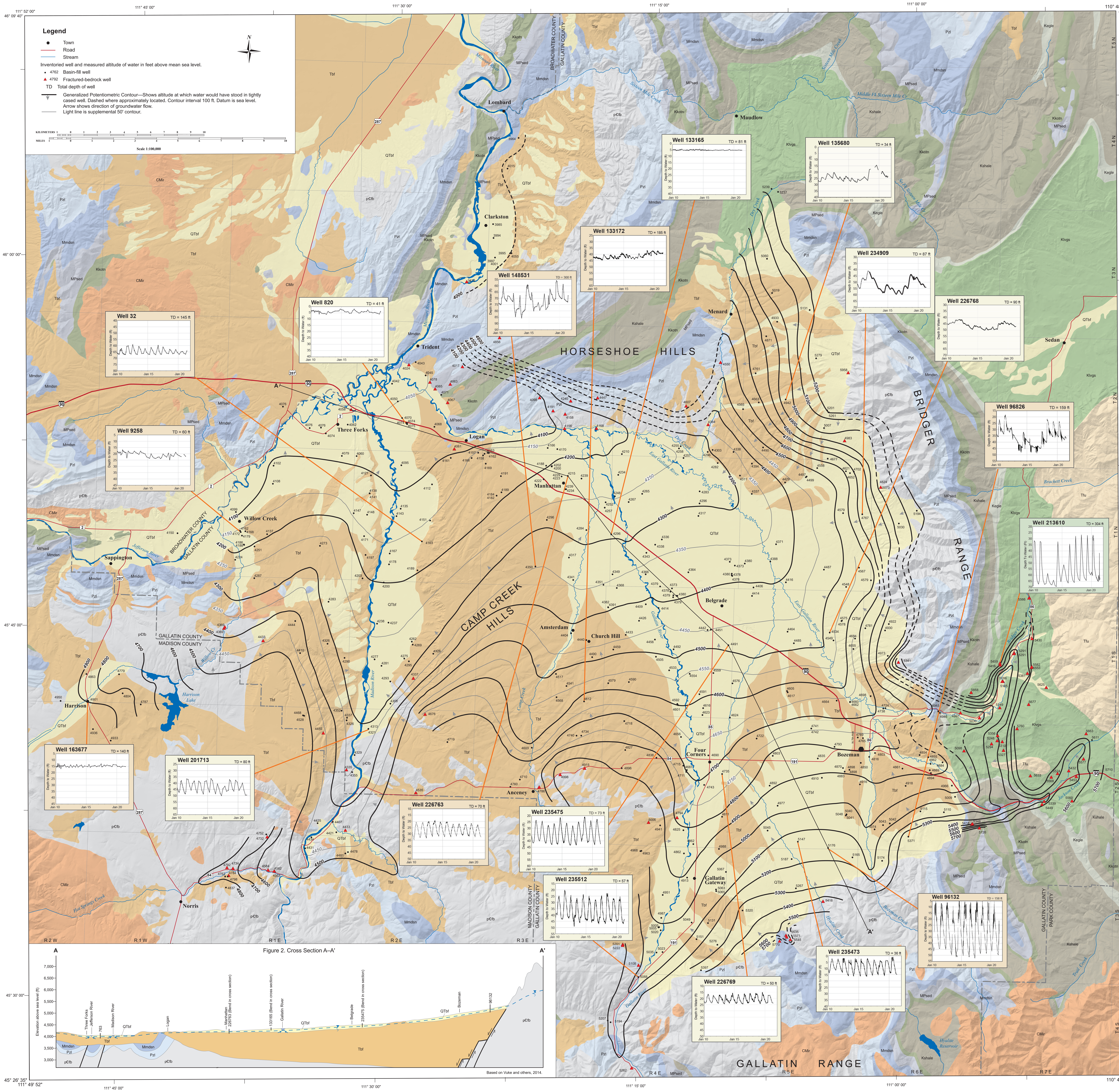

Potentiometric Surface in Gallatin, Lower Madison, Lower Jefferson, and Upper Missouri River Valleys within Parts of Madison and Gallatin Counties, Montana

James P. Madison
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Author's Note: This map is part of the Montana Bureau of Mines and Geology Groundwater Assessment Atlas for the Gallatin–Madison Area groundwater characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Gallatin–Madison Area, the reader is referred to the other maps of Montana Groundwater Assessment Atlas 8 (http://mbmggwic.mtech.edu).

This map represents the potentiometric surface for the unconsolidated basin-fill and fractured-bedrock aquifer system in the Gallatin, lower Madison, lower Jefferson, and upper Missouri river valleys within Madison and Gallatin Counties (fig. 1). In the map area, wells are completed mostly within the surficial unconsolidated alluvial and Tertiary basin-fill deposits or in fractured bedrock on the valley margins (fig. 2). On a basin scale, the basin-fill aquifer and surrounding bedrock typically function as a single hydrogeologic unit.

A potentiometric surface represents the altitude to which water levels rise in wells completed in an aquifer; it is useful for determining the general direction of groundwater flow and estimating depth to water at a given location. In unconfined conditions, the potentiometric surface is generally a subdued representation of the regional topography; the highest groundwater altitudes coincide with the regional topographic highs and the lowest altitudes with the regional topographic lows. Lateral groundwater movement will be in a direction perpendicular to potentiometric contours from higher to lower altitudes, as indicated by the flow arrows on this map. Across the map area, groundwater generally flows away from mountainous recharge areas and the valley margins (regional topographic highs) towards and parallel to the major surface drainages (regional topographic lows). The potentiometric surface altitude at a site may be subtracted from the land-surface altitude at that location to yield the approximate depth to water.

Groundwater levels fluctuate in response to natural and anthropogenic causes such as wet or dry climate anomalies, groundwater withdrawals, and land use. The fluctuations occur at seasonal, annual, or multi-year frequencies and provide insights on groundwater recharge and stresses acting on aquifers. Long-term (10+ year) hydrographs for 19 wells are included on the map to show representative groundwater-level fluctuations. Across the map area, groundwater levels fluctuate annually between 1 and 45 ft. The hydrographs show two main patterns of seasonal fluctuation that reflect different sources of recharge: (1) a natural pattern that reflects seasonal and interannual climate variability, and (2) an "irrigation" pattern that reflects recharge from leaky irrigation canals and over-applied irrigation water. Although the seasonal water-level fluctuations vary with respect to timing and magnitude, Michalek and Sutherland (2020) determined that long-term hydrographs from this region do not show declining trends.

Hydrographs that show a natural (unirrigated) recharge pattern reflect water levels generally rising in spring and early summer due to infiltration of snowmelt and increased precipitation. These water levels decline during the late summer and fall, reaching seasonal lows in the winter months (hydrograph 213610). Changes in climate such as droughts or wet periods manifest as multi-year water-level declines or increases. Well hydrograph 234909 shows a declining trend from 2012–2015, increasing from 2016–2019, and decreasing from 2020–present. A similar response is observed in other wells east of the East Gallatin River, which is also located outside the area of intense irrigation practices.

On the hydrographs that show an irrigation pattern (e.g., 201713, 226769, or 235473), water levels rise sharply at the beginning of the irrigation season, in late spring. Water levels remain elevated (a blunt peak or plateau) during the summer months while irrigation is ongoing, and sharply decline when irrigation water is "turned off." Water level decline persists until the next irrigation period begins in the spring of the following year. The irrigation response is observed in wells 226763, 235475, 226769, 235473, and 96132 between Jackson Creek/East Gallatin River and the Camp Creek Hills. In this area, a 2,000-mi network of irrigation canals and laterals distribute water to about 5,350 acres (Michalek and Sutherland, 2020). The timing and magnitude of water-level fluctuation is consistent from year to year because irrigation practices that affect groundwater recharge have not significantly changed in the past 30 years. As demonstrated by Michalek and Sutherland (2020), some land has been taken out of production and flood irrigation has been replaced by wheel lines and center pivots. Although such changes may cause decreased groundwater recharge, these hydrographs demonstrate that water levels have not changed appreciably over the past decade.

This potentiometric surface map builds upon and expands the potentiometric maps of Hackett and others (1960) and Slagle (1995).The map is based on about 500 measured water levels gathered during site visits between January 2008 and December 2012 (Carstarphen and others, 2015).[1] Water levels were measured over a 4-year period across multiple seasons. Both of these factors can introduce variations in water levels and introduce error into the potentiometric contour configuration. Long-term well hydrographs for wells completed in the basin-fill and surrounding bedrock do not show water-level trends that would change the configuration of the potentiometric contours; these hydrographs show seasonal water-level fluctuations of 15 ft or less. Relative to the scale of this potentiometric map and the contour intervals, use of water levels measured across a 4-year period and during different seasons does not introduce noticeable error in interpretation.

This potentiometric surface map is a general interpretation of regional conditions and groundwater flow directions. Readers interested in site-specific interpretations should reevaluate the data with an appropriate contour interval.

This map and an ArcGIS Map Package with contours and point data are available at the Montana Bureau of Mines and Geology's publication website, http://www.mbmg.mtech.edu/mbmgcat/catmain.asp.

[1]Water-level measurements and other site information are available from the Montana Bureau of Mines and Geology's Ground Water Information Center (GWIC) database, http://mbmggwic.mtech.edu.

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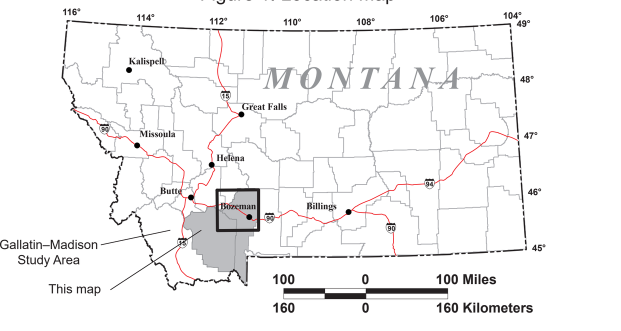
Hydrogeologic Framework

	Regional Aquifers[1]		Regional Confining Units[2]
Unconsolidated to weakly consolidated basin-fill. Lenticular beds of clay, silt, sand, gravel.	QTbf	Cenezoic Basin-Fill/Alluvial Aquifer	
	Tbf	Tertiary Basin-Fill	
Cretaceous sandstone beds within Kootenai, Eagle, and Fort Union Formations. Primary porosity and permeability in combination with secondary permeability along fractures.	Tfu	Tertiary Fort Union Aquifer	
			Kshale Bearpaw Fm
	Kegle	Cretaceous Eagle Aquifer	
	Klvgs	Cretaceous Livingston Group	
			Kshale Claggett Fm
	Kkotn	Cretaceous Kootenai Aquifer	
			Kshale Colorado Group
Fractured bedrock with mostly secondary porosity and permeability along fractures and/or solution cavities.	CMir	Cenezoic and Mesozoic Igneous Rocks	
	MPsed	Mesozoic–Paleozoic Sedimentary Rocks	
	Mmdsn	Mississipppian Madison Group Aquifer	
	Pzl	Lower Paleozoic Sedimentary Rocks	
	p€fb	Precambrian Fractured Igneous, Metasedimentary, and Metamorphic Rocks	

Modified after Crowley and others, 2017.
[1]Aquifer where saturated with water.
[2]Locally may yield water to wells from sandstone.

Figure 1. Location Map



Shaded relief created from 10 m digital elevation model of the U.S. Geological Survey National Elevation Dataset.
Projection: Montana State Plane FIPS 2500 International feet.
Datum: North American Datum of 1983 (NAD83).