CHAPTER 2

PLANNING A LONG-TERM SOIL MOISTURE MONITORING NETWORK

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Learning Outcomes

Collection of metadata prior to network establishment has the capacity to affect the quality of long-term SWC monitoring and should be considered during the planning stage.

Resource allocation for long-term site and data maintenance should be a part of network planning and/or new site establishment.

Soil moisture data can be collected either across a long time period (long-term) or temporarily over discrete periods. In this document, temporary data are defined as data designed to be collected over short time periods to support answers to very specific management or basic hydrologic research questions. The collection of such datasets is supported by pre-determined and guaranteed availability of resources. Data collected over the long term but marked by discrete periods of collection are also considered temporary. Such datasets are not considered in this document.

Long-term monitoring networks considered in this document differ from temporary and/or discrete data collection in three main ways. First, long-term networks often serve multiple stakeholders. Secondly, they are designed to produce consistent and continuous data over long periods (>10 years), continually, and at high temporal frequency (e.g., 15 minutes, hourly, etc.). Finally, resources supporting the network are often inconsistent and may become available all at once or in phases. More often than not, networks' resources come with a lot of uncertainty. Hence, a sound planning exercise at the time of installation can help fulfil immediate stakeholder needs and allocate resources in a manner that allows room for planned growth if resources should become available in the future.

The factors described in the following sections of this chapter should be incorporated into network planning. These recommendations were identified based on a survey of existing long-term monitoring networks (Table 1).

INVOLVEMENT OF LOCAL SOIL EXPERTS

Soil experts are best involved prior to planning sensor installation at any site. Soil Water Content (SWC) is often reported in different units based on stakeholder needs (Chapter 3), and several of these units require ancillary information that must be collected at the time of installation. A quality soil moisture dataset also requires field-based information, which is best collected by a soil expert at the time of sensor installation. Experts may include soils staff at a local National Resources Conservation Service (NRCS) office, university, or private company. Network operators can also reach out to the NCSMMN at soilmoisture@noaa.org or the American Association of State Climatologists (AASC)'s mesonet community as a contact point (https://stateclimate.org/) for recommendations. In addition to a soil expert, it is useful to reach out to other nearby, existing long-term networks for other ancillary information in the region. The specific soil-based ancillary information that should be collected at the site is described in the Metadata Guidance document.

Table 1. List of networks that responded to the survey

	Participating networks	Contact names	State
1	Alabama Mesonet	Lee Ellenburg	Alabama
2	Delaware Environmental Observing System	Kevin Brinson	Delaware
3	Florida Automated Weather Network (FAWN)	William Lusher	Florida
4	University of Georgia	Pam Knox	Georgia
5	Hawaii Mesonet	Thomas Giambelluca	Hawaii
6	Purdue Mesonet	Beth Hall	Indiana
7	Kansas Mesonet	Chip Redmond	Kansas
8	Manitoba Agricultural Weather Network	Timi Ojo	Manitoba, Canada
9	Michigan State University Enviroweather	Keith Mason	Michigan
10	Automated Weather Data Network	Jamie Lahowetz	Nebraska
11	Rutgers New Jersey Weather Network	Dave Robinson	New Jersey
12	NC ECONet	Sean Heuser	North Carolina
13	North Dakota Agricultural Weather Network	James Hyde	North Dakota
14	Oklahoma Mesonet	Ethan Becker	Oklahoma
15	National Ecological Observatory Network (NEON)	Edward Ayres	National network, U.S.
16	Atmospheric Radiation Measurement (ARM) user facility	Jenni Kyrouac	National network, U.S.
17	U.S. Climate Reference Network (USCRN)	Ronald Leeper	National network, U.S.

Note: The above list was compiled based on a survey of existing long-term monitoring networks. Information was collected using a *Google Form* that was sent out to mesonet operators in the American Association of State Climatologists (AASC) network and the soil moisture working group.

SITE SELECTION TO ENSURE DATA LONGEVITY

Station longevity is critical for many applications of soil moisture data, given that stakeholder needs often require long-term time series analysis. Hence while sites should be regionally and locally representative, choosing a site that is expected to be available for long-term installation is advised. The longevity of quality soil moisture data from a site differs from other typical weather-based measurements that are collected at long-term monitoring sites because soil moisture sensors are harder to re-orient or move post-installation. This includes avoiding having the site move even as little as a few meters, since it will entail uninstalling the soil moisture sensor. Such movement could also significantly alter the moisture dynamics that are recorded by the sensor, and any field-based calibration exercise and collection of ancillary data for the site will need to be repeated for the new location. Moving sensors can also limit the use of that site for long-term comparisons. Factors that may cause a site to move include changes in ownership of land, management activities, etc. For example, operational challenges like vehicular movement in agricultural lands or operational difficulties associated with burning a forested site could require a site to be moved. Public versus private lands may have different permitting requirements. For example, if public lands are used, compliance with Section 106 of the National Historic Preservation Act of 1966 (NHPA) is required.

SENSOR SELECTION

Sensor selection should primarily be driven by performance in specific soils (Mane et al., 2024). However, a network operator may also need to consider the availability of future resources, since some sensors may have more maintenance and post-validation requirements than others. Additionally, while it is also possible that different sites within a network can be served by different types of sensors depending on the soil, using the same sensors across all stations is preferable for maintaining consistency over the long term. Such a case may arise when soils across a network span a wide range of bulk electrical conductivity values, and certain soils require more expensive sensing technology, while others can be serviced by cheaper sensing technology (Chapter 5). In such a case, a network operator would need to plan for either (1) using different sensors at different sites, which may be problematic in the long run for operation and maintenance; or (2) managing resources to purchase standardized sensors for all locations, which may end up being considerably more expensive. Network operators will need to make executive decisions based on their specific funding availability. Standardization is helpful in scenarios where future funding is limited, especially for trained personnel. It is highly recommended to reach out to the soils department of the state's land-grant universities, other regional networks collecting soil moisture data, or other mesonets to solicit guidance regarding the choice of sensors. The NCSMMN community can also provide this type of guidance.

DOCUMENTATION OF INSTALLATION PROTOCOLS

Resources must be invested in carefully documenting protocols followed at the time of installation. This is important since personnel changes can cause loss of information that may not be easily reclaimed at a later point without significant investment of additional resources. Since each site is different and sensors are installed in the subsurface, documentation of protocols must be done independently for each site. Proper documentation also enables transparency for stakeholders. Standardized protocols as developed by NEON (https://data.neonscience.org/data-products/DP1.00094.001) and Oklahoma Mesonet (McPherson et al., 2007) are good examples.

AUTOMATION OF NETWORKS AND DATA STORAGE NEEDS

Resources allocated for automation of sites can also help mitigate issues pertaining to uncertain future funding. Automation includes data telemetry and automated quality control protocols developed by experts. Resources must either be allocated for maintaining servers of information, which require dedicated and trained personnel, or developing partnerships with existing data management companies. There are several private companies that offer these services. However, it should be noted that either of these choices comes with its own set of associated costs.

PLANNING RESOURCES FOR ANCILLARY DATA

To ensure high-quality soil moisture data, long-term measurements should be accompanied by relevant atmospheric and biophysical measurements. These measurements are useful for implementing several quality control and quality assurance practices (Chapter 7). At a minimum, atmospheric data should include rainfall measurements. Further, depending on resources available, air temperature, relative humidity, and additional datasets that help measure the water budget in greater detail can be added. In terms of biophysical datasets, soil temperature data are essential and must be collected for quality control practices. Other recommended biophysical measurements are detailed in the Metadata Guidance document.