

CHAPTER 4

METADATA TYPES

Proposed metadata requirements for soil moisture data collection by the NCSMMN can be grouped into the categories of network, site, sensor, and soils information, as originally proposed by Cosh et al. (2021). Descriptions of categories of metadata types are provided below. A complete list of all metadata variables, along with recommended units, data types, and file type is given in Appendix A.

Network

A description of the network, purpose, and data usage policies will help users understand how to interpret data for different applications.

- **Affiliation:** A statement or list of organizations managing the network.
 - University, department; federal, state, or local government agency; private or non-profit organization
- **Mission and intended data application:** A statement of the motivation, purpose, and intended use of data provided by the network. Examples of purposes are: for weather monitoring, emergency management, climate forecasting, or hydrologic prediction.
- **Quality Assurance/Quality Control (QA/QC) protocols:** A statement and explanation of any quality control procedures used to flag or remove data after collection but before distribution. (See the NCSMMN [Soil Moisture Data Quality Guidance](#) document for further information.)
 - Thresholds: Upper and lower limits of data values beyond which data are considered erroneous or inaccurate.
 - Removal of erroneous data: Description of how erroneous data are treated (i.e., removed, flagged but not removed, etc.)
 - Explanation of QC flags: If QC flags are used, each flag should have an accompanying explanation and justification.
- **Installation protocol:** A description of the installation procedure for soil moisture sensors, indicating the method used (i.e., pit, auger hole, other method), depths of installation, cable management strategy, and orientation of sensors at each depth (i.e., vertical or horizontal).
- **Operations and maintenance information:** A statement of the types and frequency of regular maintenance at monitoring sites.
 - Maintenance frequency: Statement of how often a person physically visits each site.
 - Types of checks done during visits: Description of instrumentation and site checks completed, ideally in the form of a checklist used by maintenance personnel.

- **Metadata update schedule:** Statement of frequency of updates to the metadata that may change over time (e.g., seasonal photos).
- **Contact information:** Who is the Principal Investigator or Primary Contact, and who is the Technical Point of Contact for questions about the data? If a user finds a problem with the data, how should it be reported?
- **Telemetry and latency:** Statement of how data are transferred from the station (i.e., cellular data, radio, wifi, satellite), how often they are transmitted, and the latency between data transmission and posting to an accessible archive.
- **Frequency of all measurement types:** Statement of how often data are measured and whether or not measurements are averaged or manipulated prior to reporting (i.e., 15-minute data aggregated to daily mean values).

Site

A description of site conditions including classifications, textual descriptions, and photographs or images will provide users helpful context about the conditions under which data are being gathered.

- **Photos:** Photographs provide users with context for understanding site characteristics including vegetation, soil profiles, and landscape position. All photos are helpful, but photos of soil profiles and the surrounding vegetation and landscape are especially useful. Photographs are listed in the order in which they should be taken during installation. All photographs should be properly named to include dates, site name, sensor depth, and other relevant information.
 - Before installation (for sites yet to be installed)
 - **Sensor(s):** Once soil moisture sensors are installed, they will no longer be visible.
 - **Installation site:** A photo of the soil moisture sensor installation location prior to disturbance, either from the air or from the ground, to provide context and for comparison to post-disturbance vegetation characteristics.
 - During installation (for sites yet to be installed)
 - **The hole, pit, or trench in which the sensor will be installed:** Prior to sensor installation, a photo should include a measuring tape or meter stick for scale and should clearly show the full depth of the soil profile into which sensors will be installed.



Figure 2. Photo of soil profile and soil moisture sensors installed to a depth of 1.0 m. Photo Credit: Briana Wyatt.

- Installed sensor(s) and placement of cables or leads: After sensor installation, a photo should be taken showing the positions of sensors relative to the top and bottom of the pit, trench, etc., as well as relative to the other sensors, if any (Figure 2).
 - After installation
 - Vegetation cover and soil above the sensor's location: A photo showing the disturbance resulting from sensor installation.
 - Images in each cardinal direction showing site surroundings: Four photos taken from the sensor installation location showing vegetation, landscape, obstructions, etc., in each cardinal direction.
 - Aerial imagery: Image showing location of site, as well as surroundings within a given radius (Figure 3).
- Seasonally
 - Vegetation cover above the sensor's location: Photos of vegetation above the sensors may be useful to determine whether the installation disturbance caused changes in vegetative cover.
 - Changes in soil conditions: If applicable, photos of dynamic soil properties such as cracks from dry soils, erosion, deposition, or accumulating organic matter (Figure 4).
- Decommissioning (if applicable)
 - Vegetation cover: Photo of the sensor installation site prior to removing sensors as documentation of last known condition of the site.
 - Sensor/sensor damage: If any sensor prongs, heads, or cables are damaged, document with a photo.
- Daily/Live: Daily photos of a site using equipment such as a PhenoCam (Figure 5).
 - Image information: Cardinal direction and tilt angle of the camera.



Figure 3. Panoramic image of a soil moisture monitoring site showing the vegetation conditions surrounding the site. Photo Credit: Ali Azizi.

- **Station name/ID:** The unique identifier used by network to distinguish between sites
 - Full station name
 - Unique station ID: May include numbers, letters, or a combination of the two, but should be unique to a single site and contain no spaces.
- **State/County**
 - The state name
 - County name
 - [Federal Information Processing Standards](#) (FIPS) code
- **Latitude and Longitude**
 - Latitude and longitude in decimal degrees, to five decimal places (~1 m in accuracy) using the World Geodetic System 1984 (WGS84) datum. Any additional geolocation information should be consistent with this reference point and all information should be provided. For instance, any UTM coordinates should include zones and units.



Figure 4. Photos showing differences in dormant (A) and growing season (B) vegetation in an agricultural field adjacent to a soil moisture monitoring site. Photo Credit: Briana Wyatt.



Figure 5. PhenoCam imagery from July (A) and September (B) 2018 at the CAF-LTAR Boyd North National Ecological Observatory Network (NEON) site. Image Credit: [PhenoCam](#).

- **Elevation**

- Distance in meters above Mean Tide Level (MTL), formerly Mean Sea Level (MSL), as an integer value.

- **Slope, aspect, and landform (for sites with relief)**

- Aspect (degrees): Cardinal direction that a landscape primarily faces.
- Slope Gradient (percent): The steepness of the landscape slope calculated as length of rise over length of run as a ratio.
- Slope Shape: The description of the curvature of the landscape both vertically and horizontally (e.g., linear slope, convex slope, concave slope, Figure 6).
- Landscape Position: Position of site within a hillslope, if applicable (Figure 7).

- **Land use or land cover**

- Land use/land cover category from the [USGS National Landcover Database](#)
 - At site
 - Nearby (within 100 m), if different than site
- Dominant vegetation cover (if available and different than USGS classification)
- Changes in land use or land cover and approximate date of change: A description of the history of the site or recent land use is helpful to understand long-term data series. If possible, include information about prior soil disturbances, such as the presence of roadways, trails, and other soil movement.

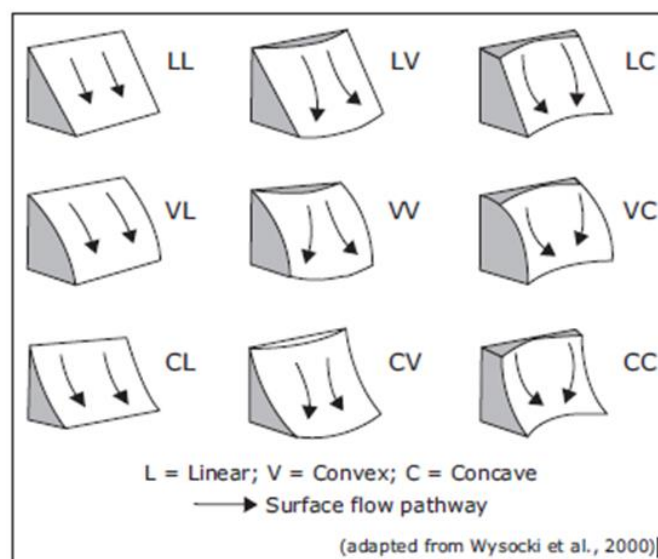


Figure 6. Diagram showing nine types of landscape shapes. Figure Credit: Wysocki et al (2000).

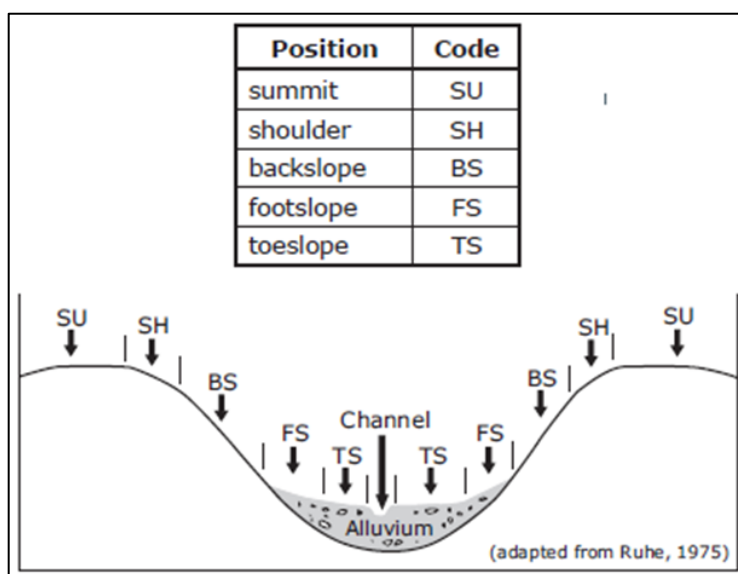


Figure 7. Diagram of landscape positions. Figure Credit: Ruhe (1975).

- **Dates**

- Installation date
- Data connectivity date: Date site was connected to cellular, satellite, or radio communications network.
- Data availability date: Date that data from the site became available for use. If a soil “healing time” is used, include that information here.
- Decommission Date

- Relocation date (if applicable): If a site is moved to a location more than 10 m from the original site, the date of the relocation should be recorded, along with new metadata information regarding site location and description. If a site is moved to a location more than 10 m away from the original site, or to a location with significantly different soil types, this should be considered as a new site and given its own unique ID.
- **Nearby obstructions and water features**
 - Type of obstruction or water feature- Description of all obstructions or water features within 100 m radius of the site (i.e., tree, building, stream, dam, etc.).
 - Height of obstructions- For each obstruction, provide an estimated height.
 - Distance from site- For each obstruction, provide an estimated distance from the monitoring location.
 - Aerial photo of site.
- **Site maintenance record:** Documentation of all maintenance performed at a given site. Records may be digital or hand-written but should be stored in perpetuity and available for reference internally, even if not publicly available.
 - Date and time of visit.
 - Name of person doing maintenance.
 - Type of maintenance done or any observations while on-site.
- **Record of sediment deposition or erosion:** If deposition or erosion is known to occur at a site, measurements should be made using an erosion pin or other method near the sensor location, taking care not to disturb or injure soil moisture sensors.
- **Ancillary soil measurements-** Additional data reported by soil moisture sensors or necessary for proper data interpretation
 - Bare soil versus vegetated: Description of soil surface and vegetation characteristics, including whether vegetation is trimmed or cut and when.
 - Soil temperature: Expressed in °C, these data may be especially important in regions where soils freeze during the winter.
 - Matric potential: Expressed in kPa.
 - Electrical conductivity: Expressed in dS m⁻¹.
- **Ancillary weather measurements**
 - List of any above-ground variables measured (i.e., precipitation, wind speed/direction, incoming solar radiation, etc.), instrument type used to collect them, and heights of measurements for each variable.

Soil Moisture Sensors

- **Depths:** Depth of installation below soil surface [cm] and estimated measurement volume being captured.
- **Location** (direction and azimuth) relative to the instrument tower.
- **Sensor model and manufacturer**
- **Sensor calibration type:** Manufacturer vs. site-specific, etc.
 - If site-specific, describe method of calibration
- **Date of sensor installation** (if different than site deployment date)
- **Raw data types and associated units**

Soils and Soil Samples

Samples should be collected at each sensor depth at the time of installation, even if there is no budget or plan for future analyses.

- **[NRCS Soil Survey Geographic Database \(SSURGO\)](#) map unit key**
 - Note if consistent or not with observed soil type/texture.
- **Profile or pedon description**
 - Based on [USDA-NRCS classification system](#)/nomenclature.
 - Photo of profile or soil core with depth reference (meter stick or tape).
- **Texture:** Sand, silt, clay
 - Sand, silt, clay percentages at each sensor depth
 - Method used to determine percentages (hydrometer, pipette, other)
 - Fraction of coarse fragments (i.e., rocks) by volume
 - Textural class (USDA-NRCS system)
- **Bulk density:** Mass of dry soil per unit volume
 - Measured bulk density at each sensor depth.
 - Method used for estimating bulk density (core method, clod, other).
- **Mineralogy**
 - Major and minor components of the minerals in the soil and/or parent material derived at each sensor depth.
- **Soil water retention**
 - Water retention at -10 kPa (optional), -33 kPa, and -1500 kPa at each depth.

- Intact or disturbed samples.
- Additional water retention points, if available.
- Method used to measure water retention (Tempe cells, pressure chambers, Hyprop, dewpoint potentiometer, other).
- Water content at saturation (θ_s) - calculated using saturated and dried mass of soil sample, or estimated using the measured bulk density and assuming saturation water content is equal to porosity.
- **Saturated hydraulic conductivity (K_s)**
 - Method used to estimate K_s .
- **Aggregate stability**
 - Method of determining aggregate stability (wet, dry, other).
- **Organic matter layer**
 - Depth to mineral soil
 - Percent (%) area covered surrounding site
 - Type of vegetation litter: evergreen vs. deciduous.
 - Relative amount of decomposition: fresh, intact material verse unrecognizable litter (e.g., peat).
 - Hydrophobicity: description of whether soil is hydrophobic and method used to determine hydrophobicity.
 - Changes over time: Description of losses or accumulations of organic matter during monitoring period.