Data Map for Wells and Springs Visited during the Lincoln–Sanders Counties Ground Water Characterization Study

Camela A. Carstarphen, Sara C. Edinberg, James P. Madison, and Alan R. English

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Author's Note: This map is one in a series of maps for the Lincoln–Sanders Counties groundwater characterization study area. It is intended to stand alone and includes where data were collected, the types of data, and aquifer descriptions. Additional maps released will allow an integrated view of the hydrogeology of the study area. These maps will be available to view and download at the Ground Water Characterization page of the MBMG website. An interactive web map for this work can be viewed at our GIS data hub site: https://gis-data-hub-mbmg.hub.arcgis.com/.

INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG) Ground Water Characterization Program visited 667 sites, including groundwater (590 water wells, 23 springs, 1 mine adit), surface water (31 streams, 16 lakes, and 2 canals), and precipitation (4). This work was completed between 2018 and 2024 as part of the Lincoln and Sanders Counties groundwater characterization study (figs. 1, 2, appendix A). The study area does not include the part of Sanders County within the Flathead Reservation (fig. 2). This map and associated appendices show the locations of visited sites and present the data collected.

Visited wells were chosen from more than 13,000 wells recorded in the Ground Water Information Center (GWIC) database for Lincoln and Sanders Counties. Visited sites were selected to obtain representative data from all aquifers. A total of 28 wells and 1 surface-water site (Crystal Lake) were instrumented with pressure transducers to record hourly water-level readings to understand seasonal groundwater fluctuations and connection to surface water. Eleven MBMG statewide monitoring network wells are also located in the study area and provided long-term water-level data (appendix B).

GEOLOGIC UNITS AND AQUIFERS

The study area consists of intermontane valleys filled with unconsolidated sediments of alluvial and glacial origin. The valleys are surrounded and underlain by faulted and folded Precambrian Belt Supergroup (Mesoproterozoic) bedrock. In places, the Precambrian rocks are intruded by dikes and sills of Mesoproterozoic age, and mafic laccoliths and plutons of Cretaceous and Tertiary age. Ground Water Information Center geologic codes were assigned to each well and spring (table 1) by comparing well completion and lithologic information to published geologic maps (Breckenridge and others, 2012; Burmester and others, 2012a,b,c; Coffin and others, 1971; Harrison and others, 1986, 1992; Johns, 1970; Lonn and others, 2007; Lewis and others, 2012; Sears, 1991). The GWIC geologic code (e.g. 400WLCC, e.g. 112OTSH, table 1) refers to the geologic age (e.g., 400 is Mesoproterozoic, 112 is Pleistocene) and either the depositional environment (e.g., OTSH is outwash) or the formal geologic member, formation, or group name (e.g., WLLC is Wallace Formation). A complete list of geologic codes can be found on the GWIC website (https://mbmggwic.mtech.edu).

The study area geologic units were combined into hydrogeologic units (aquifers), and grouped into either basin-fill or fractured-bedrock aquifers; aquifer descriptions are presented in table 1. Most visited wells and springs are completed in or sourced from the basin-fill aquifers (446, 73%) and a lesser amount in fractured-bedrock aquifers (165, 27 %). Three sites do not have geologic or hydrogeologic codes and are not included in table 1.

SITE VISITS

Visited sites were selected to provide baseline data for the basin-fill and fractured-bedrock aquifers. Coordinates for each site were determined using a navigation-grade global positioning system or web-based digital map. Site elevations were derived from 1-m lidar coverage for both counties. Township, range, section, and tract information were derived from 1:24,000-scale topographic maps. Where possible, field data collected included static-water level, pumping-water level, discharge, and water-quality field parameters (temperature, pH, specific conductance, dissolved oxygen, reduction-oxidation potential). The water-quality field parameters represent stabilized readings attained after an average 30-min pumping duration. Samples (n = 226) were collected from selected wells (n = 212), springs (n = 13), and surface water (n = 1) after field parameters stabilized and/or three well volumes of water were discharged (table 1). Samples were analyzed at the MBMG analytical lab for major ions, trace elements, nitrate, and stable water isotopes. Some wells could not be pumped or accessed to measure water-quality field parameters or water levels. Site field data and sampling status are included in appendix A; complete analytical results, including stable water isotopes (^{2}H and ^{18}O), are available from the GWIC database (https://mbmggwic.mtech.edu/). Some sites were sampled for stable water isotope analysis only (65 wells, 2 springs, 28 surface water, 2 precipitation, and 2 snowpack). Ninety-one samples (89 sites, including two precipitation sites and one surface water,Crystal Lake) were analyzed for tritium (radioactive isotope of hydrogen) by the University of Waterloo Environmental Lab (appendix A). Precipitation was collected in Plains, Montana between November 2019 and October 2023 (n = 32) as monthly composites; 4 samples were analyzed for tritium (May and October, 2020). Six precipitation samples were collected in Libby, Montana (April 2019–October 2019) as monthly composites and two samples were analyzed for tritium (June 2019 and October 2019; Carstarphen and Timmer, 2024; Carstarphen and Li, 2024). Two high-elevation snowpack samples were analyzed for stable water isotopes (Turner Mountain, May 2019; Chicago Peak, March 2023).

A special focus study area (fig. 3) located in and around Eureka, Montana, resulted in a potentiometric map (Madison and Blythe, 2019). Additional sampling in 2024 focused on strontium and carbon isotopes and rare-earth elements at 10 sites (8 wells, 1 spring, 1 adit; appendix A). Eight of the ten sites had dissolved inorganic carbon isotope analysis (MBMG Analytical Lab), and strontium isotope analysis ($^{87}Sr/^{86}Sr$, University of Waterloo Environmental Isotope Lab). Nine of these sites were analyzed for rare-earth elements by West Virginia University Institute for Sustainability and Energy Research Analytical Lab (these data are not available currently through GWIC and will be presented in future study area publications).

DATA AND DATA SOURCES

All data and water-quality analysis results are available from the GWIC database (https://mbmggwic.mtech.edu). Land ownership, hydrography, public land survey, lidar, and road data were obtained from the Natural Resource Information System, Helena (https://nris.msl.mt.gov/). All latitude and longitude data are NAD83; map display is NAD83 Montana State Plane.

ACKNOWLEDGMENTS

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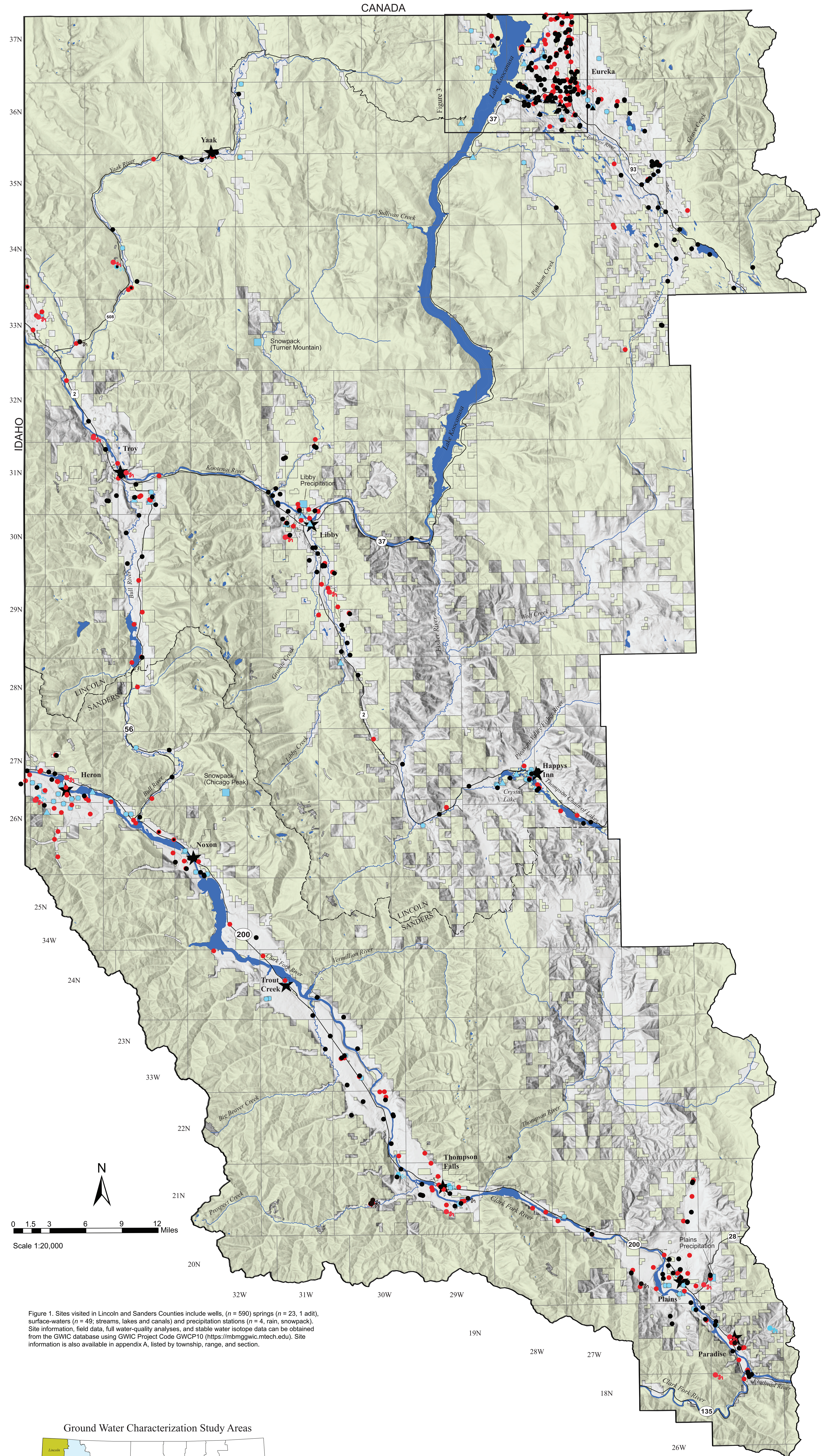

Figure 1. Sites visited in Lincoln and Sanders Counties include wells, (n = 590) springs (n = 23, 1 adit), surface-waters (n = 49; streams, lakes and canals) and precipitation stations (n = 4, rain, snowpack). Site information, field data, full water-quality analyses, and stable water isotope data can be obtained from the GWIC database using GWIC Project Code GWCP10 (https://mbmggwic.mtech.edu). Site information is also available in appendix A, listed by township, range, and section.

Table 1. Site visits and samples by geologic completion (GWIC Geologic Code) and hydrogeologic unit (aquifers) with aquifer descriptions.

	Era	Period/Age	GWIC Geologic Code	Hydro-geologic Unit	Number of Wells and Springs Visited	Number Sampled	Aquifer Description
Basin-Fill	CENOZOIC	Quaternary	111ALVM	Qal	35	11	**Modern alluvial aquifers** Surficial, unconfined alluvial aquifers. These unconsolidated deposits of sand, gravel, and boulders are present along modern-day rivers and streams. Along the Lower Clark Fork River, these deposits maybe submerged by reservoirs.
			112ALVM, 110ALVM, 112OTSH, 112DRFT	Qalo Qg	411	146	**Pleistocene shallow and deep aquifers** Glacial deposits: glaciofluvial alluvium and outwash (Qalo) consist of thick deposits of coarse sand, gravel, and boulders; may also include Pleistocene alluvium (pre-lake and flood deposits) preserved at depth. Till, lacustrine clays, and delta lake deposits (Qg), consist of poorly sorted clays and silts interbedded with discontinuous gravel and cobbles. Glacial Lake Missoula, Kootenai, Troy, and Fisher lacustrine deposits, composed of laminated silt and clay, may act as a confining or semi-confining unit where continuous in the subsurface.
		2.58 Ma Tertiary *66 Ma*					*Presence in study area is limited*
Bedrock	MESOZOIC	Cretaceous	211PLNC	TKig	1	1	**Igneous fractured-rock aquifers** The Cretaceous igneous rocks are a hornblende–biotite granite, quartz monzonite, and granodiorite that occur as stocks and small unmapped dikes in and near the Cabinet Mountains (e.g. Dry Creek stock east of Bull Lake). Some of these stocks and sills may be younger (Tertiary). Characterized by fracture permeability.
		Jurassic Triassic					*No rocks of this age are mapped in the study area*
	PALEOZOIC	Permian Pennsylvanian Mississippian Devonian Ordovician Cambrian					*Very limited presence in study area; only small outcrops of Devonian and Cambrian*
		1000 Ma					
	PROTEROZOIC	Meso-proterozoic *1600 Ma*	400BELT 400MSSL,400WLLC, 400RVLL,400PRCD 400LBBY, 400STRP, 400SIYH-	pCfb	164	67	**Precambrian fractured-rock aquifers** Metasedimentary sandstones, shales, and carbonate rocks, typically exposed at the surface along valley margins and present at depth (beneath glacial deposits and alluvium) in valley bottoms. These units are faulted and folded. Groundwater is present where the rock is sufficiently fractured. The older Prichard Formation has numerous mafic sills and dikes of the same age. These units are coded specifically to formation where possible in the geologic code but otherwise grouped as 400BELT. They are all treated as a single hydrogeologic unit, pCfb.

Note. Two wells, one spring, and one sampled surface-water site were not assigned geologic codes.

Eureka Special Focus Area

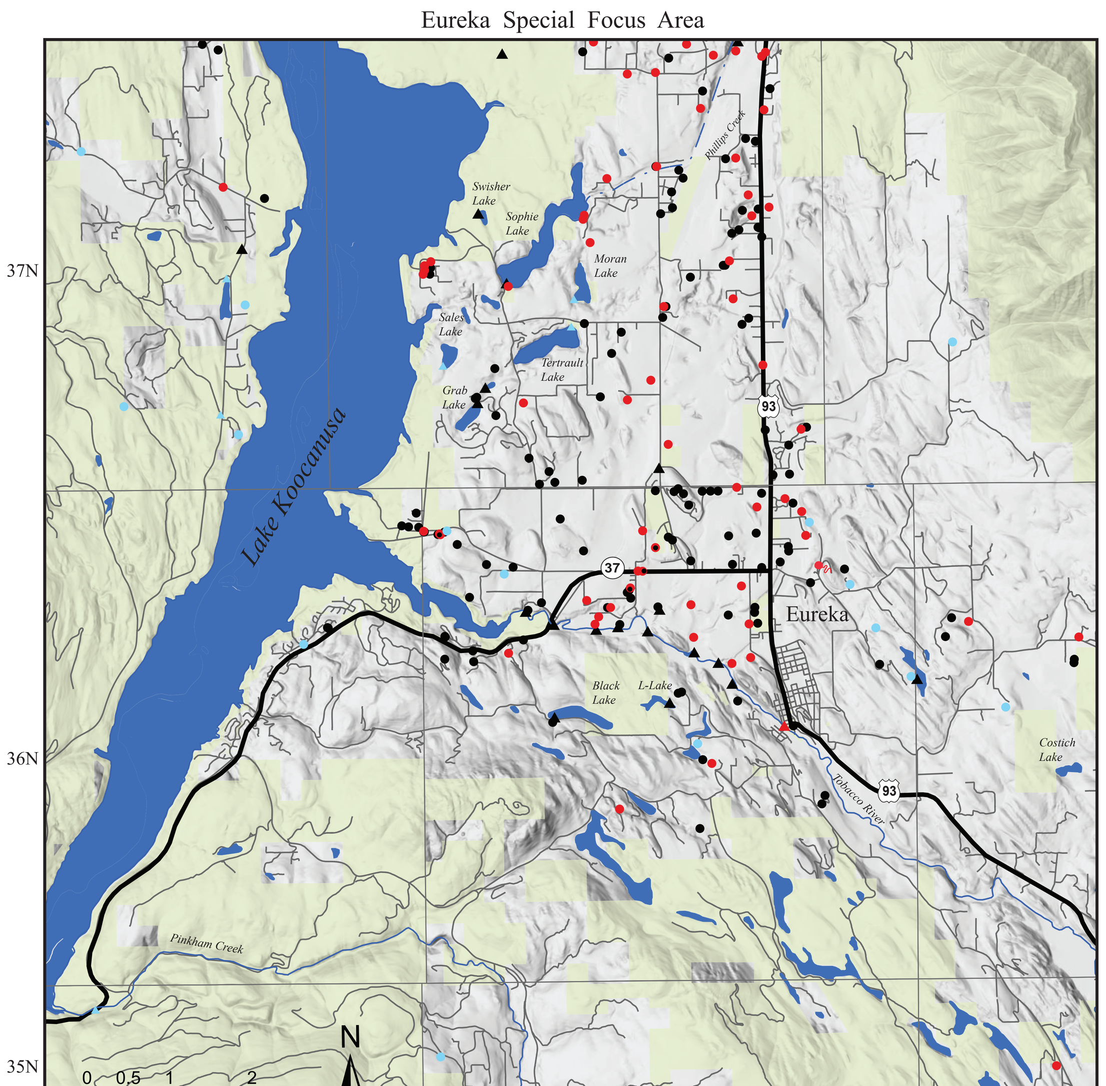

Figure 3. Sites visited in the Eureka special focus area; data were published in 2019 (Madison and Blythe, 2019).

Ground Water Characterization Study Areas

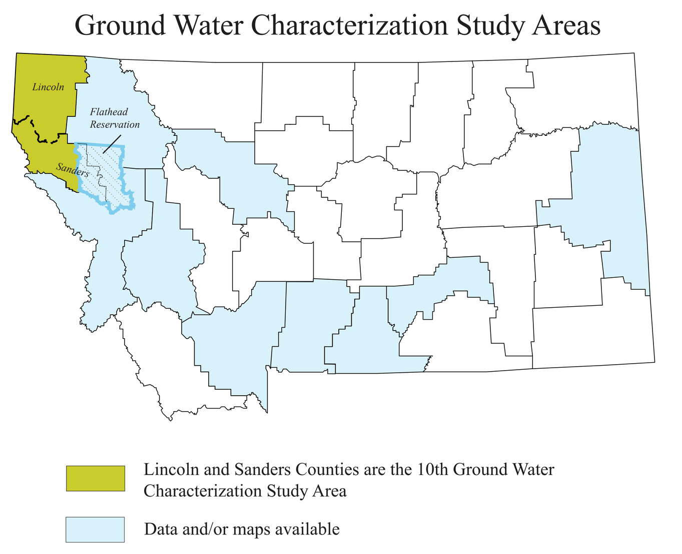

Figure 2. The study area, shown in green, includes Lincoln and Sanders Counties (not including Flathead Reservation).

Legend

Site-type symbol
- Well
- Spring
- Surface water (stream, lake, canal)
- Precipitation station (monthly collection, snowpack)

Hydrography
- Stream (intermittent is dashed)
- Lake
- Primary roads
- 135 Montana road
- 2 U.S. Route
- Secondary roads

Visit-type color
- Field data only
- Water quality sample (major ion,trace metals, nitrate, stable-water isotopes)
- Stable water isotope sample only
- Water-quality sites included in 2024 additional sample effort (rare earth elements, inorganic carbon isotopes, sulfate isotopes, and/or strontium isotopes)
- Towns
- Township Boundary
- County Boundary
- Federal Land

Basemap layers are from the Montana State Library (https://msl.mt.gov/geoinfo/data/msdi)
Projection: NAD 1983 StatePlane Montana*
Vertical Datum: 1988 North American Vertical Datum
Horizontal Datum: NAD 1983 North American Datum
*Map has been rotated to align North to top of map page (4.84°)

Shaded relief from 10-meter digital elevation model from U.S. Geological Survey National Elevation Dataset, available from the Montana State Library: https://msl.mt.gov/geoinfo/data/flathead_basin_mapping_project_-_2009/lidar_data/

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Maps may be obtained from:
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Montana Bureau of Mines and Geology
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Butte, Montana 59701-8997
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