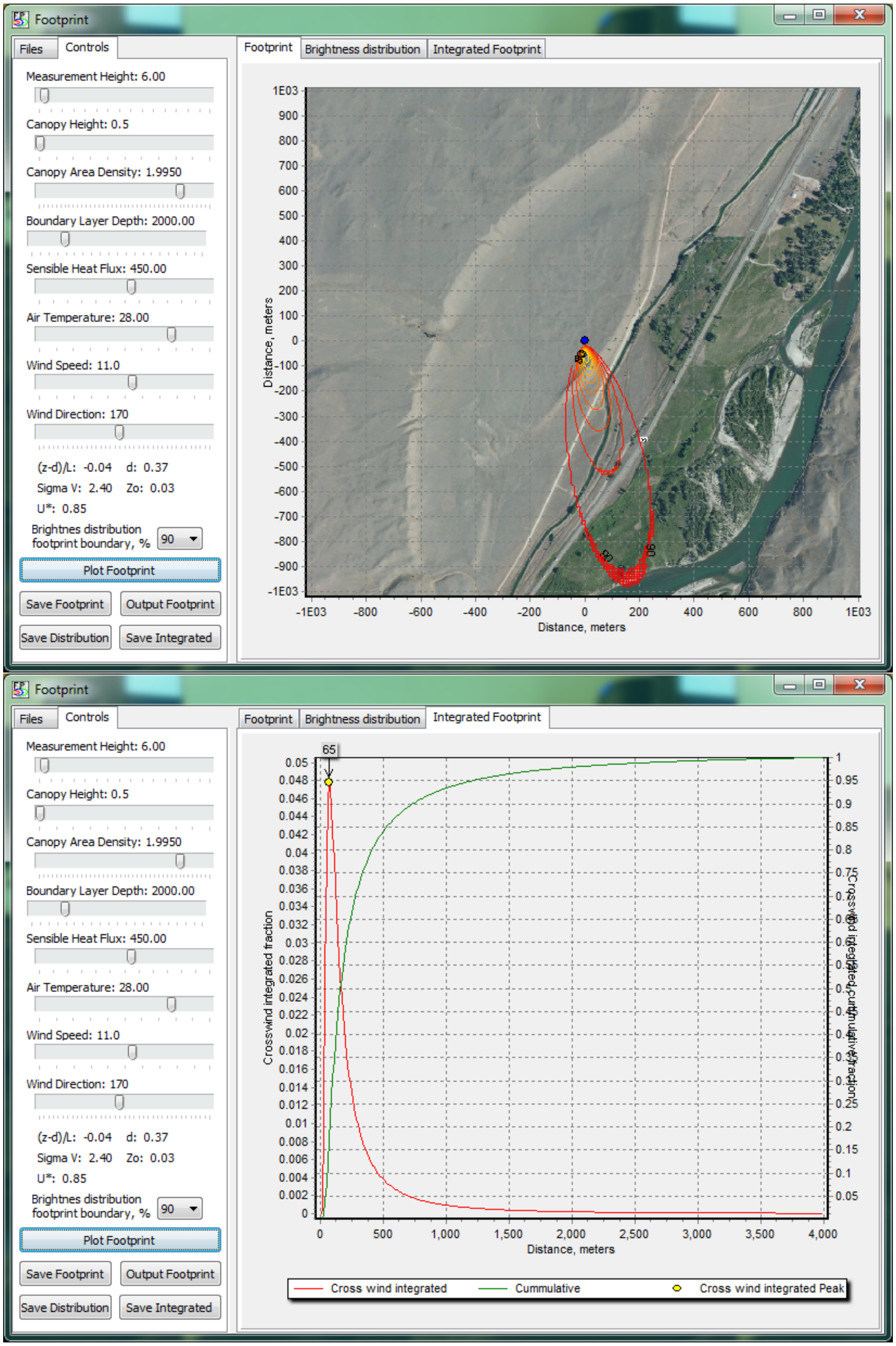


Figure 57. Paradise Valley Relocatable site summer daytime (convective) footprint output with mean wind speed (secondary wind direction)

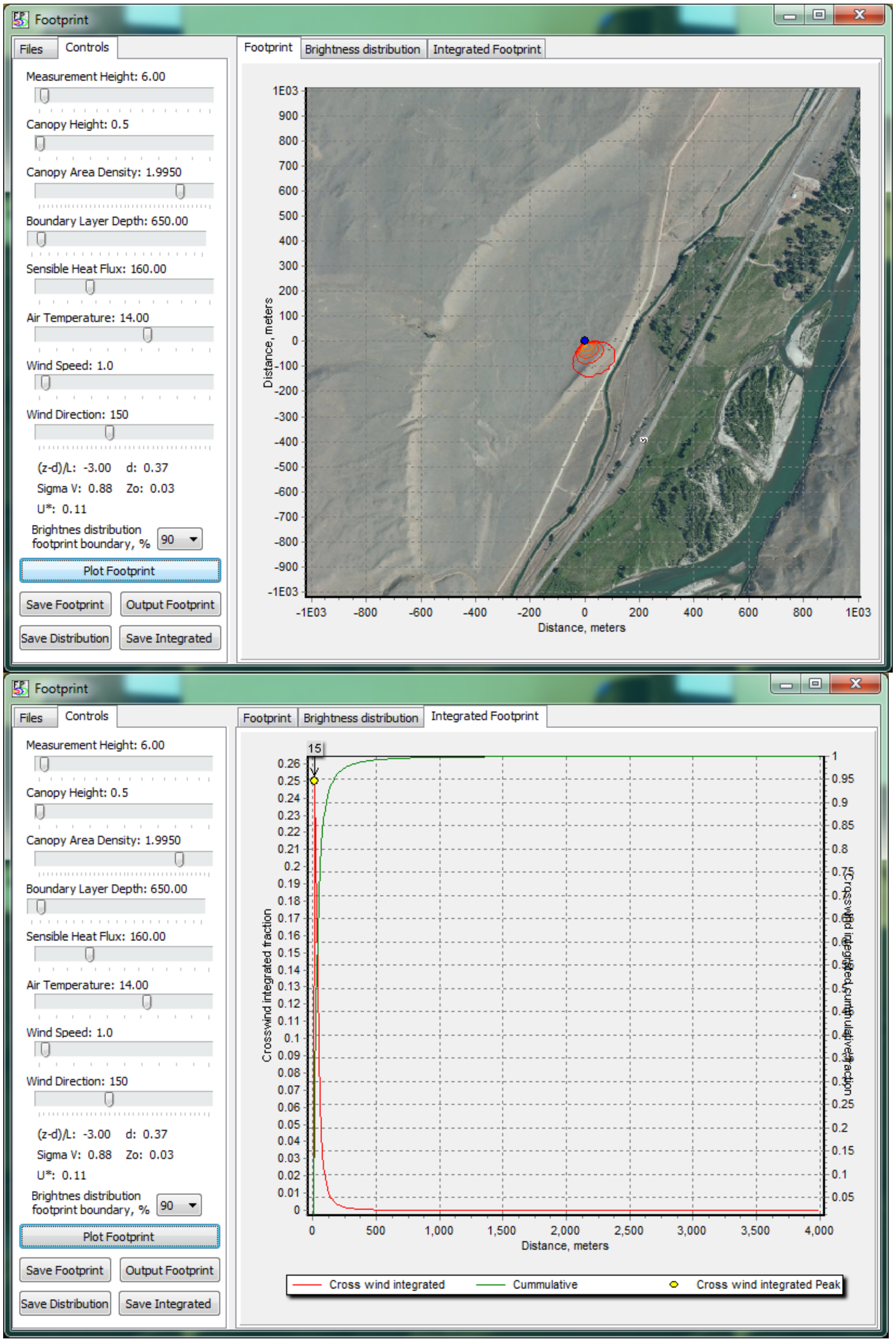


Figure 58. Paradise Valley Relocatable site summer nighttime (stable) footprint output with mean wind speed

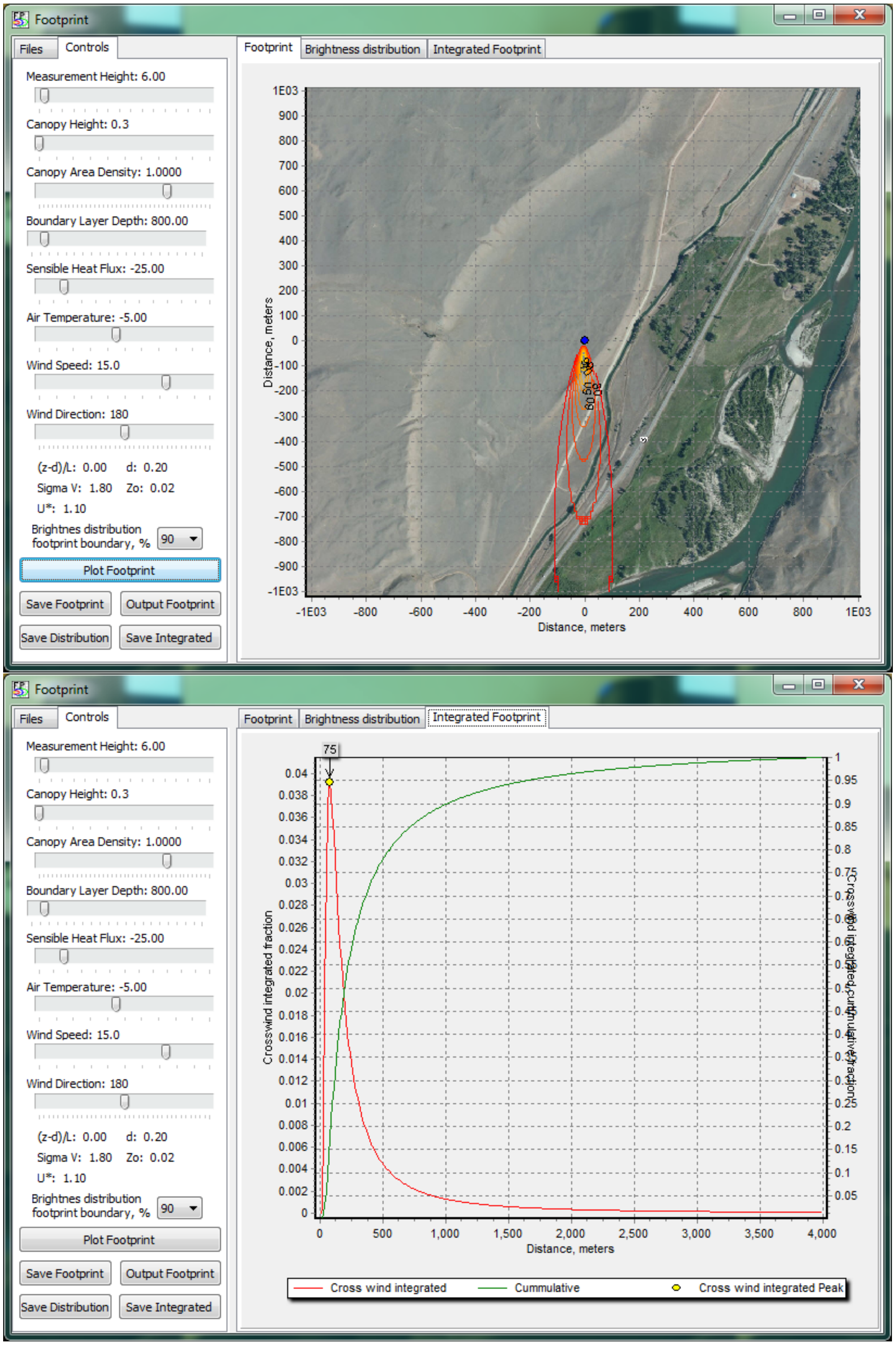


Figure 59. Paradise Valley Relocatable site winter daytime (convective) footprint output with max wind speed

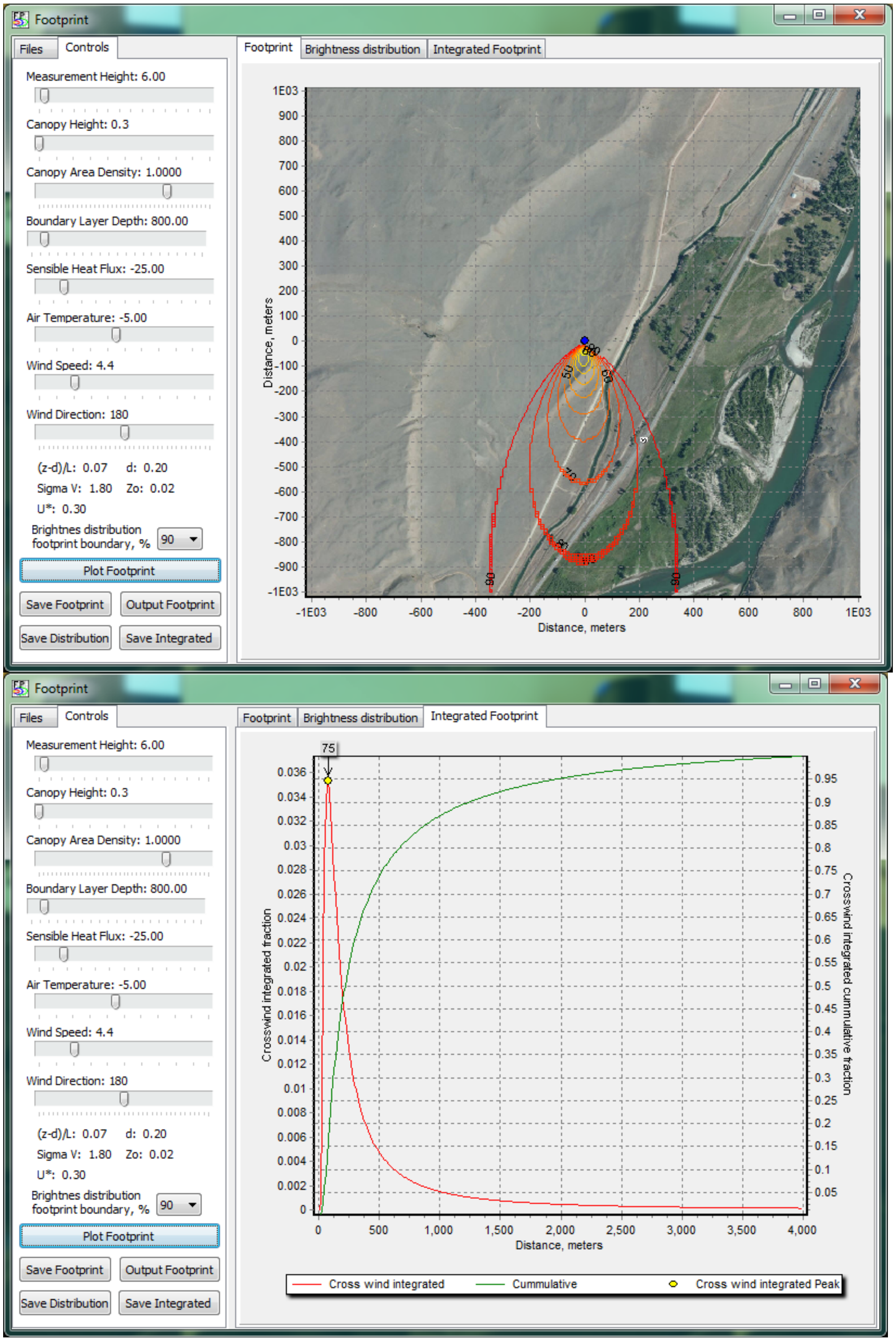


Figure 60. Paradise Valley Relocatable site winter daytime (convective) footprint output with mean wind speed

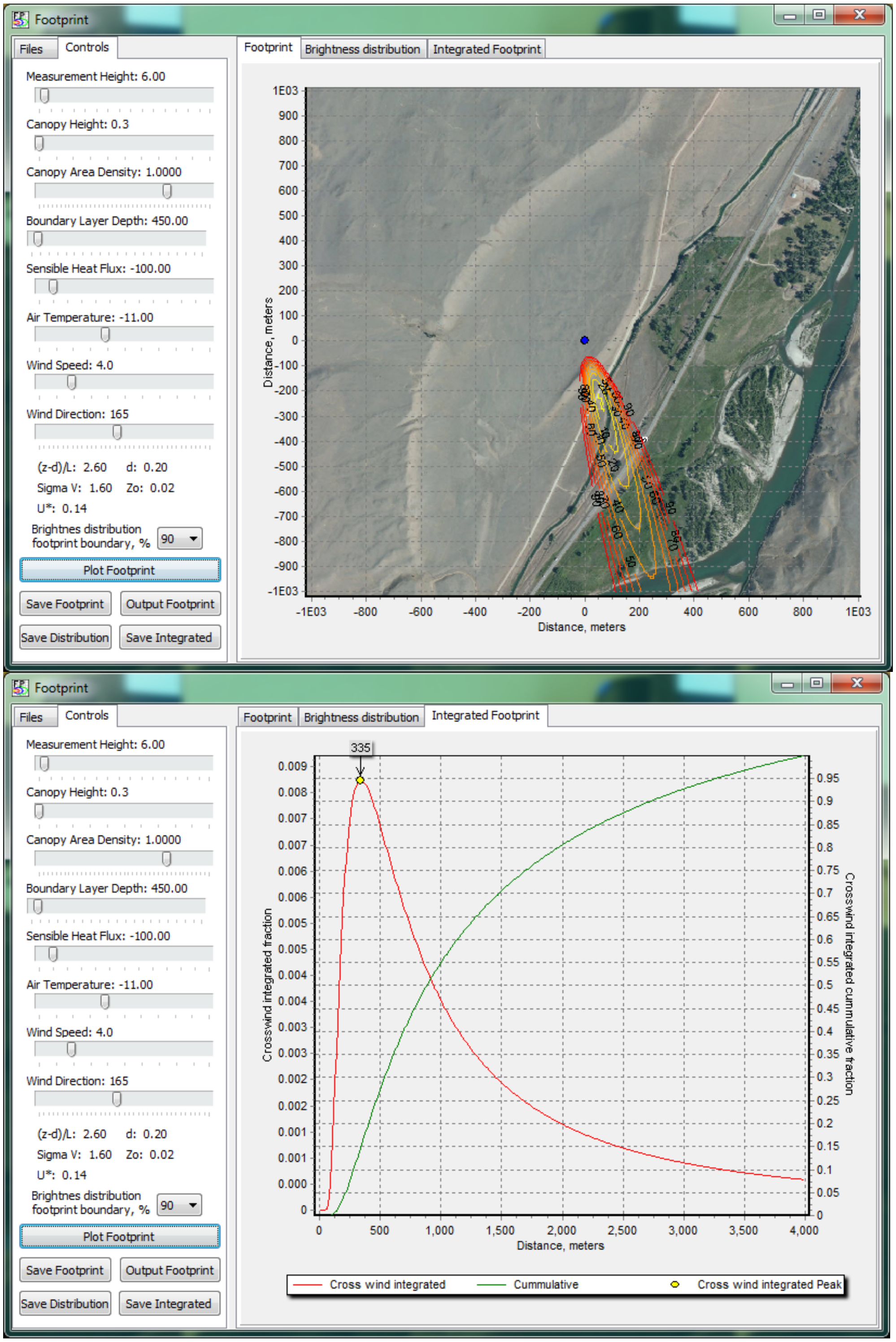


Figure 61. Paradise Valley Relocatable site winter nighttime (stable) footprint output with mean wind speed

5.4.5 Site design and Tower Attributes

Proposed tower location is at 45.39395, -110.71662 degrees.
Based on the wind roses and interpretation of the terrain map, the prevailing wind directions are from south and southwest along the valley and secondary prevailing wind direction from north during the summer season, and some winds from west direction due to the air drainage along the slope of the hill to the west. Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the west will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure. An **instrument hut** should be outside the prevailing wind airshed to avoid disturbance in the measurements of wind and should be positioned to have the longer side parallel to frequent wind direction to minimize the wind effects on instrument huts and to minimize the disturbances of wind regime by instrument hut, and in this case, instrument hut should be positioned on the southeast toward tower and have the longer side parallel to SW-NE direction. Therefore, we decide the placement of instrument hut at 45.39390, -110.71640 degrees. The distance between the tower and the instrument hut is ~ 17 m.

The canopy height for grassland ecosystem is ~ 0.3 m. Therefore, we require 4 **measurement layers** on the tower with top measurement height at 6 m (the actual tower height will be 8 m due to NEON tower design), and remaining levels are at 4 m, 2 m and 0.3 m, respectively, to best characterize the fluxes on the tower top and environmental conditions in profile.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. No **wet deposition collector** will be deployed at this site. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 18. Site design and tower attributes for Paradise Valley Relocatable site. 0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan or best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed			130 to 220 degrees (major) and 350 to 40 degrees (secondary)		Clockwise from first angle
Tower location	45.39395	-110.71662	--	--	
Instrument hut	45.39390	-110.71640			
Instrument hut orientation vector	--	--	200°-20°		
Instrument hut distance z	--	--	--	17	
Anemometer/Temperature boom orientation	--	--	270°	--	
Height of the measurement levels*					
Level 1				0.3	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				4.0	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Figure below shows the proposed tower location, instrument hut location, airshed area and access road.

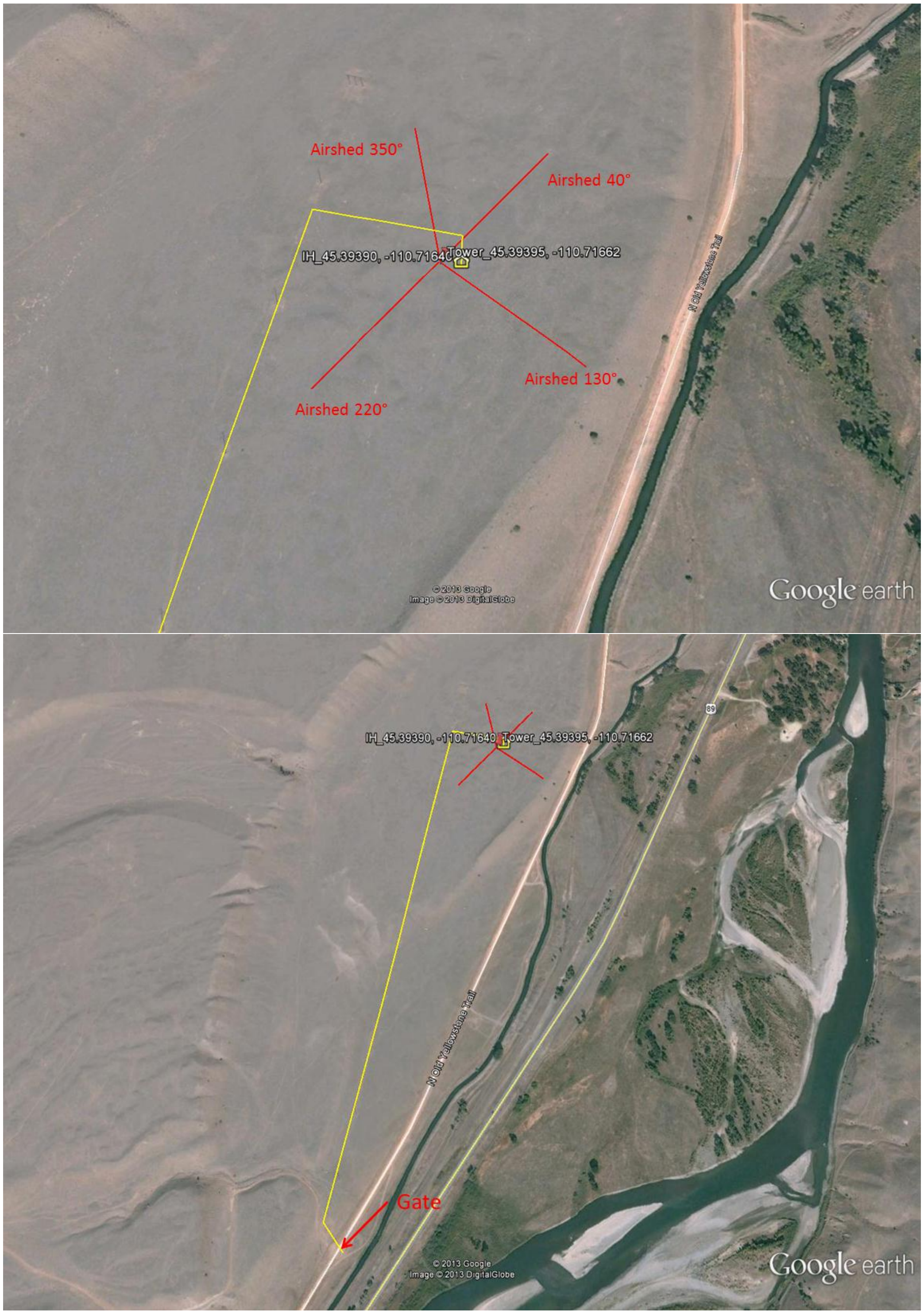


Figure 62. Site layout for Paradise Valley Relocatable site.

i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 130^{o} to 220^{o} (major airshed, clockwise from 130^{o}) and 350^{o} to 40^{o} (secondary airshed, clockwise from 350^{o}) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut. Per host's request, during operation, foot traffic to access instrument hut should start at the gate and along the old trail next to power line, which is ~ 1 mile in length. The straight line here is just the approximate route, and do not present how exactly the old trail runs.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36' wide footprint. While the final design is not yet known, there are some general criteria that can be outlined. We assume that the boardwalk width is 36" (0.914 m). Material is not known, but must be fire proof, and in some locations the site is seasonally flooded and inundated with water. Boardwalks may also provide a scratching structure for grazing animals that in turn, would wear and unduly impact the site. Site by site evaluations must be done.
Specific boardwalks at this site:

- Gravel path from N Old Yellowstone Trail road to instrument hut, pending landowner decision.
- Boardwalk from the instrument hut to the tower
- Gravel path to soil array
- No boardwalk/path from soil array path to individual soil plots.

The relative locations between tower, instrument hut and boardwalk can be found in the diagram below:

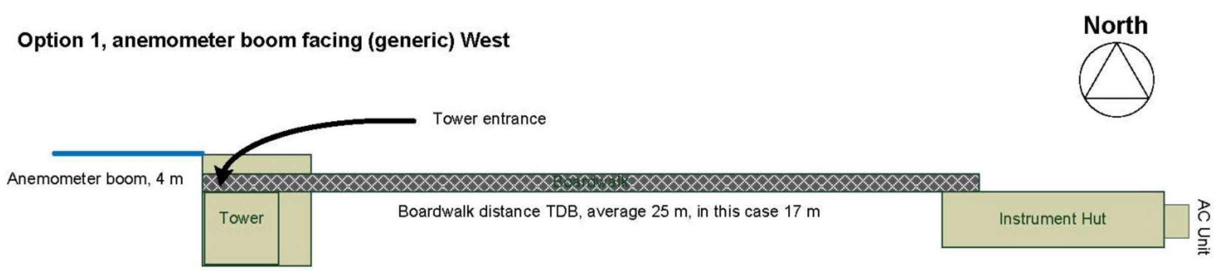


Figure 63. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram when boom facing west and instrument hut on the eastern side of the tower. The actual design of boardwalk (or path if no boardwalk required) and instrument hut position will be joint responsibility of FCC and FIU. At Paradise Valley Relocatable site, the boom angle will be 270 degrees, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~17 m. The instrument hut vector will be SW-NE (200°-20°, longwise).

5.4.6 Information for ecosystem productivity plots

The tower should be positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland and Rocky Mountain Subalpine-Montane Mesic Meadow). Based on the wind roses and interpretation of the terrain map, the prevailing wind directions are from south and southwest along the valley and secondary prevailing wind direction from north during the summer season, and some winds from west direction due to the air drainage along the slope of the hill to the west. According to our best knowledge, we would suggest FSU EP plots are placed within the boundary of 130° to 270° from tower. The 90% signals for flux measurements are within a distance of 750 m from tower during summer max wind condition and within 160 m during the daytime mean wind conditions, and 80% within 410 m and 70 m for max wind speed and mean wind speed, respectively, while 90% signals are within 1250 m and 80% signals within 700 m during winter daytime. Signals collected during winter nighttime can be from few kilometers away.

5.5 Issues and attentions

This is an active grazing site from June to October. Cattle fence may be needed to protect instruments on lower tower booms and in soil array.

Power line is within 150 m from tower location to the west. Power line runs NE-SW direction across this site. And host suggested the operation access route to instrument hut should start at the gate (45.383430°, -110.720650°, ~ 1 mile to the south of tower) and along the old trail next to the power line (see picture below). NEON should keep enough buffer zone between NEON facilities/routes and power line.

Because of the grazing activities and long distance of the access route, boardwalk is not recommended at this site. Foot traffic on path was suggested by host. It will be a challenge for Filed Operations Team to transport heavy gears during operation.

Soil pit locations are very far away from the existing road. We assume excavation machine will use the same access route as construction and operation activitities to get to the soil pit, which is along the old trail next to the power line.

This site is inside DNR fenced property, and NEON facilities is not visible from N Old Yellowstone Trail road and highway 89. Vadalism may not be a concern.

Figure 64. Photo to show the old trail at site that host suggested NEON to follow.

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