D12 FIU SITE CHARACTERIZATION: SUMMARY

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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 number's/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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LIST OF TABLES AND FIGURES

1 DESCRIPTION

1.1 Purpose

The data summarized here is used to inform the site design activities for NEON project Teams, EHS (permitting), FCC, ENG and FSU. This document summarizes the FIU site characterization data collected, analyzed, and described in the FIU D12 Site Characterization: Supporting Data (AD[01]).

1.2 Scope

This document summarizes the FIU site characterization data for three D12 tower locations: Yellowstone National Park site (Advanced), Bozeman site (Relocatable 1), and Paradise Valley (Relocatable 2). Issues and concerns for each site that need attention 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.011062	FIU D12 Site Characterization Supporting Data
AD[02]	NEON.DOC.011018	WID Between FIU and FCC
AD[03]	NEON.DOC.011008	FIU Tower Science Requirements
AD[04]	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

m.a.s.l.	Meters Above Sea Level
m.a.g.l.	Meters Above Ground Level

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 ADVANCE TOWER SITE

3.1 Desired Ecosystem

Table 1. Ecosystem at the Yellowstone Advanced tower site.

Ecosystem Type	Management activity
Open pine-dominated forest and grassland	Managed as a wildland

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). 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.

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.

3.2 Site Design and Tower Attributes

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 3. 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.

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.

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.

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:

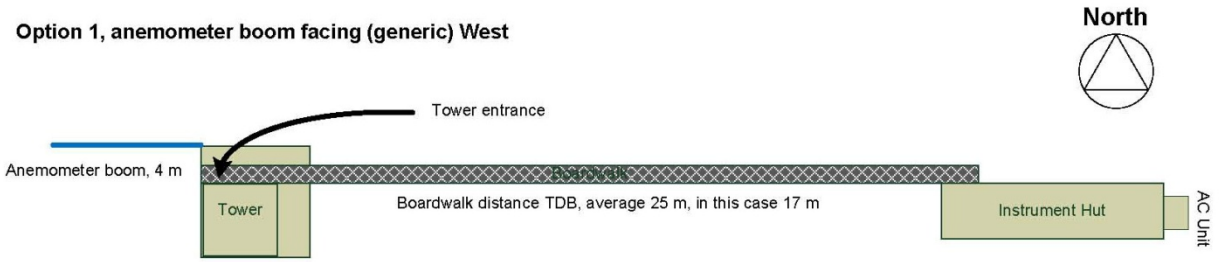


Figure 1. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the east towards the tower.

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 (135°-315°, longwise).

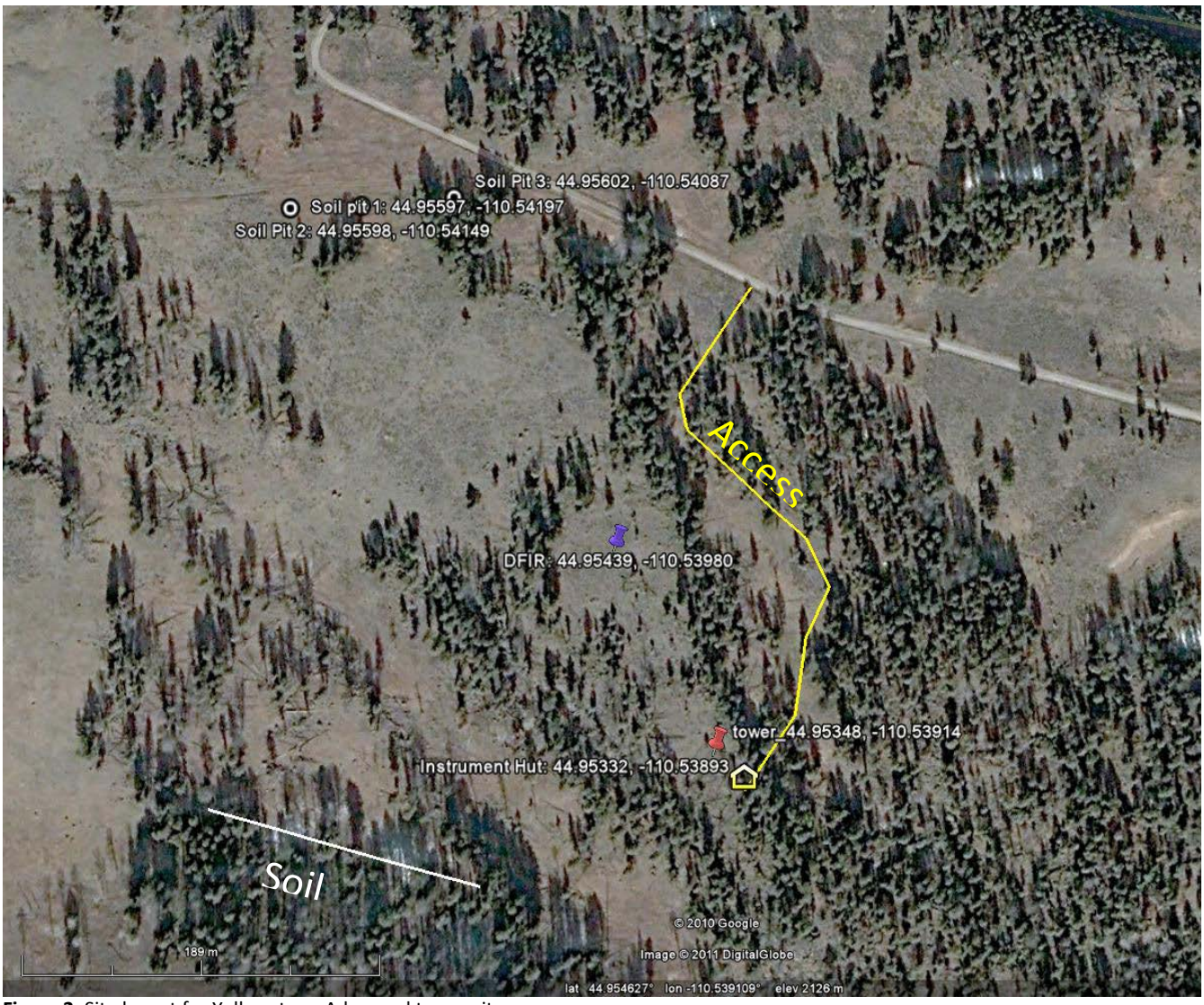


Figure 2. Site layout for Yellowstone Advanced tower site.

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

3.3 Soil Attributes

The soil array vector is ***from*** the soil plot closest to the tower ***toward*** the farthest soil plot. 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).

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 4. 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

3.3.1 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.

3.4 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 lying 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, RELOCATABLE TOWER 1

4.1 Desired Ecosystem

Table 5. Ecosystem at the Bozeman tower site.

Ecosystem Type	Management activity
Grassland	Previous house/pavement demolished field and will re-seed to turn it into lawn. May be irrigated in the future.

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. The tower is located in a small grassy area 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. 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.

Table 6. 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.

4.2 Site Design and Tower Attributes

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 7. 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.

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.
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.

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:

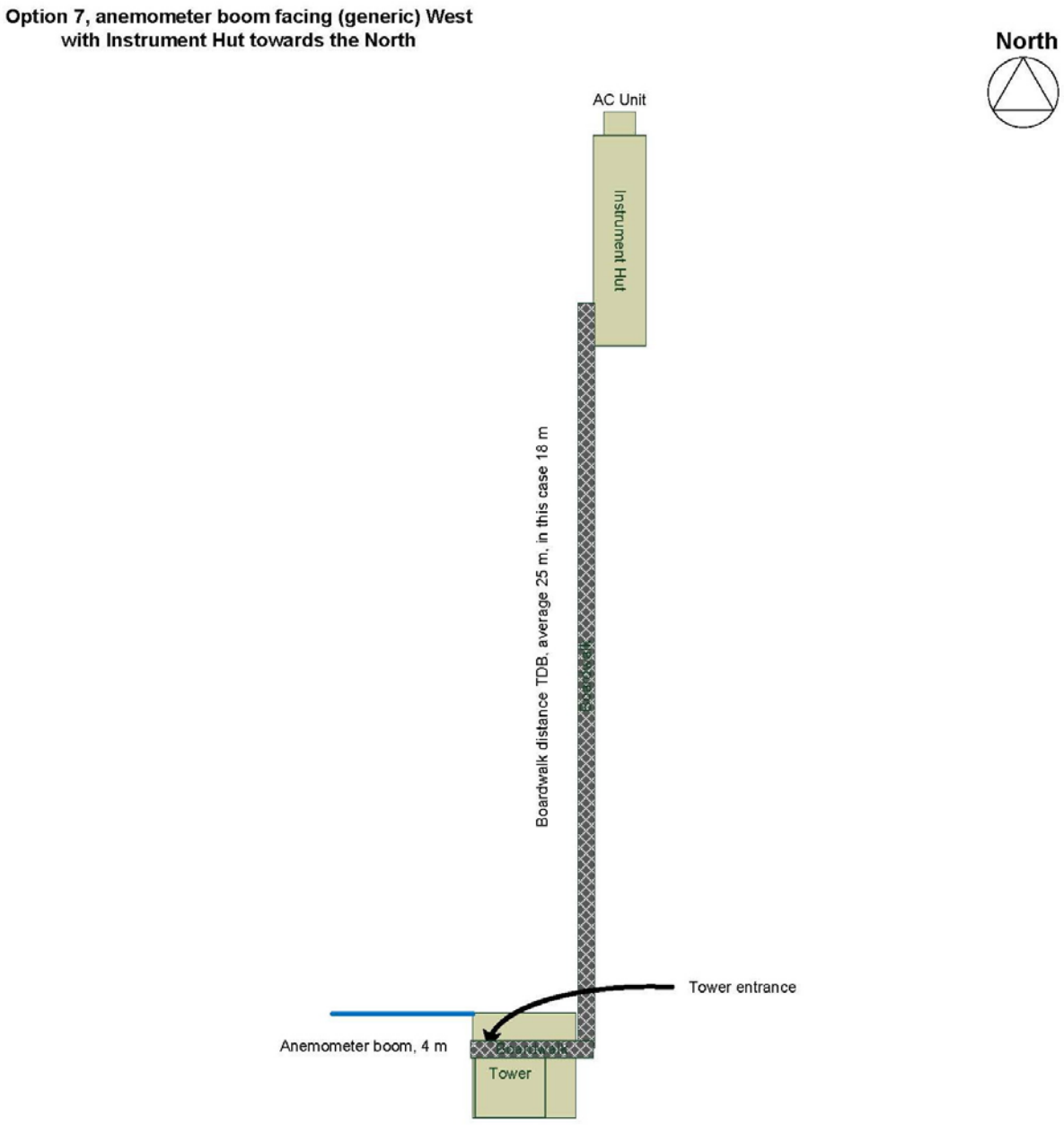
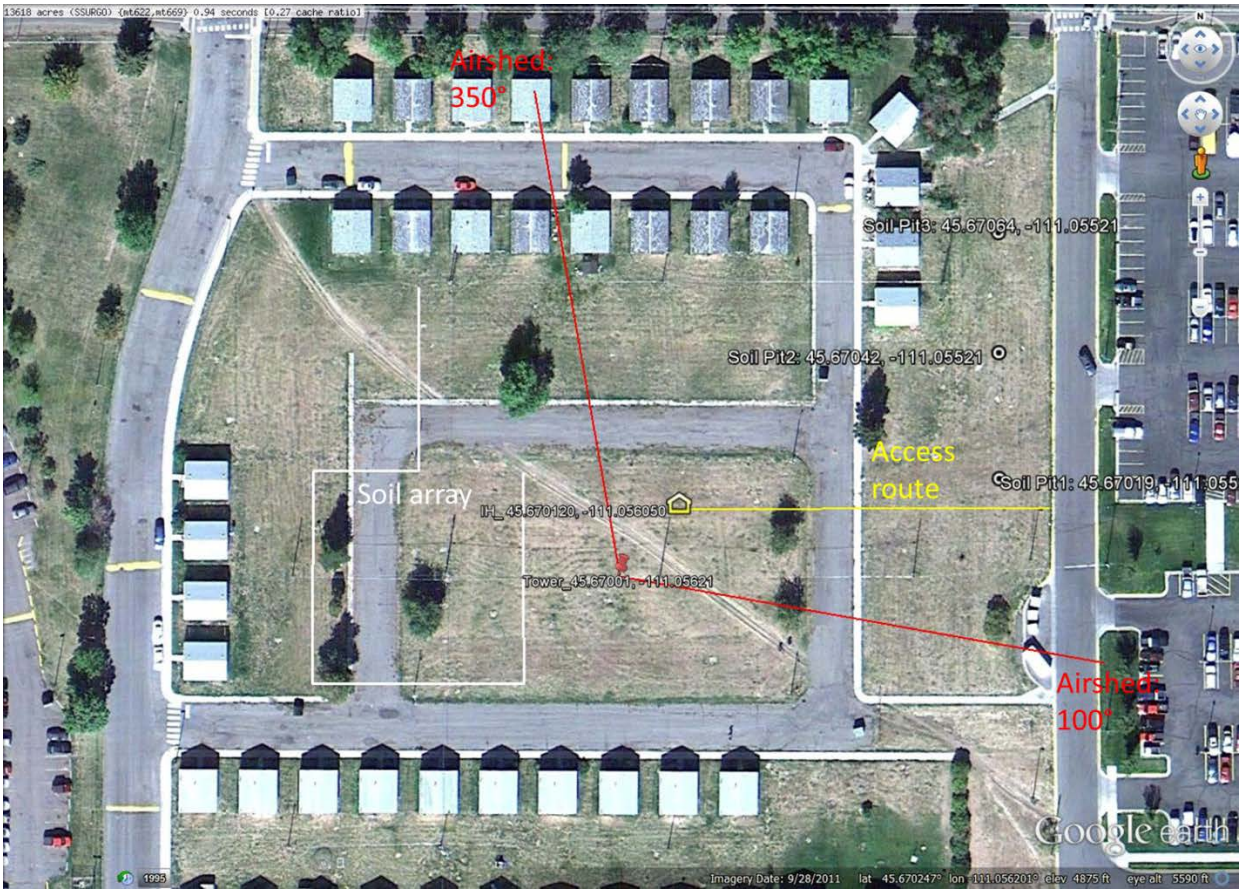


Figure 3. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the north towards the tower.

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 225°, 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 (135°-315°, longwise).


Airshed:
350°
Soil Pit3: 45.67064, -111.05521
Soil Pit2: 45.67042, -111.05521
Access
route
Soil Pit1: 45.67019, -111.055
Soil array
IHL_45.670120, -111.056050
Tower_45.67001, -111.05621
Airshed:
100°
Google earth
Imagery Date: 9/28/2011

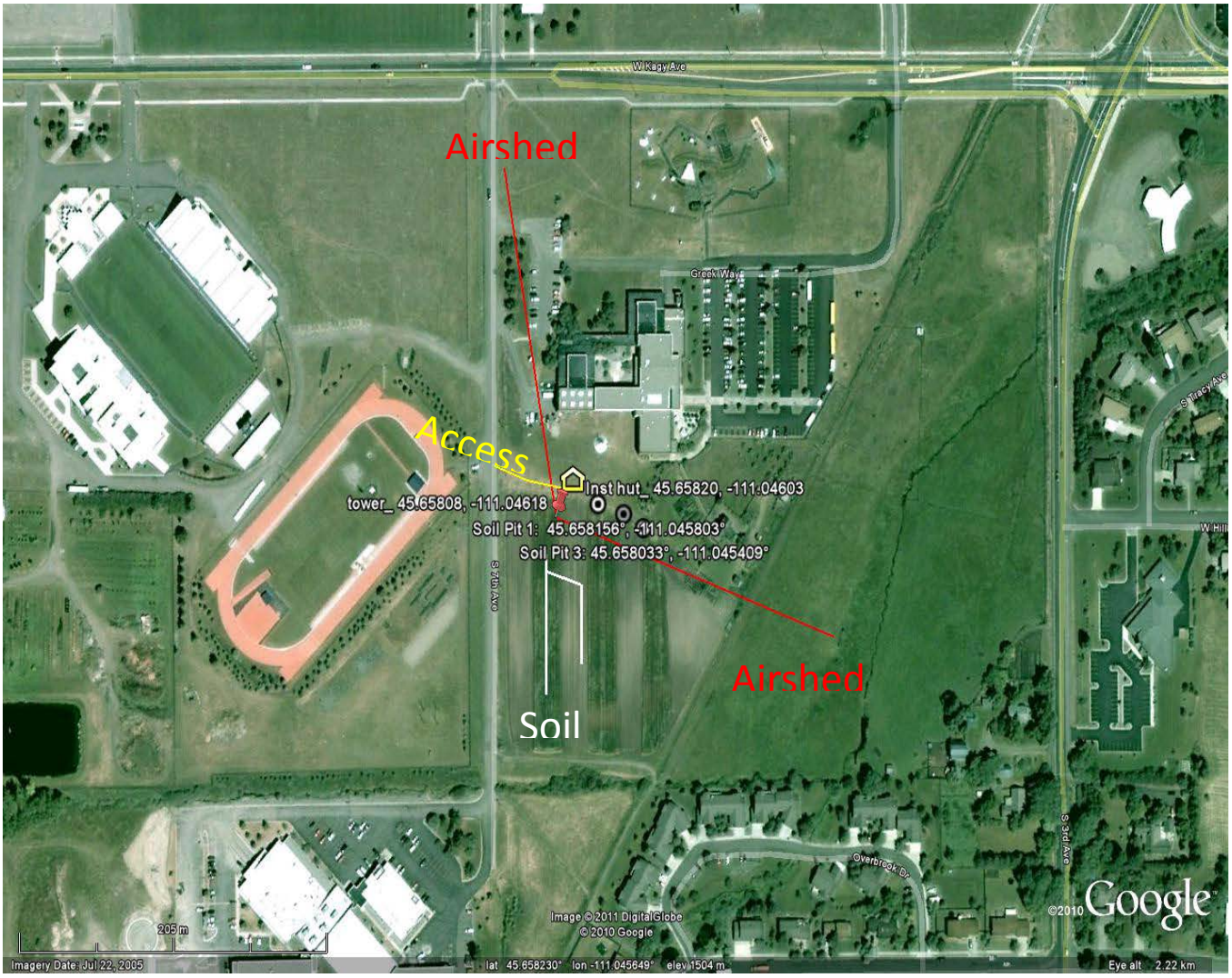


Figure 4. Site layout for Bozeman Relocatable site.

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

4.3 Soil Attributes

The soil array vector is ***from*** the southeast soil plot ***toward*** the northeast soil plot (Fig. 5).

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 8. 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.

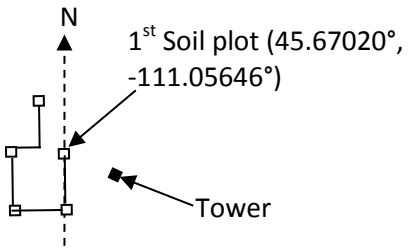


Figure 5. Schematic diagram of soil array layout in relation to tower. Soil plot positions are approximate.

4.3.1 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 100° to 350°, clockwise from 100°, 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 100° to 180° (clockwise from 100°) from tower.

4.4 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.

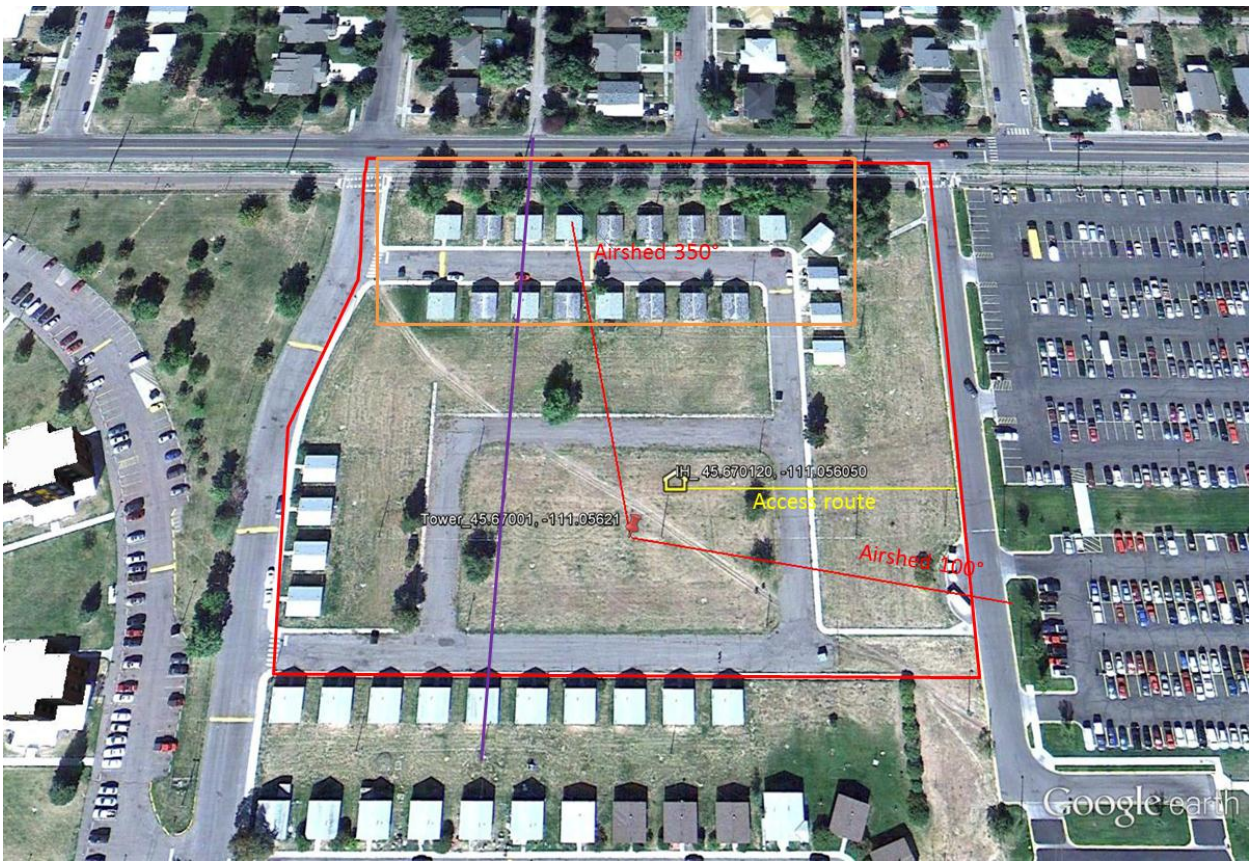


Figure 6. Map to indicate the power line (purple line) and the MSU construction staging area (orange box).

Figure 7. 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 Desired Ecosystem

Table 9. Ecosystem at the Paradise Valley Relocatable site.

Ecosystem Type	Management activity
Grassland	Grazing June to October

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. 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 10. 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

5.2 Site Design and Tower Attributes

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 11. 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.

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.
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.

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:

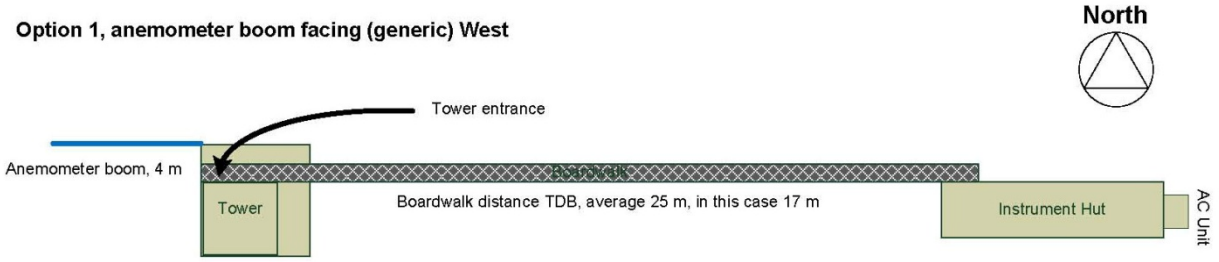
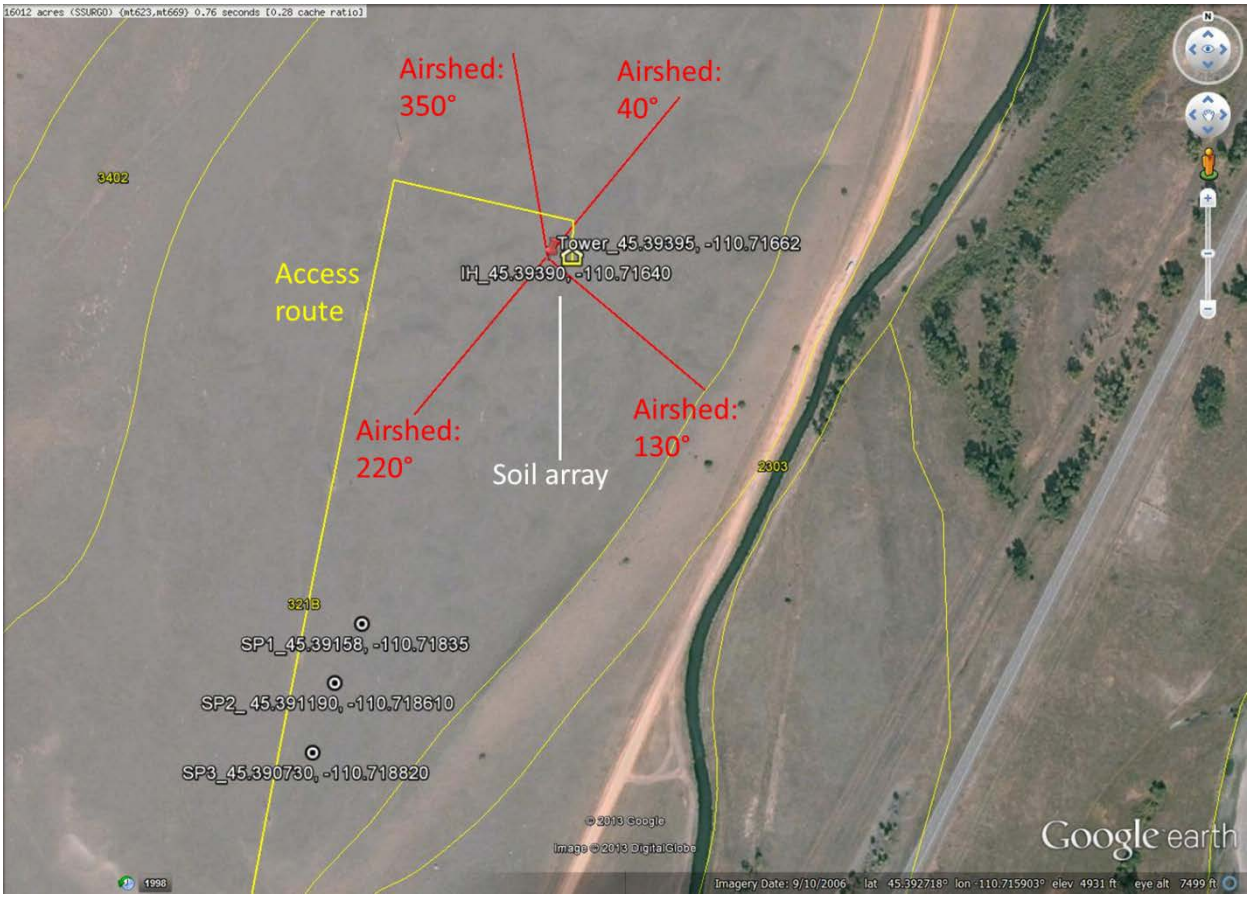


Figure 8. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

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).



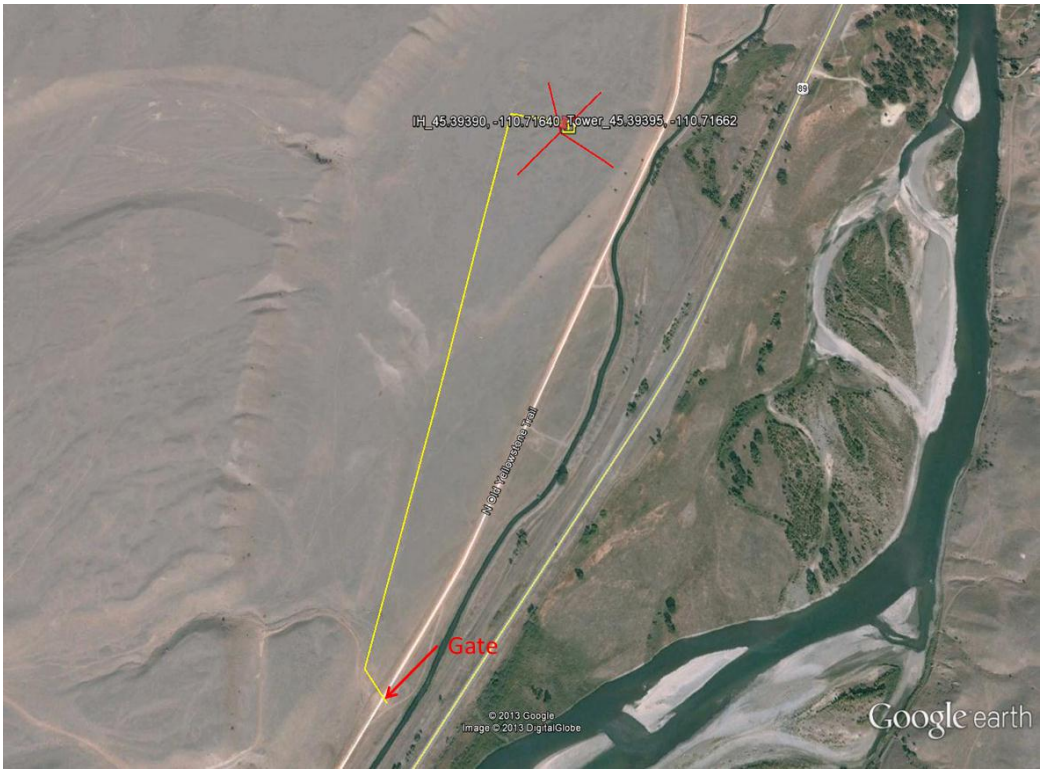


Figure 9. Site layout for Paradise Valley Relocatable site.

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 does not present how exactly the old trail runs.

5.3 Soil Attributes

The soil array vector is ***from*** the soil plot closest to the tower ***toward*** the nearest soil plot to the southwest (Fig. 8).

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 12. 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.

5.3.1 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.

5.4 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.

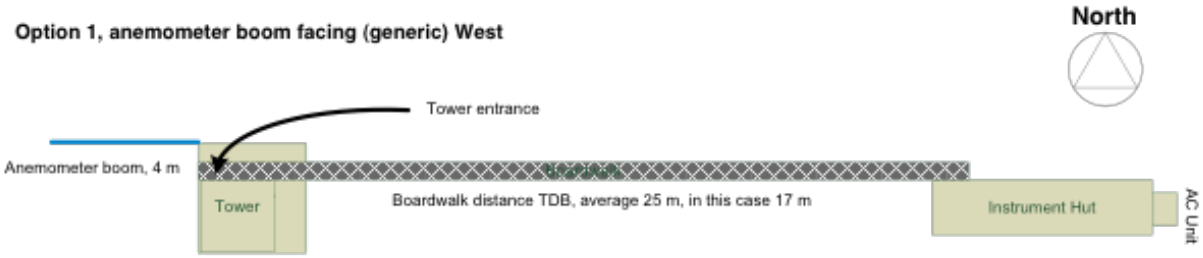
Because of the grazing activities and long distance of the access route, boardwalk is not recommended at this site. Foot traffic on path was suggested by host. It will be a challenge for Filed Operations Team to transport heavy gears during operation.

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.

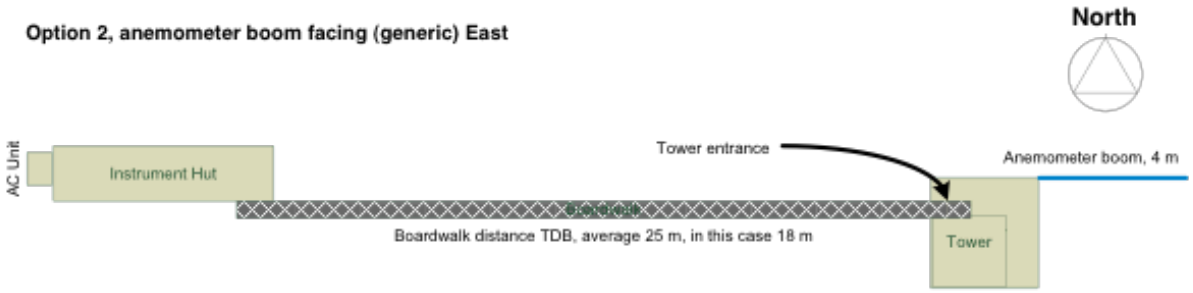
This site is inside DNR fenced property, and NEON facilities is not visible from N Old Yellowstone Trail road and highway 89. Vadalism may not be a concern.

Figure 10. Photo to show the old trail at site that host suggested NEON to follow.

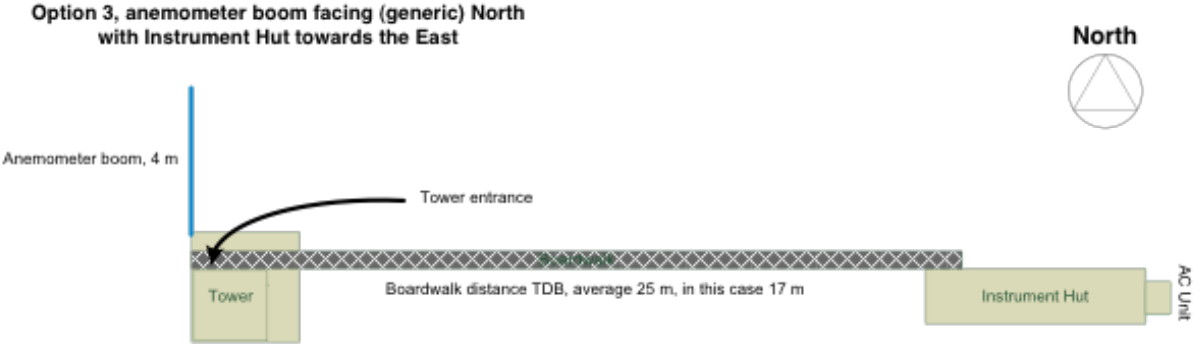
Option 1, anemometer boom facing (generic) West



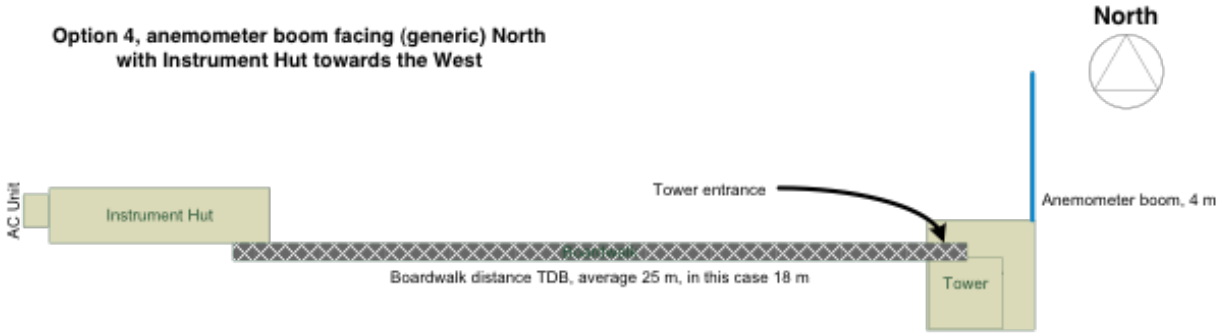
Option 2, anemometer boom facing (generic) East



Option 3, anemometer boom facing (generic) North with Instrument Hut towards the East



Option 4, anemometer boom facing (generic) North with Instrument Hut towards the West



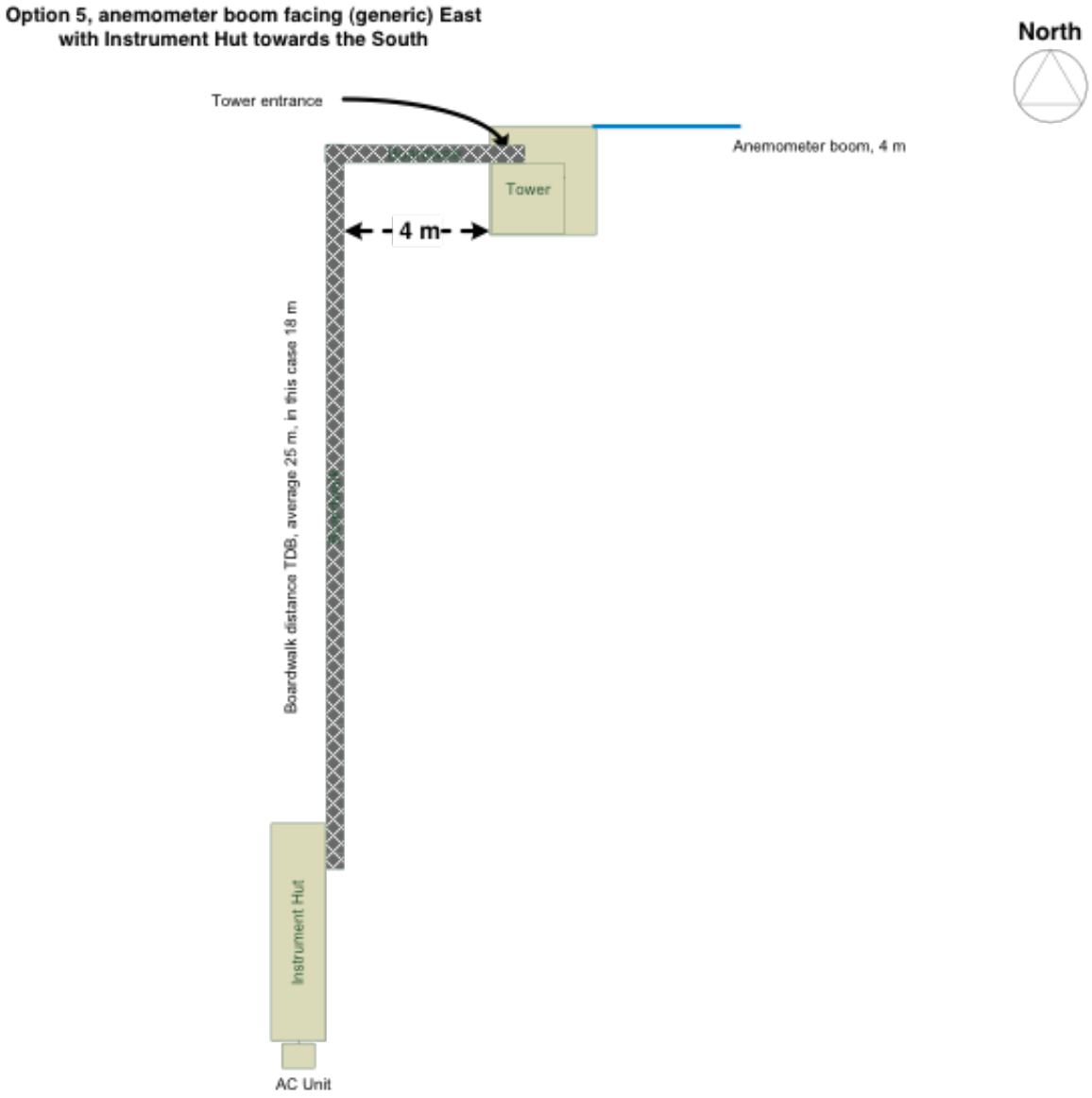
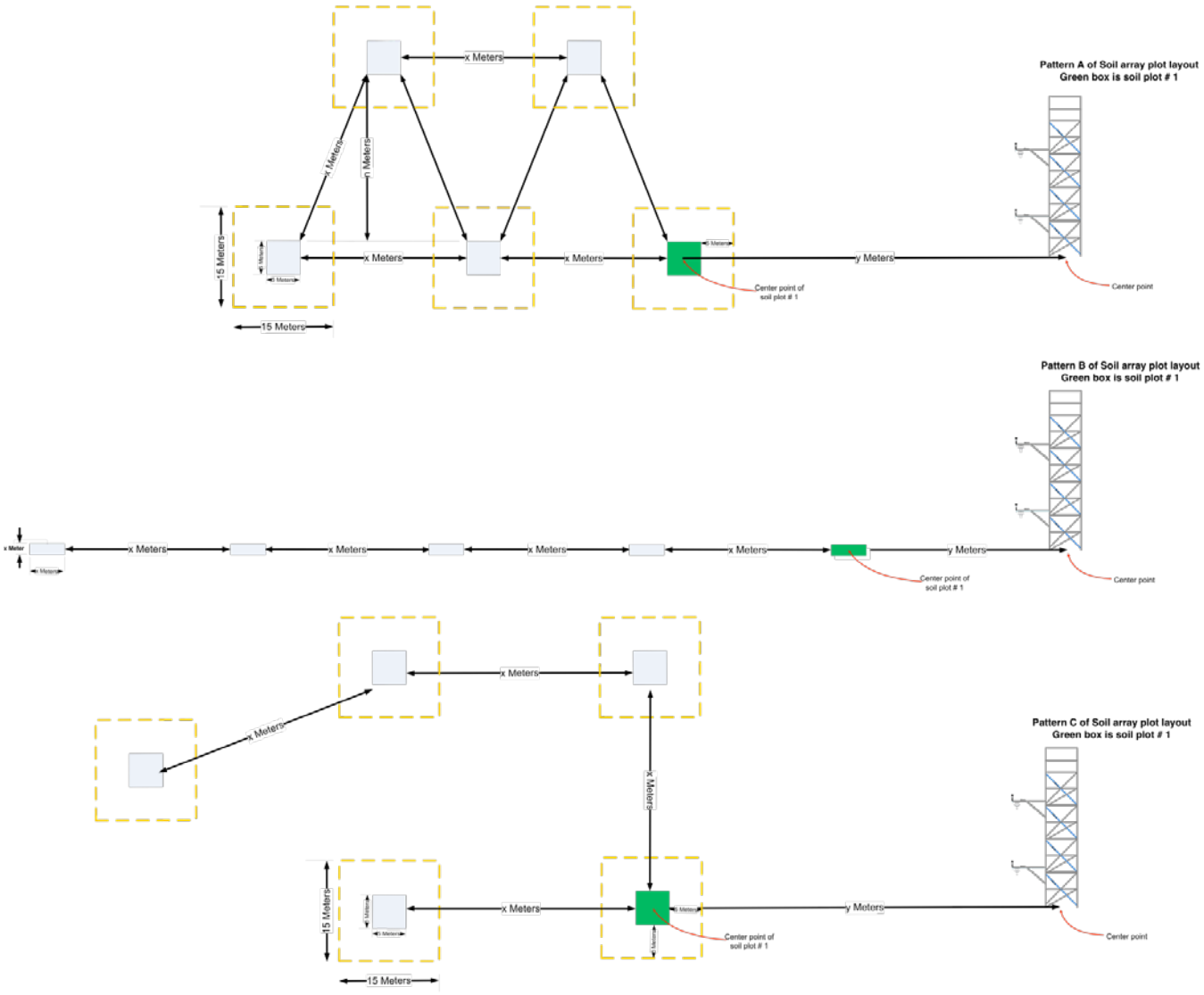


Figure 11. Generic patterns for the boardwalk configuration.

These generic configurations are from the instrument hut to the tower based on 5 generic scenarios. The five options are based on anemometer boom orientation and the leeward side of the tower where the instrument hut is located. The tower entrance is always on the North side of the tower. Exact tower and instrument hut location and orientation will be specified at each location and presented in the site characterization document.


Pattern A of Soil array plot layout
Green box is soil plot # 1
x Meters
x Meters
n Meters
15 Meters
15 Meters
x Meters
x Meters
y Meters
Center point of soil plot # 1
Center point
Pattern B of Soil array plot layout
Green box is soil plot # 1
x Meters
x Meters
x Meters
x Meters
y Meters
Center point of soil plot # 1
Center point
Pattern C of Soil array plot layout
Green box is soil plot # 1
x Meters
x Meters
x Meters
15 Meters
15 Meters
x Meters
y Meters
Center point of soil plot # 1
Center point

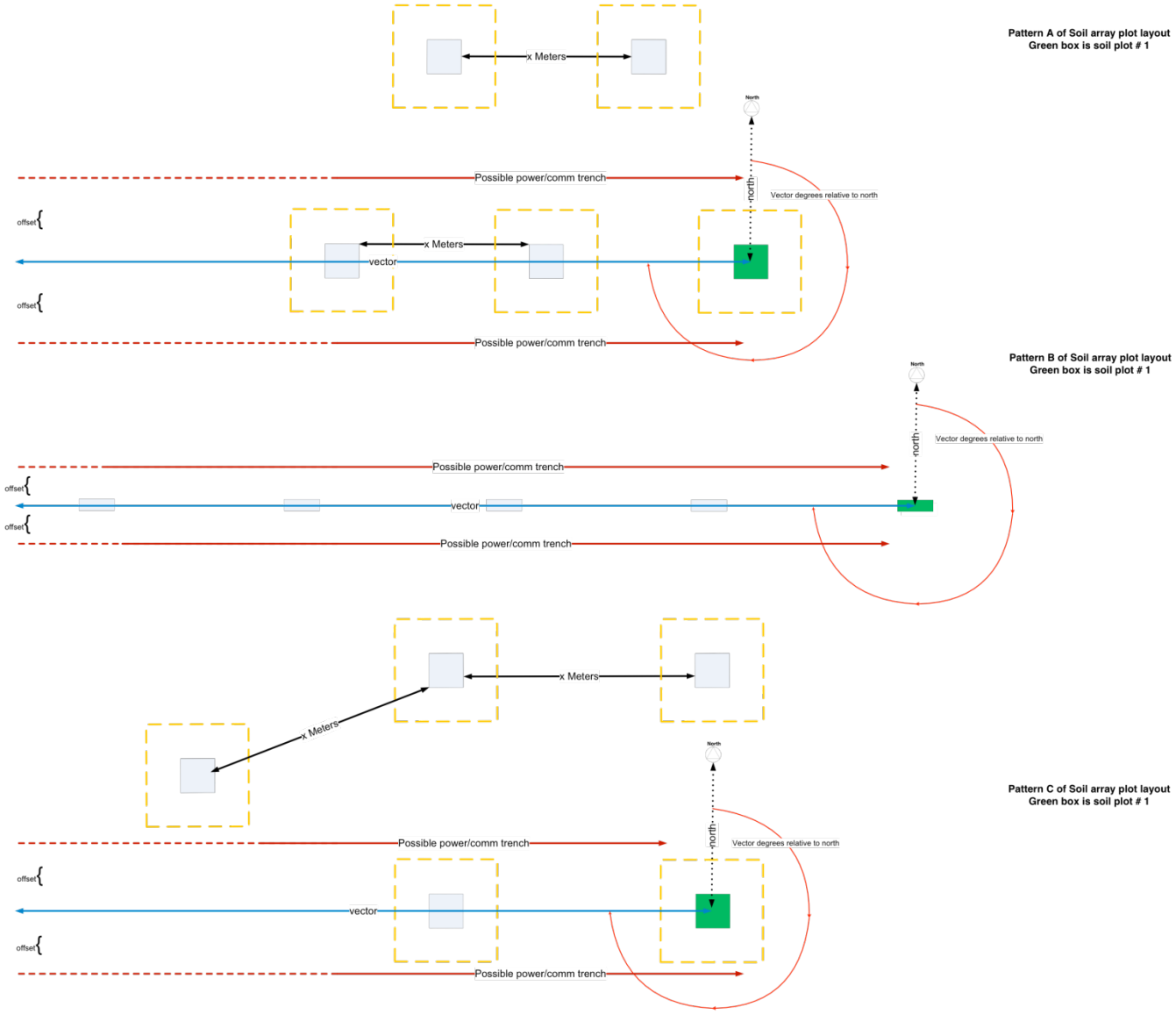


Figure 12. Conceptual diagram of Soil Array Patterns.

Outlines the orientation for the soil array and instrument hut from the center point of the tower. The x, y, z distances are i) the distance between soil plots, ii) distance between the tower centerpoint and the closest edge of soil plot, and iii) the distance between the tower centerpoint and the closest edge of the instrument hut, respectively. The yellow outline around each soil plot is the 5 m perimeter keep out zone.

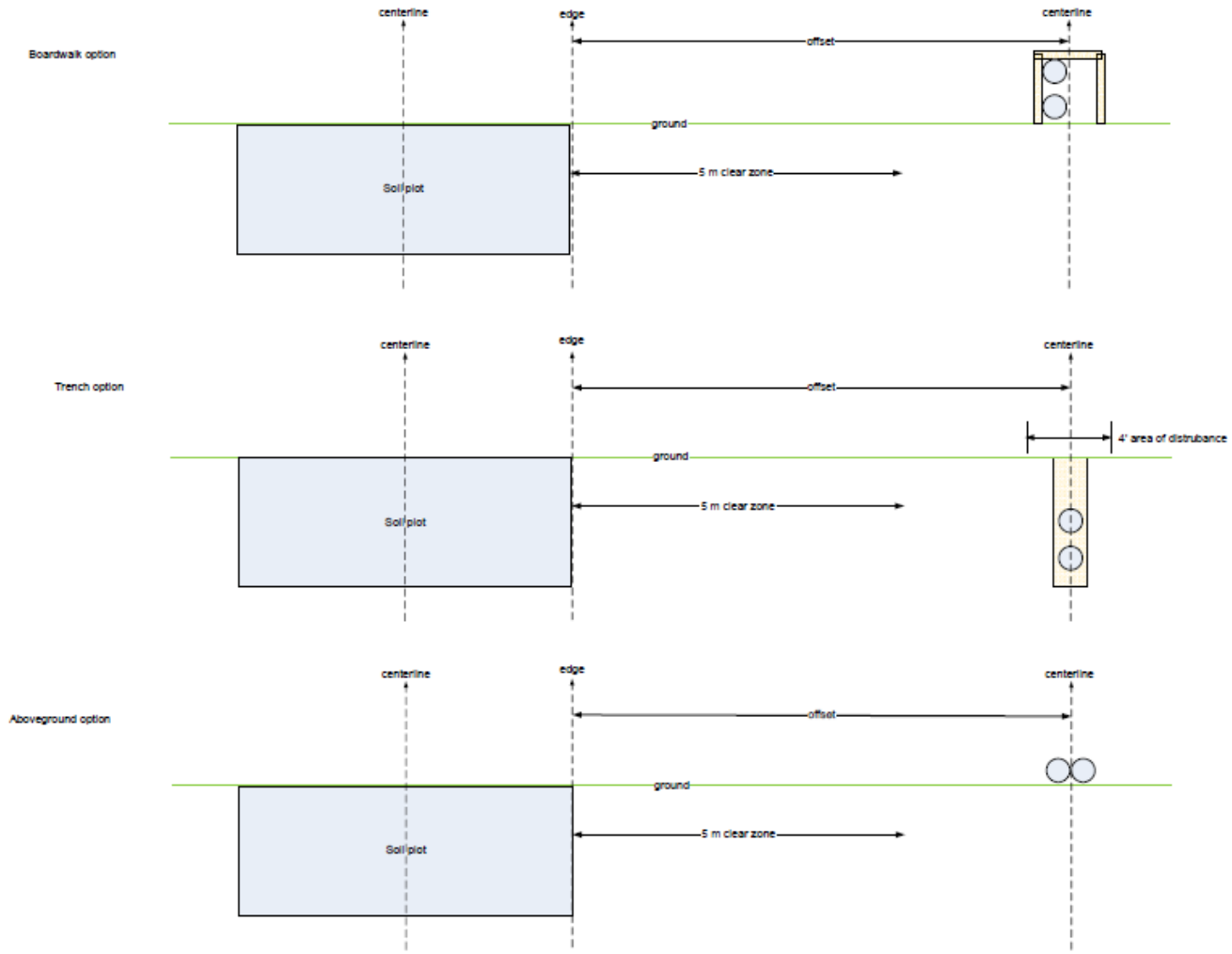


Figure 13. Conceptual diagram of power/communications line and boardwalk/path options in relation to FIU soil plots.

Boardwalk option: When a boardwalk is present the power and communication lines will typically follow the route of the boardwalk and be mounted aboveground (underneath the boardwalk). When no boardwalk is present (or the power/communication lines follow a different route than the boardwalk) the lines can be buried (Trench option) or run aboveground (Aboveground option). The aboveground option will be used instead of the trench option when trenching would be expected to cause significant disturbance to an ecosystem (e.g. cutting the roots of trees), pending landowner approval.

6 APPENDIX A. FCC SUMMARY TABLES

Table 13. FCC Summary Table for FIU site components at D12 Yellowstone Advanced site.

Site Component				**units**
Tower location	44.95348,	-110.53914		Lat, Long, in degrees
Tower location	44° 57' 12.5274"	-110° 32' 20.904"		Lat, Long in deg min sec
Tower height[f]	20			meters
Tower guying	none	Guying is not allowed in national park.		yes/none, notes
Instrument Hut location	44.95332,	-110.53893		Lat, Long, in degrees
Instrument Hut location	44° 57' 11.9514"	-110° 32' 20.1474"		Lat, Long in deg min sec
IH orientation[a]	135° - 315°			vector
Boom orientation[b]	180°			degrees
Distance from center of tower to IH center (z)		24	option 1	distance (m), option #, (location chosen to meet National Park approval)
How the Bwalk intersects the tower access	No BW. Marked footpath intersects the north-side of the tower from the southeast.			description
Air shed vector(s)[c]	South and southeast, do not know exact area boundary			Vector, clock wise from first angle
Boardwalk from AP to IH	no	National park is does not allow BW and gravel path, only marked footpath is allowed (see Figure 2)		yes/none, notes
Boardwalk to soil array	no	National park is does not allow BW and gravel path, only marked footpath is allowed		yes/none, notes
Boardwalk needed to DFIR	no			yes/none
Power and Communication trench	10 m from edge of soil plot to the centerline of the power/comms line	whichever side is easiest [e], line above ground		offset, notes

DFIR location	44.95439,	-110.53980		Lat, Long in degrees, notes
DFIR location	44° 57' 15.8034"	-110° 32' 23.2794"		Lat, Long in deg min sec
DFIR power supply	30 amp AC power from tower			description
Soil plot 1st location	44.95288,	-110.54069		Lat, Long in degrees (center point)
Soil plot 1st location	44° 57' 10.368"	-110° 32' 26.4834"		Lat, Long in deg min sec
Soil plot distance between plots (x) and from tower (y)	31 m	139 m		x, y (meters)
Soil array pattern and vector[d]	B	285°		A, B, or C, vector
Soil plot dimensions	5 m x 5 m			L x W (meters)
Soil profile pit primary	44.95597,	-110.54197	Unknown, possible >2 m	Lat, Long, and expected depth
Soil profile pit primary	44° 57' 21.492"	-110° 32' 31.092"		Lat, Long in deg min sec
Soil profile pit alternative 1	44.95598,	-110.54149	Unknown, possible >2 m	Lat, Long, and expected depth
Soil profile pit alternative 1	44° 57' 21.5274"	-110° 32' 29.3634"		Lat, Long in deg min sec
Soil profile pit alternative 2	44.95602,	-110.54087	Unknown, possible >2 m	Lat, Long, and expected depth
Soil profile pit alternative 2	44° 57' 21.672"	-110° 32' 27.1314"		Lat, Long in deg min sec
Fencing needs	none	none	none	IH, Soil Arrays, Guy anchors
Presence of large grazing animals	Likely, wild animals like bison, moose, dear, etc			description
Site management*	Managed as a wild land			description
Any additional site specific information	Open pine-dominated forest and grassland. Large grazing wild animals were found nearby. Protection of sensors on the lower level on the tower and at soil array may be added in the future if necessary.			description
Magnetic declination	12° 27' E changing by 0° 9' W/year			At time of site visit

Table 14. FCC Summary Table for FIU site components at D12 Bozeman Relocatable 1-111°

Site Component				**units**
Tower location	45.67001	-111.05621		Lat, Long in degrees
Tower location	45°40'12.04"	-111° 3'22.36”		Lat, Long in deg min sec
Tower height[f]	30 m			meters
Tower guying	Yes			yes/none, notes
Instrument Hut location	45.67012	-111.05605		Lat, Long in degrees
Instrument Hut location	45°40'12.43”	-111° 3'21.78”		Lat, Long in deg min sec
IH orientation[a]	135°-315°			vector
Boom orientation[b]	225°			degrees
Distance from center of tower to IH center (z)		18	Option 7	vector, distance (m), option #
Air shed vector(s)[c]	100° to 350° but has higher frequency from 100° to 180°			vector, clockwise from first angle
Boardwalk from AP to IH	No BW. Gravel path from AP to IH.			yes/none, notes
Boardwalk between tower and IH	Yes, BW between tower and IH			
Boardwalk to soil array	Gravel path to soil array			yes/none, notes
Boardwalk needed to DFIR	NA			yes/none
DFIR location	NA			Lat, Long
Power and Communication line	10 m from edge of soil plot to the centerline of the power/comms line	whichever side is easiest[e], trended below ground		offset, notes
DFIR power supply	na.			description
Soil plot 1st location	45.67020°	-111.05646°		Lat, Long (center point)
Soil plot 1st location	45°40'12.72"	-111° 3'23.26"		Lat, Long in deg min sec
Soil plot distance between plots (x) and from tower (y)	33 m	29 m		x, y (meters)
Soil array pattern and vector[d]	C	0°		A, B, or C, vector

Soil plot dimensions	5 m x5 m			L x W (meters)
Soil profile pit primary	45.67019	-111.05521	>2 m	Lat, Long, and expected depth
Soil profile pit primary	45°40'12.68"	-111° 3'18.76"		
Soil profile pit alternative 1	45.67042	-111.05521	>2 m	Lat, Long, and expected depth
Soil profile pit alternative 1	45°40'13.51"	-111° 3'18.76"		Lat, Long in deg min sec
Soil profile pit alternative 2	45.67064	-111.05521	>2 m	Lat, Long, and expected depth
Soil profile pit alternative 2	45°40'14.30"	-111° 3'18.76"		Lat, Long in deg min sec
Fencing needs	none	none	none	IH, Soil Arrays, Guy anchors
Presence of large grazing animals	No			description
Site management*	Previous house/pavement demolished field and will re-seed to turn it into lawn.			description
Any additional site specific information	Lawn, periodically irrigation will occur.			description
Magnetic declination	12° 48' E changing by 0° 9' W/year			At time of site visit

Table 15. FCC Summary Table for FIU site components at D12 Paradise Valley Relocatable 2

Site Component				**units**
Tower location	45.39395	-110.71662		Lat, Long in degrees
Tower location	45°23'38.22"N	-110°42'59.83”		Lat, Long in deg min sec
Tower height[f]	6.0			meters
Tower guying	None			yes/none, notes
Instrument Hut location	45.39390	-110.71640		Lat, Long in degrees
Instrument Hut location	45°23'38.04”	-110°42'59.04”		Lat, Long in deg min sec
IH orientation[a]	200° -20°			vector
Boom orientation[b]	270°			degrees
Distance from center of tower to IH center (z)		17	Option 1	distance (m), option #
Air shed vector(s)[c]	130 to 220 degrees (major) and 350 to 40 degrees (secondary)			vector, Clockwise from first angle
Boardwalk from AP to IH	Gravel path			yes/none, notes
Boardwalk between tower and IH	Yes, BW between tower and IH			
Boardwalk to soil array	Gravel path	No BW or path to individual soil plots		yes/none, notes
Boardwalk needed to DFIR	NA			yes/none
Power and Communication line	10 m from edge of soil plot to the centerline of the power/comms line	whichever side is easiest [e], trench below ground		offset, notes
DFIR location	NA			Lat, Long
DFIR power supply	NA			description
Soil plot 1st location	45.39372°,	-110.71651°		Lat, Long in degrees (center point)
Soil plot 1st location	45.39372	-110.71651		Lat, Long in deg min sec
Soil plot distance between plots (x) and from tower (y)	25 m	27 m		X, Y (meters)
Soil array pattern and vector[d]	B	180°		A, B, or C, vector, notes

Soil plot dimensions	5 m x 5 m			L x W (meters)
Soil profile pit primary	45.39158	-110.71835	> 2 m	Lat, Long, and expected depth
Soil profile pit primary	45°23'29.69”	-110°43'6.06”		
Soil profile pit alternative 1	45.391190	-110.718610	> 2 m	Lat, Long, and expected depth
Soil profile pit alternative 1	45°23'28.28”	-110°43'7.00”		Lat, Long in deg min sec
Soil profile pit alternative 2	45.390730	-110.718820	> 2 m	Lat, Long, and expected depth
Soil profile pit alternative 2	45°23'26.63”	-110°43'7.75”		Lat, Long in deg min sec
Fencing needs	Yes, around tower and possibly soil array			IH, Soil Arrays, Guy anchors
Presence of large grazing animals	Yes, cattle			description
Site management*	Grazing June to October			description
Any additional site specific information				description
Magnetic declination	12° 34' E changing by 0° 9' W/year			At time of site visit

Notes;
[a]parallel to the long side of the IH
[b]From tower point to this direction
[c]Clockwise from first angle, recommend reviewing FIU site characterization summary report
[d]From 1st plot toward other plots if pattern B, from 1st plot toward nearest neighbor (see diagram of the patterns)
[e]see Appendix A. Options for Soil Array, second figure.
[f]Tower Height is for FIU requirements; actual tower height will increase toward the next section height.
IH = instrument hut
AP = auxiliary portal
*burn information that may affect boardwalk, IH, or tower infrastructure, or other management activities