

Response to the NEON RFI
by
The Consortium for Connectivity at Continental Scales (3CS)

TITLE: Tenderfoot Creek Experimental Forest

1. Submitting Domain: **NORTHERN ROCKIES (12)**

2. RFI Response: **CORE WILDLAND SITE**

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1.0 Abstract

1.1 Name of the NEON domain. The Tenderfoot Creek Experimental Forest (TCEF) is located within the Northern Rockies domain (12), referred to as the Northern Rocky Mountain Ecological Observatory (NoRMEO) by the region's scientists, and sometimes abbreviated as NRM on NEON-related maps and tables.

1.2 Geographic coordinates (latitude/longitude) and size (acres). The approximate center of TCEF is Latitude 46° 55' N, Longitude 110° 53' W. The Experimental Forest (EF) is 9125 acres (3693 ha) in size. Maps of TCEF boundary and DEM are attached (ESRI shapefile).



Locator map:

For a larger image and additional maps go to <http://flbs.umt.edu/sitemaps/tenderfoot.aspx>

1.3 Site's characteristics that make it an ideal NEON site. TCEF is located in the Little Belt Mountains on the Lewis and Clark National Forest, approximately 90 air miles north of Bozeman, MT and 45 air miles southeast of Great Falls, MT. It contains excellent examples of lodgepole pine forests and meadow vegetation types characteristic of the continental climate in this part of the Northern Rockies. Lodgepole pine forests are the 3rd most extensive type in the Rocky Mountains (approx 15 million ac). Fire-dependent lodgepole pine communities comprise a significant component of mid- to upper-elevation forests in the Northern Rockies, providing wildlife habitat, livestock forage, water and watershed protection, recreational opportunities, wood products, and expansive viewsheds.

Administered by the US Forest Service's Rocky Mountain Research Station (RMRS), TCEF's status as an Experimental Forest ensures long-term site security, administrative continuity, and openness to collaboration and experimental manipulation. The TCEF contains the headwaters of Tenderfoot Creek, a major drainage flowing into the Smith River which in turn flows into the Missouri River, an ideal setting for aquatic research in a nested-watershed design. TCEF also includes the 1100-acre Research Natural Area (Onion Park RNA).

A legacy of active research, including manipulative experiments, has produced a number of data sets including: forest stand information, site-specific fire histories, streamflow, sediment production, water chemistry, climate, snowpack, fish population, stream geomorphology, fish habitats, wildlife (birds, small mammals, wolverine), as well as maps (forest stands, geology, soils, fuels, vegetation, watershed boundaries, contour/DEM, GPS'd locations of sampling sites), and 2005 LIDAR imagery. Current research infrastructure includes 11 electronically gauged streams, two Natural Resource Conservation Service snow telemetry (SNOTEL) sites, and two Eddy-flux towers (operated by collaborators from Montana State University). The SNOTEL sites have additional weather and climate sensors over and above the standard SNOTEL configuration.

2.0 Characteristics Relative to Domain

General information about the key characteristics of the Domain is provided in **Appendix I. Deployment Strategy: Northern Rocky Mountains Domain** (p 10), which also describes the proposed deployment strategy for NEON infrastructure that was developed by the region's scientists.

The Tenderfoot Creek Experimental Forest was designated in 1961 for hydrology and ecology research in the lodgepole pine forest type. This forest type is the fourth most extensive timber type west of the Mississippi River covering more than 15 million acres and is the third most extensive type in the Rocky Mountains of the USA. Seral, fire-dependent lodgepole pine communities comprise a significant component of mid- to upper-elevation forests in the Northern Rockies, providing wood products, wildlife habitat, livestock forage, water and watershed protection, recreational opportunities and expansive viewsheds. Many lodgepole pine stands are in late-successional stages and at high-risk to pests and catastrophic fires. These mature stands have only modest potential for biological response to silvicultural treatments. However, timber harvest is the most useful tool managers have for reducing risks, achieving non-timber objectives, and sustaining lodgepole pine ecosystems.

TCEF is highly representative of subalpine forest types comprised primarily of lodgepole pine communities. There are four forest habitat types present on the Experimental Forest: subalpine fir/grouse whortleberry; subalpine fir, blue huckleberry; subalpine fir, bluejoint; and subalpine fir whitebark pine/grouse whortleberry. Besides these four climax types, a portion of the area is dominated by the lodgepole pine/huckleberry community type. In this case, however, the community type is attributable to the subalpine fir/grouse whortleberry habitat type because of the extensive and continuous presence of fir regeneration and old growth throughout the forest. Within the Experimental Forest there are 132 mapped stands of different age classes. There are also four other general land classifications on the forest including talus slopes, rock outcrops, grassland parks, and wet meadows.

The climate in the Little Belt Mountains is continental with rare incursions of Pacific maritime climate and air masses along the Continental Divide from Marias Pass south. Average annual precipitation ranges between 380 to 510 mm (15 to 20 inches) in the drier foothill regions on the south side of the Little Belts and over 1,020 mm (40 inches) on some of the alpine ridges in the central parts of the range.

Annual precipitation on Tenderfoot Creek Experimental Forest averages 880 mm (35 inches) and ranges from 594 to 1,050 mm (23 to 41 inches) from the lowest to highest elevations. Monthly precipitation generally peaks in December or January at 100 to 125 mm (4 to 5 inches) per month and declines to a late July through October dry period of only 50 to 60 mm (2 to 4 inches) per month. Approximately 70 percent of the annual precipitation falls during November through May, usually in the form of snow. Intense summer thunderstorms are relatively rare, and most overland flow and associated soil erosion are associated with snowmelt. Runoff from the forest is estimated to average about 250 mm (9.8 inches) per year. Peak flow usually occurs in late May or early June and is generated by snowmelt or in combination with rainfall. Lowest flows

usually occur from August through winter months. Annual water yields have been estimated for the past 400+ years.

The most extensive soil groups are the loamy skeletal, mixed Typic Cryochrepts and clayey, mixed Aquic Cryoboralfs. Rock talus slopes are prominent on the perimeter of the Forest, but rock outcrops are confined chiefly to areas adjacent to main stream channels. Soils in the grassland parks range from well to poorly drained. Seeps and springs are common over the entire forest.

The geology of TCEF is characterized by igneous intrusive sills of quartz porphyry, Wolsey shales, Flathead quartzite, and granite gneiss. The northern part of the forest occupies the highest elevations and steepest upland topography and is underlain by igneous intrusive granitic rocks. The arched bedrock in the area was formed from metasediments of Cambrian Age consisting mainly of argillites and quartzites. Glaciation has influenced the landform, producing broad basins in which the streams are beginning to establish a water-carved dendritic pattern.

3.0 Ownership, Accessibility, and Use Constraints

3.1 Ownership status. TCEF is located entirely on National Forest lands (Lewis and Clark National Forest) and is administered by the United States Forest Service's Rocky Mountain Research Station whose headquarters are located in Fort Collins, Colorado.

3.2 Entity currently owning property. USDA Forest Service is the legal owner. Local administration is RMRS's Forestry Sciences Laboratory in Missoula, Montana; Ward McCaughey, a research scientist with RMRS is the manager of the Experimental Forest.

3.3 Restrictions on the use of, or access to, the site. TCEF is a typical USFS Experimental Forest in that it is open to research and educational use that does not interfere with on-going studies and fits within the management plan for the Forest. Prospective users work with the manager, Ward McCaughey to develop an acceptable research or education project/program. The variety of on-going research studies by RMRS scientists and PIs from several Universities including the University of Montana and Montana State University is evidence of the open collaboration that exists.

3.4 Existing easements. None.

3.5 Long-term (30+ years) accessibility and availability. TCEF was established in 1961 for long-term hydrologic research and RMRS plans to maintain TCEF for research, monitoring and education for at least the next 30 years. Some Experimental Forests and Ranges have been in existence for nearly 100 years. Summer access to TCEF is by gravel road (Forest Service road 839), approximately a 13-mile drive west of US 89. Winter access is by snowmobile, snowcat, or skis.

3.6 Restrictions on the feasibility of conducting experiments on the site. As their name implies, Experimental Forests such as TCEF allow manipulative experiments. All experiments and or monitoring efforts would need to be developed with and coordinated through the site manager,

Ward McCaughey and the Lewis and Clark National Forest. TCEF has been receptive to collaborative studies, and that cooperative attitude will continue.

3.7 Environmental assessment: Date and Outcome. An environmental assessment was conducted on TCEF in the late 1990's just prior to an experimental manipulation (shelterwood-with-reserve treatments) being installed in 1999 and 2000 through a collaborative research effort called the Tenderfoot Research Project (described below). Copies of this project are available from Ward McCaughey.

3.8 Environmentally sensitive site characteristics. There are no known endangered species or archaeological issues within the boundary of TCEF. A complete list of known vascular flora was recently published in Madroño (Mincemoyer, Scott A., Birdsall, Jennifer L. 2006. Vascular flora of the Tenderfoot Creek Experimental Forest, Little Belt Mountains, Montana. Madroño, 53(3) 211-222.)

3.9 Airspace restrictions. There are no known airspace restrictions.

4.0 Existing Infrastructure

4.1 Existing and/or potential housing facilities. Other than gaging stations, weather stations, and instrument shelters, there are no existing permanent facilities at TCEF. The RMRS is willing, however, to cooperate and coordinate building of any new year-round housing. An administrative site of three to five acres has been located on TCEF, but the site has not been developed. During summer months, two travel trailers, parked on National Forest land at a temporary administrative site adjacent to the TCEF boundary, provide temporary quarters for field crews. A third trailer is also located on site for equipment and storage.

4.2 Existing and/or potential laboratory facilities. As with the housing situation described above, there are no permanent laboratory facilities on the Experimental Forest. However, RMRS is willing to cooperate and collaborate in the building of laboratory, educational, meeting, and housing facilities on the designated administrative site within the Experimental Forest.

4.3 Availability of electrical, gas, or other power, and water sources for facilities and field use. Currently the only electrical power available is through use of generators and solar panels. An electrical power line is located approximately 10 miles from the Experimental Forest, and wind and water generation is certainly feasible. Currently, there are no water wells on TCEF, but water is not a limiting factor in the Little Belt Mountains and RMRS is willing to cooperate and collaborate with the installation of a well or wells.

4.4 Existing computer resources and cyberinfrastructure. All computer use is accomplished by individual scientists utilizing personal or institution specific laptop computers. Generators at the temporary administrative site are used for running computers and recharging batteries. Telemetry currently exists for data streaming from existing flux towers and other instruments. This could easily be expanded as needed.

4.4.1 Internet access. Because there are no permanent facilities on the Forest there is no direct internet access lines available. However, there is internet access via satellite and cell phone connections.

4.4.2 Data and information management policies. No specific policy is in place at this time other than we expect collaborators to willing to share data.

4.5 Road access to and within the site. TCEF is located along Forest Service road 839, 13 miles west of US highway 89. There are several main internal roads for accessing stream gages and the recent experimental treatment units. All other roads are within or on the border of three of the four boundaries of the Forest. The western boundary is accessed by trails only. Most roads within the Experimental Forest are gated and so closed to motorized vehicles except for administrative use. Roads within the EF are gravel and maintained by the Lewis and Clark National Forest.

4.6 Security measures. As described above, most roads within TCEF are closed to motorized vehicles except for administrative use only. This same travel restriction would apply to any new roads or access trails established in the future. RMRS views research site security and integrity as paramount for maintaining long-term studies, and we anticipate no change in that position. Any additional security measures would be coordinated through the RMRS and the Lewis and Clark National Forest. It is relatively easy to access the Forest by ATV, however, vandalism has not been an issue within TCEF.

5.0 Supplementary Information

5.1 Description of existing gradients at the site. TCEF is located in the west-central part of the Little Belt Mountains with an elevational gradient from 6300 to 7800 feet. It occupies a transition zone in the west-central part of the Little Belts from rolling mountain parks with rounded peaks that rise about 500 feet above the upland of the range to deeply incised canyons that drain the west slope of the Little Belts. The continental climate that prevails in this portion of the Northern Rockies means that the elevation range within the Forest provides relatively steep gradients of temperature and precipitation, particularly in relation to snowpack depth and duration. Combinations of aspect and elevation provide a range of forest and meadow habitats.

TCEF is bisected by Tenderfoot Creek, which is incised as deeply as 2400 feet. The steep inner canyon of Tenderfoot Creek opens upward onto narrow parks, which are rimmed on the north and south by rounded peaks that rise to elevations of about 7200 to 7800 feet. At the east end of the Forest, the divide of Onion Park separates drainages flowing east into Belt Creek from drainages flowing west into Tenderfoot Creek and the Smith River. Quartzite Ridge, Williams Mountain, Reynolds Mountain, and Woods Mountain on the south, and the Iron Mountain – Monument Peak ridgeline north of Tenderfoot Creek enclose the Tenderfoot Creek drainage. Thus the Experimental Forest comprises the headwaters end of a west-sloping basin that drains steeply into the Smith River, about 20 miles to the west. This geographic setting is controlled by the resistance to erosion of rock units that underlie the area and by young geologic uplift of the mountains.

Overstory vegetation ranges from Douglas-fir, lodgepole pine, subalpine fir, Engelmann spruce, and aspen in the lower elevations to whitebark pine, lodgepole pine, subalpine fir and Engelmann spruce at the upper elevations. Meadows are scattered throughout the upper elevations and scree areas are found on steep hillsides.

The geology of TCEF is simple in terms of the rock and sediment units present and the geologic structure of the area. By contrast, the geologic history records a complex series of events that has influenced both the succession of rock units and the erosion that has produced the present physiography of the area. A complete Geologic Report has been produced by Dr. Mitchell Reynolds of the USGS and is available through the Experimental Forest manager.

5.2 Site history and legacy data. The Forest was established in 1961, but prior to 1991 there had been no formal research activities at TCEF other than the collection of basic data on soils, timber inventory, and habitat typing. Not to diminish these efforts, this baseline data represents a rich legacy set of existing conditions. Hydrologic and climatic monitoring sites and equipment were installed in the early 1990s to develop pretreatment baseline information for the Tenderfoot Research Project, a manipulative experiment that tests an array of management treatments for regenerating and restoring healthy lodgepole pine forests through emulation of natural disturbance processes while avoiding catastrophic-scale disturbances. Prescribed burning for seedbed preparation and fuels reduction is a major component of this research project.

There are a number of baseline data sets for TCEF including standard forest stand information and site-specific fire-history information. Other available data and map sets include: stream flow and sediment production data from 10 flumes and 1 open-channel site; water quality from 10 flumes; snow interception data; fish population data; stream channel characterization; fish habitat surveys; maps of forest stands, geology and soils; fuels data; vegetation and biophysical data; wildlife data (birds, small mammals, wolverine); forest boundary and contour maps; digital elevation maps; GPS maps of data locations; climate variables; 1999 IKONOS imagery; and 2005 LIDAR imagery. Also available are aerial photos from several past flights including aerial obliques of the entire Forest.

5.3 Recent and ongoing research and monitoring activities relevant to NEON. TCEF is the only experimental forest in the Northern Rockies that features the lodgepole pine forest type. It was established in 1961 for watershed research in subalpine Eastside Rockies forests. Research emphasis on the Experimental Forest was expanded in 1991 to develop and evaluate ecosystem-based treatments for sustaining productivity and biodiversity of lodgepole pine forests and associated watersheds. Water-related issues are still of high concern, and through ecosystem-based management all forest resources will be considered and integrated into research planning.

The RMRS's Work Unit RWU-4151, Ecology and Management of Northern Rocky Mountain Forests, made a commitment in 1992 and installed hydrologic and climatic instrumentation for collection of baseline data prior to initiation of research activities. The Tenderfoot Research Project, initiated in the mid 1990s, took a multi-disciplinary approach to evaluating ecosystem-based treatments through a series of replicated experimental treatments. The experimental treatments were installed in 1999 and 2000 with prescribed burning in 2002. Treatment units

also serve as demonstration sites where the public can view new management alternatives and see results first-hand.

Hydrologic monitoring began in 1992 and consists of eleven stream gauging sites – ten flumes and one open-channel rated site. Each gauged site currently has an electronic recorder measuring stream discharge every 15 minutes. Water production (discharge, Q) continues to be monitored to the present and will continue well into the future. Daily sediment production from May 15 to September 30 is measured at eight of the eleven stream gage locations. This sediment monitoring began in 1994 and will continue. Dissolved nutrient samples are collected and analyzed from ten stream gage locations three times per year – once at low flow just prior to peak runoff in April, near peak runoff in early June, and a third time at low summer-base flow in late September.

Two manual weather stations were installed in the early 1990's, one at the lower elevations of the Experimental Forest and one at a higher elevation. Through a collaborative effort between the USDA Forest Service, RMRS and the USDA Natural Resources Conservation Service in 2001, these stations were converted to snow telemetry (SNOTEL) sites. Both sites are web accessible -- the low-elevation site is Stringer Creek and the high-elevation site is Onion Park.

Two eddy-flux towers were installed on the Experimental Forest in 2005, one a 110' tower overtopping a mature lodgepole pine stand and the second located nearby is a short 15' tall tower sited in a riparian meadow. The towers were installed by Dr. Brian McGlynn from Montana State University through a National Science Foundation grant. In 2006 the eddy-flux towers were incorporated into the Ameriflux program. Dr. McGlynn has two primary studies associated with the eddy-flux tower and other associated sub-studies:

1. Hydrological linkages between landscapes and streams: Transferring reach- and plot-scale understanding to network and catchment scales.
2. Watershed carbon distribution and flux across environmental gradients.

In 2005, the entire Experimental forest was flown for LIDAR producing imagery at a 1-meter resolution. This was a jointly funded effort between Montana State University, RMRS, and the USDA Forest Service's Remote Sensing Applications Center (RSAC) located in Salt Lake City.

5.4 Institutional diversity of partnership for site. Current research and monitoring partners include several National Forests (Lewis and Clark, Helena, Gallatin, Beaverhead/Deerlodge, and Bitterroot), the Natural Resources Conservation Service's Snow Survey and Water Supply Forecasting unit, the State of Montana Water Quality Department as well as the State's Department of Fish, Wildlife and Parks, and faculty and students from both Montana State University and The University of Montana. There is great potential for dramatically increasing use by faculty and students from colleges and universities around the region, and RMRS would welcome that expansion of program and collaborators.

Users within RMRS come from the RMRS Bitterroot Ecosystem Management Research Project (BEMRP), and RMRS Research Work Units: RWU-4151, Ecology and Management of Northern Rocky Mountain Forests (Missoula); RWU-4201, Wildlife Habitats (Missoula); RWU-

4403, Fire Ecology and Fuels (Missoula); RWU-4401 Fire Behavior; RWU-4302 Soil and Water Management (Boise); and RWU-4203 Enhancing Fish Habitats (Boise).

5.5 Partnerships with minority-serving institutions, overall academic community and two-year colleges. Current partnerships have not specifically included Historically Black Colleges and Universities, Hispanic Serving Institutions, Tribal Colleges or other regional minority-serving institutions or community and two-year colleges. RMRS currently works with students from the Salish Kootenai College in Western Montana, but there is no educational use of TCEF by minority-serving colleges or universities at this time. In part, the low use of the Forest for education is understandable given the distance from regional tribal colleges, or any regional colleges or universities for that matter. An overnight stay would be required for most schools. With NEON cyberinfrastructure support, however, this could rapidly change with the Forest's data being directly accessible to college classrooms anywhere. It is easy to imagine a web-based educational program that would involve the span of academic communities.

Appendix I. Deployment Strategy: Northern Rocky Mountains Domain (NRM)

NRM straddles the Continental Divide and is characterized by north-south trending mountain ranges that influence subcontinental climate patterns such that the western portion of the Domain has a warmer, wetter maritime climate with most precipitation in winter, and the eastern portion has a drier, colder continental climate with summer precipitation. Local orography modifies these patterns with gradients from warmer and drier valley bottoms to colder and wetter mountain tops. As a consequence, vegetation grades from wet temperate coniferous forests in the west to valley bottom grasslands and cold temperate montane forests to the east. Fire regimes vary in severity and frequency with these regional and local climate and vegetation patterns. The deep mountain snowpacks feed the headwaters of the three major river systems of western North America (Columbia, Missouri-Mississippi, and Colorado). The region is unique in the lower 48 states in having all native terrestrial vertebrates present. Human populations and land use are in transition from small communities focused on agriculture, timber and mining to thriving small cities and surrounding exurban sprawl. This growth is especially focused in valley bottoms and lower-elevation treeline, setting up conflicts with wildlife and natural resource management.

NEON's continental-scale questions involving climate change, land use change and invasive species are also important within this Domain. The effects of climate warming are already apparent with snowmelt and spring runoff peaking about two weeks earlier than in the 1950s, and significant fall rains coming about 10 days later. This translates into earlier growing seasons, longer periods of summer drought, and lower streamflows in a region where water is limiting. The low streamflows constrain human water access, threaten native aquatic species, and favor expansion of aquatic invasives. In terrestrial systems, changes in climate and land use such as irrigation and exurban development have altered the spatial and temporal patterning of NPP. Severe stand-replacement fires are now occurring in lower treeline forests which are adapted to frequent ground fire, threatening the high levels of native biodiversity and putting expanding exurban development at risk. The modification of NPP has also resulted in herbivores shifting their range to irrigated valley bottoms, with attendant increases in population and enhanced spread of disease. Such changes in aquatic and terrestrial ecosystems have strong potential feedbacks that could negatively affect many ecosystem and economic components. In brief, the region provides a great opportunity to understand interactions of these changes and derive ways to mitigate negative effects on ecosystems and human well being.

Given the overlap of issues and questions both within-domain and across all western domains, we propose to establish three transects from urban to wildland sites that span the maritime-to-continental gradient (Fig 1). Along each transect, sites will be selected to characterize four or five land-use types: urban, exurban, agricultural/managed, and wildland (Fig 2). The maritime-to-continental climatic gradient will be sampled continuously via permanent tower installations at the wildland sites of each transect, one of which will be the Core Wildland Site. The relocatable installations will be deployed at sites in different land-use classes, sampling three different land-use classes in the initial installation. Funds will be sought to maintain the initial wildland tower installations, with new towers added at the appropriate land-use positions along each gradient. If funds are not obtained, the relocatable towers will be repositioned at sites along transects on 2- to 3-year time periods. (Fig 3). The simultaneous deployment of the land-use

towers to different land-use classes will allow early model parameterization. As more land-use classes are sampled in successive time periods, parameterization will improve.

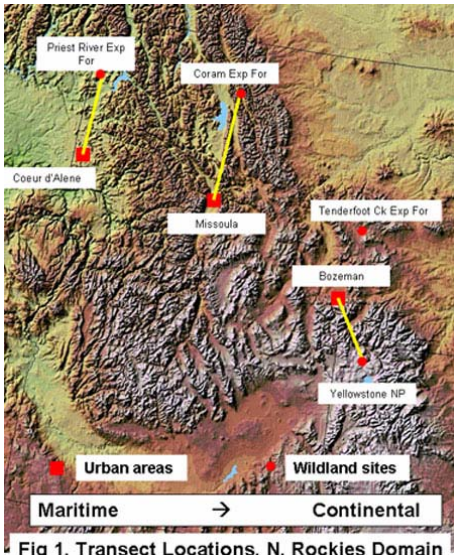


Fig 1. Transect Locations, N. Rockies Domain

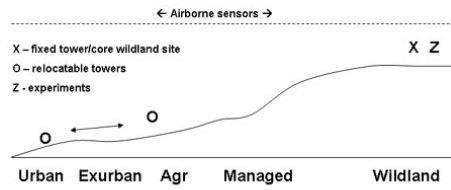


Fig 2. Urban to Wild Transect

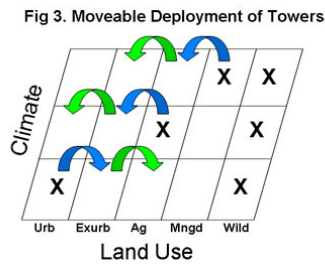


Fig 3. Moveable Deployment of Towers

Four candidate Core Wildland sites have been identified: Priest River Experimental Forest in Idaho (PREF_ID_NRM, maritime), Coram Experimental Forest near Glacier National Park (CEF_MT_NRM, maritime/continental), Tenderfoot Creek Experimental Forest (TCEF_MT_NRM, continental), and the Northern Range within Yellowstone National Park (YNR_MT_NRM, continental).