Wisconsin Geological and Natural History Survey
DIVISION OF EXTENSION
UNIVERSITY OF WISCONSIN–MADISON

Supplemental report on Wisconsin bedrock topography, 100-meter resolution

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Matthew J. Rehwald, J. Elmo Rawling III

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Contents

Abstract

The elevation of the bedrock surface in Wisconsin is an important metric for decision makers around the state. Here, data and interpretations from a variety of sources were compiled to model the statewide, three-dimensional bedrock surface using modern GIS tools. Areas of shallow bedrock were delineated first, then merged with deeper water well and borehole bedrock data to generate an initial bedrock surface. This initial surface was then regenerated using the bedrock data, plus wells and boreholes that did not reach bedrock but had bottoms deeper than the initial modeled surface. Finally, the resulting surface was compared to the topographic ground surface and lowered to ground level in areas where the modeled bedrock surface was above ground. Confidence in the quality of the final modeled surface is high in areas of shallow bedrock and dense data coverage, but lower in areas of deeper bedrock with sparse observed or interpreted data. This digital representation of the bedrock surface should be considered a first estimate of the statewide bedrock surface; no effort was made to interpret the surface beyond the data cited within this report. Further modification of this estimate of bedrock elevation in Wisconsin will require additional detailed studies.

Introduction

Bedrock elevation and sediment thickness maps and datasets address many societal and scientific problems including Quaternary and bedrock geology mapping, groundwater susceptibility, mineral and aggregate resource management, engineering, agronomy, and forestry (Hart and others, 2021). In Wisconsin, multiple factors have motivated the creation of a new, digital map of statewide bedrock elevation. Primarily, modern GIS-based software allows for the transparent compilation of data from multiple sources using a repeatable, quantitative interpolation method. Importantly, this approach would allow new data to be incorporated in the future. An additional motivation is that existing maps of statewide bedrock topography are generalized and missing key data sources. This report summarizes the data sources and methods used to generate a statewide 100 x 100-meter square pixel raster of bedrock topography for Wisconsin.

Previous work

Previous efforts to estimate the elevation of the bedrock surface in Wisconsin have been conducted at various scales. The U.S. Geological Survey (USGS) compiled a regional (1:5,000,000-scale) bedrock elevation and depth-to-bedrock map that includes Wisconsin (Soller and Garrity, 2018). The most recent depth-to-bedrock map of Wisconsin was compiled by Trotta and Cotter (1973). This map was published at the 1:1,000,000-scale, but the data used to generate it are undocumented. Many finer-scale studies conducted by the WGNHS have included both estimates of bedrock elevation and depth to bedrock and are used in this compilation (see Data sources section). Hart and others (2021) summarize methods used to make depth to bedrock maps in Wisconsin.

Data sources

Shallow bedrock datasets: ≤4 ft (1.2 m)

A dataset representing shallow bedrock was compiled from a combination of point and polygon data from geologic map data (fig. 1) in the U.S. Geological Survey Geologic Map Schema (GeMS) (U.S. Geological Survey National Cooperative Geologic Mapping Program, 2020) and Soil Survey Geographic (SSURGO) data (fig. 2) mapped by the U.S. Natural Resources Conservation Service (NRCS) (Soil Survey Staff, 2022). The dataset was collectively called shallow bedrock because its components all had a maximum depth to bedrock of 4 ft. Depth to bedrock was set to 0 to 3 ft for map units that are described as having shallow bedrock throughout their extents (Clayton, 1984, 1986a, 1987, 1989; Johnson, 1986, 2000; Clayton and others, 1990; Clayton and Attig, 1997; Evans, 2003; Syverson, 2007; Hooyer and others, 2021; Mode and others, 2021). Depth to bedrock was set to 0 to 4 ft for mapped areas of shallow bedrock (LeBerge and Myers, 1983; Clayton, 1986b). Depth to bedrock was set to 0 ft for outcrop locations (LeBerge and Myers, 1983; Greenberg and Brown, 1984; Mickelson, 1986; Mudrey and others, 1987; Simpkins and others, 1987; Attig and Ham, 1999). The Greenberg and Brown (1984) "bedrock indication from boulders, loose blocks, and stone piles" points were not used because adjacent well data indicated depth to bedrock of 50 ft or deeper. Those points appear to represent loose boulders and likely do not represent near-surface bedrock. Depth to bedrock was set to 2 ft for unpublished WGNHS data of polygons representing areas of shallow bedrock in Columbia County (E.D. Stewart and S. Mauel, WGNHS, unpub. data, 2024). Depth to bedrock was set to 0 ft for SSURGO map unit points with a feature type of 'ROC' (rock outcrop). Depth-to-bedrock values were directly used for SSURGO map unit polygons where a minimum bedrock depth was indicated. Depth to bedrock was set to 2 ft for SSURGO map unit polygons with a slope steeper than 11%. Steep soil map units in valley bottoms were manually reviewed and excluded where they were discontinuous from other shallow bedrock data, and their descriptions indicated they were of alluvial origin.

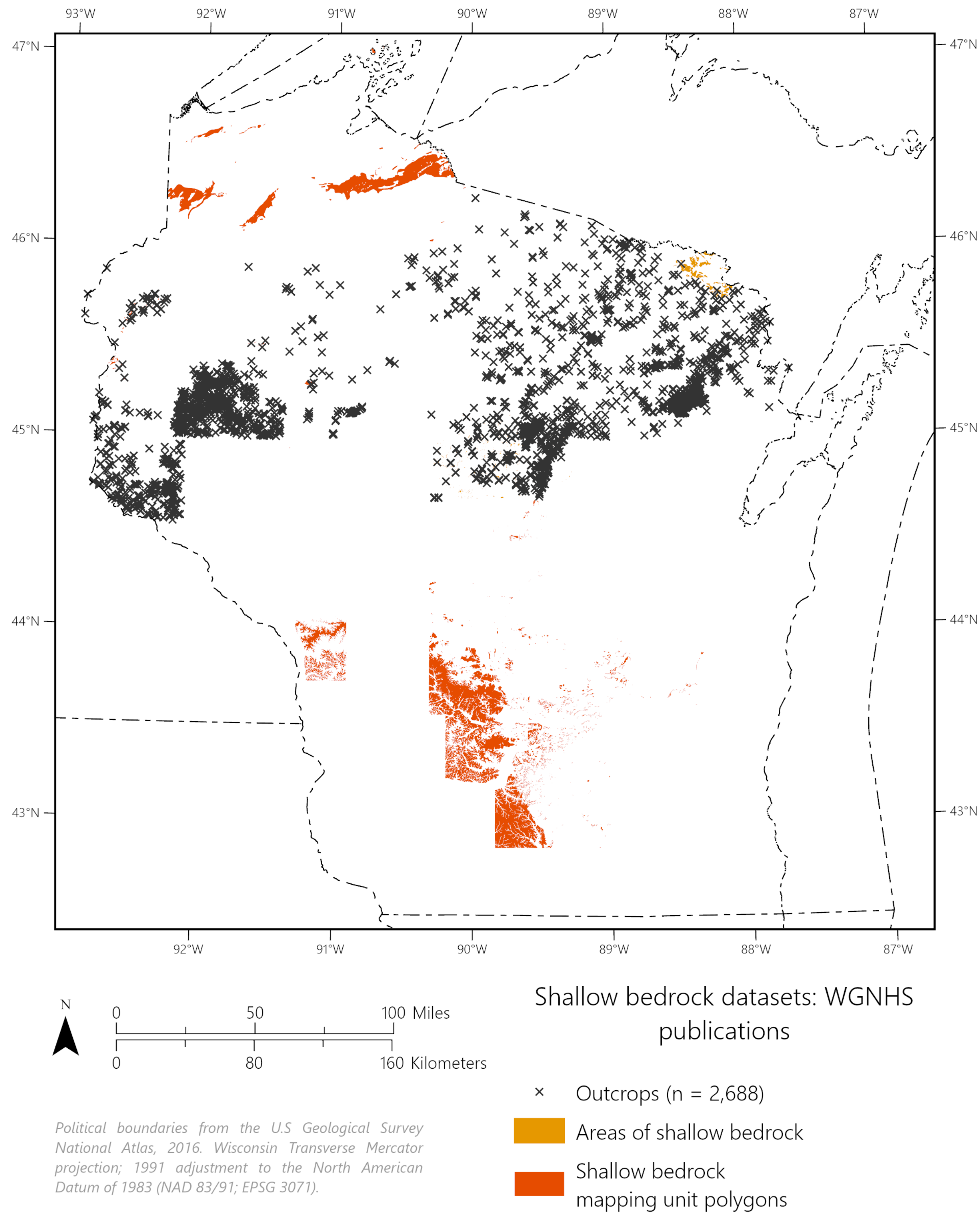

Figure 1. *Polygon datasets from previous mapping efforts indicating areas of shallow bedrock (≤ 4 ft), and points representing outcrops (see text for references).*

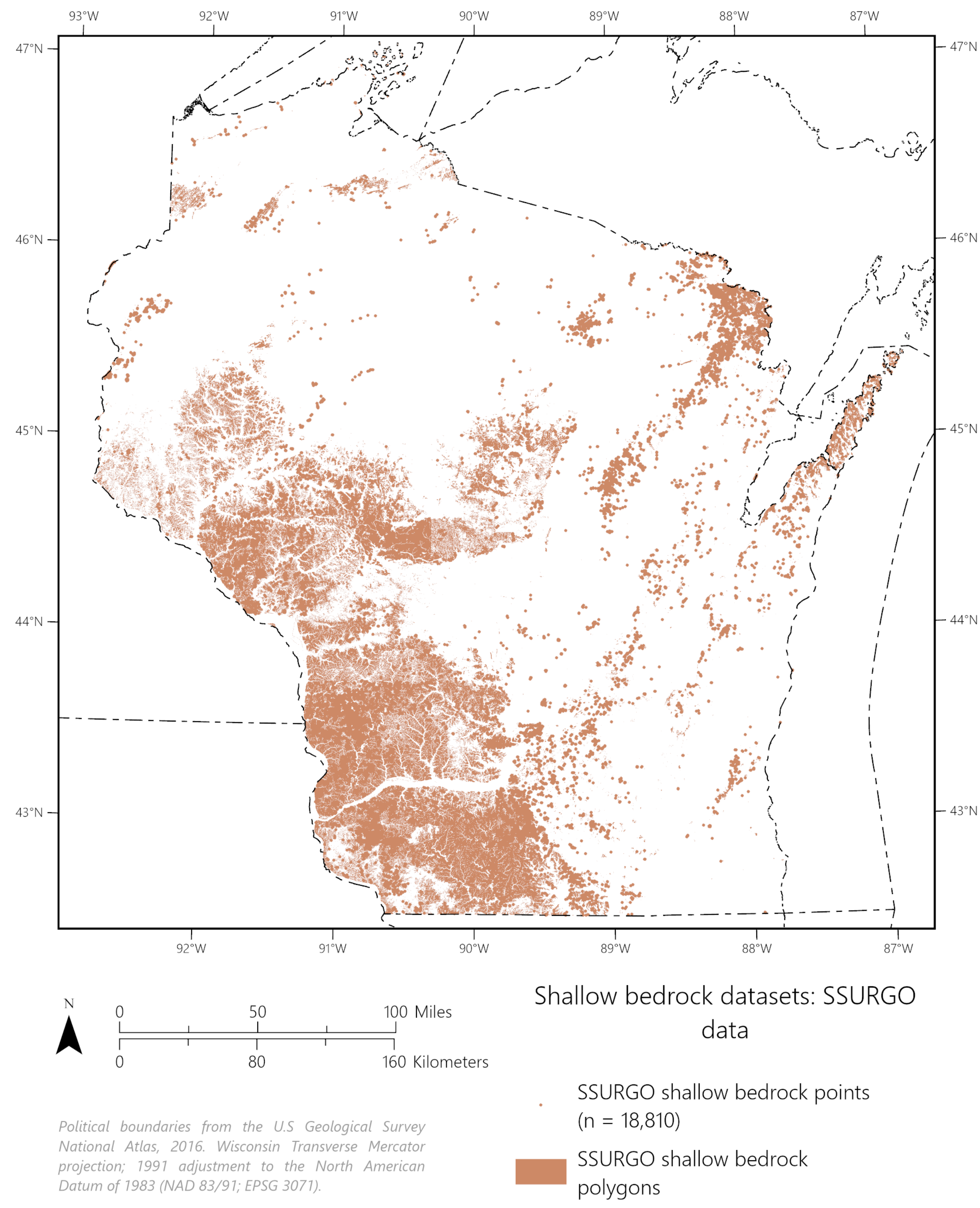

Figure 2. *Distribution of SSURGO polygons and points (Soil Survey Staff, 2022) representing shallow bedrock (≤ 4 ft).*

Deep bedrock datasets: >4 ft (1.2 m)

Bedrock depths greater than 4 ft (fig. 3) were inferred from three sources: the Wisconsin Department of Natural Resources well construction report (WCR) database (Wisconsin Department of Natural Resources, 2021), the WGNHS 'Geobase' WCR database (unpub. data, 2024), and the Minnesota Geological Survey depth to bedrock digital raster data (Minnesota Geological Survey, 2021). Records of reconstructed wells indicating artificially deep depth to bedrock and erroneous well records showing 0 ft depth to bedrock were excluded from the WGNHS data. In addition, wells with obviously different depths to bedrock compared to the surrounding neighborhood were manually checked and iteratively removed if determined not to be representative of true bedrock depth. Wells from WGNHS's internal WCR database without an identified depth to bedrock, i.e., that only intersected unconsolidated material, were used to constrain the bedrock elevation. Those well bottom depths were used as a minimum potential depth to bedrock.

Previous bedrock-elevation and depth-to-bedrock interpretations

Previously published and unpublished interpretations of bedrock elevation and depth to bedrock were incorporated to provide additional detail (fig. 4). These interpretations included the judgement of geologists, and no attempt was made to assess the original data used for these interpretations. Published sources include bedrock elevation rasters (Olcott, 1972; Evans and others, 2004; Stewart, 2024), bedrock elevation contours (Batten, 2018; Bell and Hindall, 1975; Bradbury and others, 2018a, 2018b; Fehling and others 2018a, 2018b; Gotkowitz and Zeiler, 2002; Graham and others, 2019; Johnson, 2000; Lippelt, 1988; McLaughlin, 2013; Stewart, 2021), and depth-to-bedrock contours (Johnson, 1993, 1994; Brown, 1991). Unpublished sources include bedrock elevation rasters of Manitowoc County (WGNHS, unpub. data, 2016), Green Lake County (WGNHS, unpub. data, 2017), Columbia County (WGNHS, unpub. data, 2018), and valleys in the greater La Crosse region (WGNHS, unpub. data, 2003); bedrock elevation contours of Douglas County (Stewart, E.K., WGNHS, unpub. data, 2022), Wood County (U.S. Geological Survey, unpub. data, ca. 1990), Outagamie County (WGNHS, unpub. data, 2005), Winnebago County (WGNHS, unpub. data, 2005), and the Chippewa sand mines region (WGNHS, unpub. data, 2019); and depth-to-bedrock contours of Calumet County (WGNHS, unpub. data, 2003).

Bedrock valley contours from the Trotta and Cotter (1973) map were considered for inclusion but were ultimately rejected due to their generalization. Because the Trotta and Cotter map was drawn at 1:1,000,000 scale, its linework differs substantially from the finer-scale depth-to-bedrock and bedrock elevation interpretations listed above. Figure 5 illustrates differences between the Trotta and Cotter depth-to-bedrock contours and contours in the lower Chippewa River valley from a 1:100,000-scale depth-to-bedrock interpretation (Johnson, 1994). In this example, the 100-ft depth-to-bedrock contour from Johnson crosses over both the 100-ft and 200-ft Trotta and Cotter depth-to-bedrock contours, rendering the Trotta and Cotter contours unsuitable as a data source in the absence of substantial manual editing.

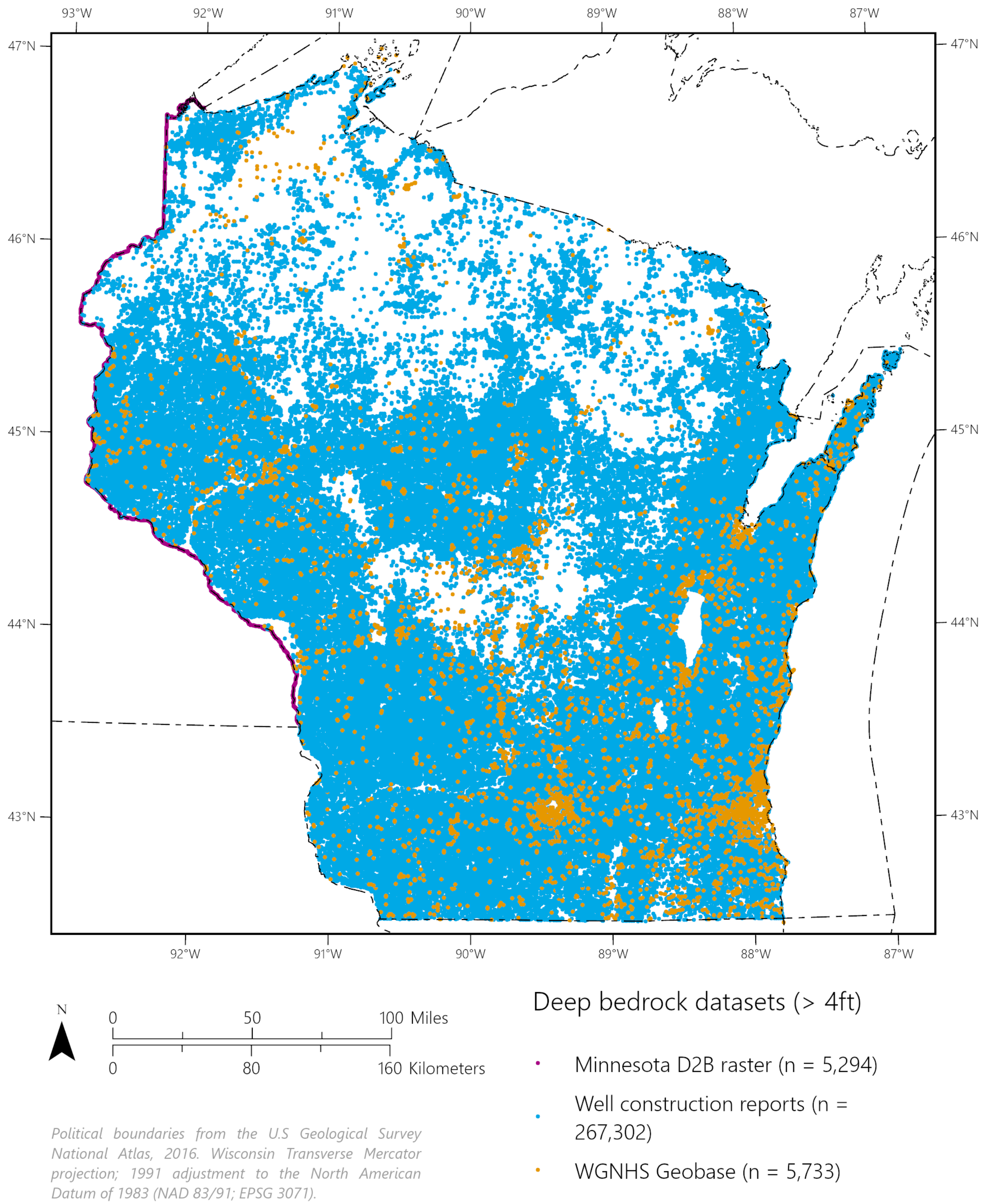

Figure 3. *Datasets for bedrock depths greater than 4 ft: Well construction reports (blue), Geobase wells and boreholes (orange), Minnesota depth-to-bedrock points (purple).*

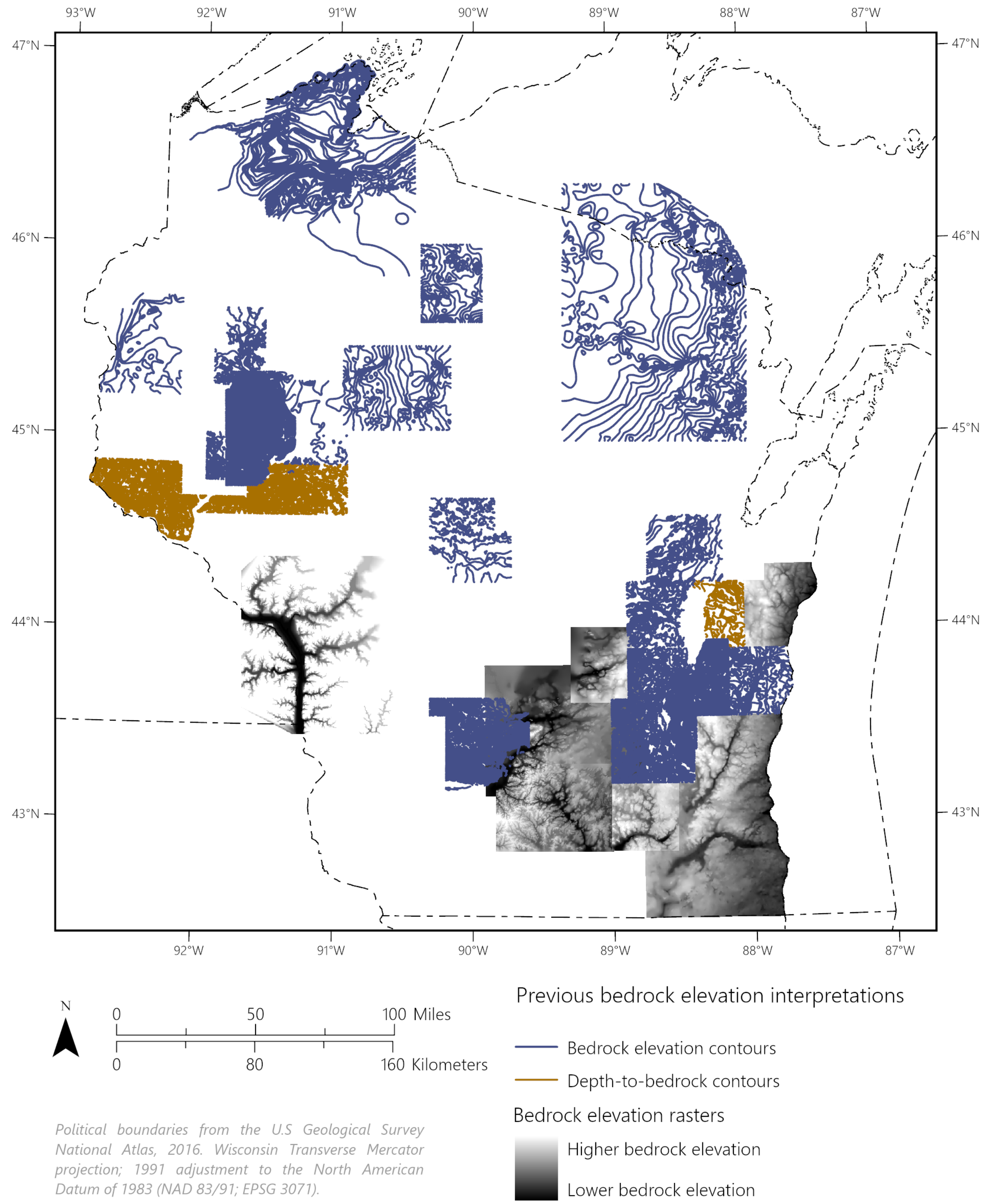

Figure 4. *Previous interpretations of bedrock topography and depth to bedrock.*

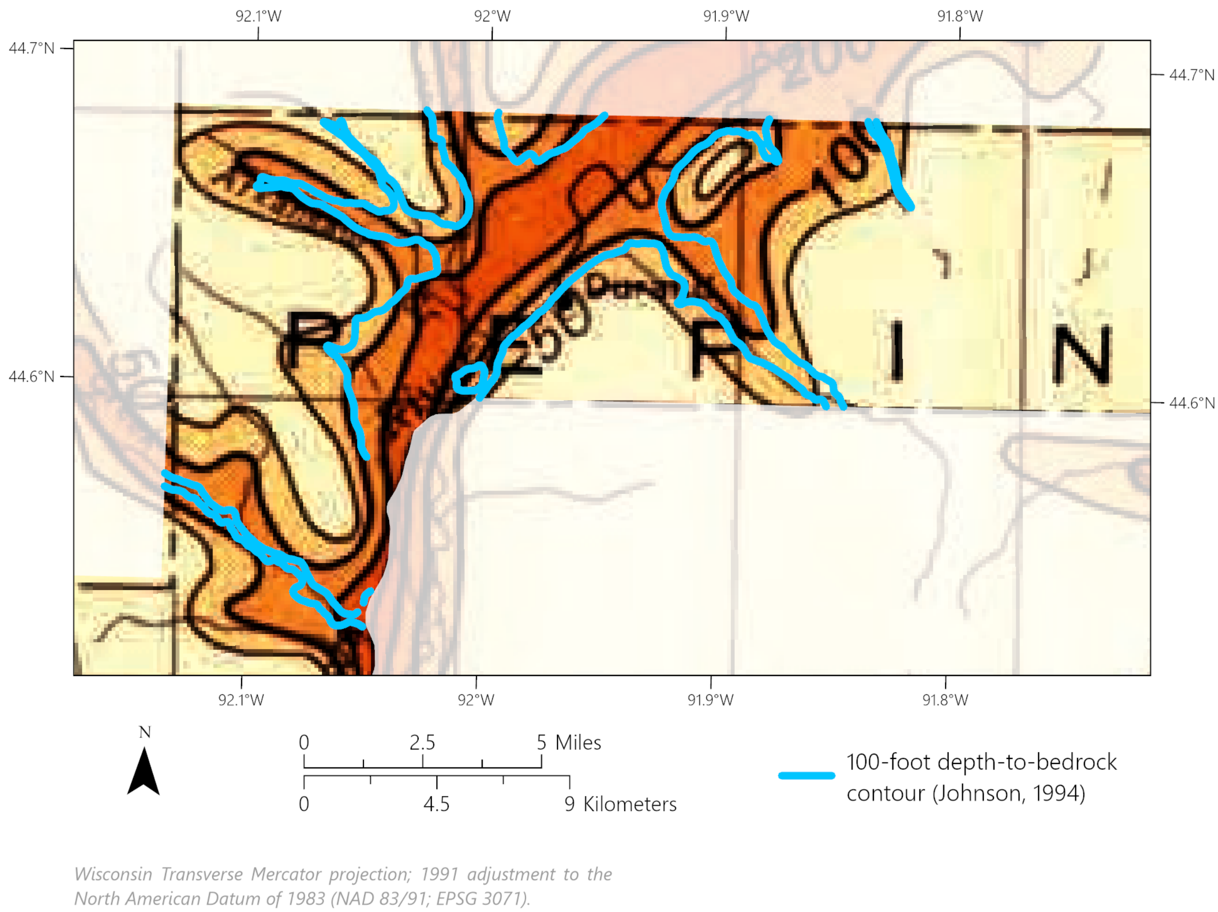

Figure 5. *Comparison of Trotta and Cotter (1973) depth-to-bedrock contours with Johnson (1994) 100-foot depth-to-bedrock contour (blue lines) in the lower Chippewa River valley of Pepin County, Wisconsin. The Trotta and Cotter contours were drawn at 1:1,000,000 scale and are masked in this figure to the footprint of Pepin County. The Johnson contours were drawn at 1:100,000 scale.*

Methods

Statewide 100 x 100-meter bedrock topography rasters have been generated recently for both Massachusetts (Mabee and others, 2023) and Pennsylvania (Giuseppe, 2024). The 100 x 100-meter resolution could be considered unnecessarily coarse in areas with dense data coverage but represents a balance that can be applied statewide across Wisconsin between those areas with dense data coverage and areas with very sparse data. This resolution of data also keeps file sizes manageable and can be easily harmonized with similar data from other states for future compilations.

Data preparation for this study followed the approach used in Massachusetts by Mabee and others (2023) by first defining a 100 x 100-meter raster to represent the ground surface, as well as providing a framework to which other datasets would be aligned. The USGS National Elevation Dataset (NED; U.S. Geological Survey 3D Elevation Program, 2017) was used as a topographic ground surface for this project due to its statewide coverage and 10-meter resolution. The NED raster was resampled to 100-meter resolution using the average elevation of each 10 x 10-meter square pixel subgrid as the output elevation value (fig. 6). The 100 x 100-meter output was used as the framework for all successive raster processing outputs. The average elevation was derived by generating 100 x 100-meter square vector polygons for raster pixels and then calculating zonal mean from the original NED 10-meter raster using each square polygon as a zone.

Additional point, polygon, raster, and contour data depicting shallow bedrock (≤ 4 ft), deeper bedrock (> 4 ft), and previous bedrock elevation and depth-to-bedrock interpretations were aligned with the surface elevation raster. Points were used without any pre-processing. Polygons were converted to points (fig. 7), first by intersecting them with the 100 x 100-meter polygon grid and then converting the resulting gridded polygons to points at their centroids, with the source dataset and depth-to-bedrock value as attributes. The resulting point datasets were aggregated into a consolidated bedrock data points feature class. Bedrock elevations were extracted from the NED 10-meter DEM by subtracting depth to bedrock from ground surface for each point.

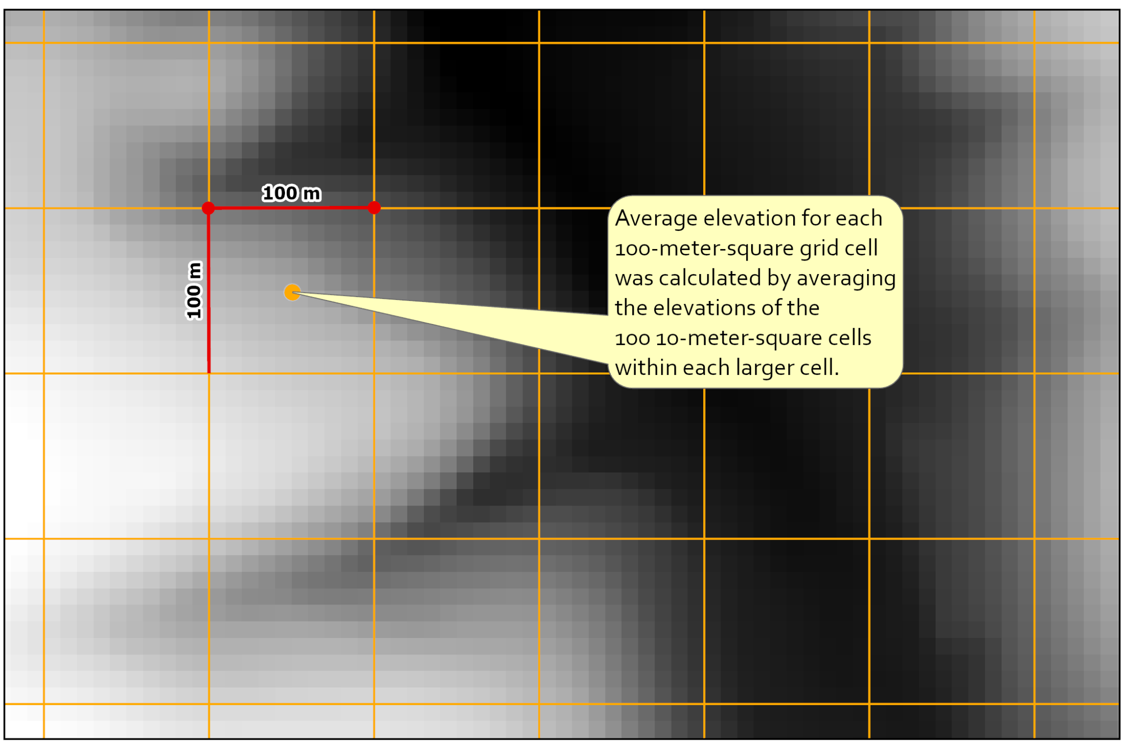

Figure 6. *Schematic detail of a 10-meter digital elevation model (black to white pixels show lower to higher elevation, respectively) fitted with a 100-meter grid (orange lines). Average elevation was calculated for the centroid of each 100-meter pixel.*

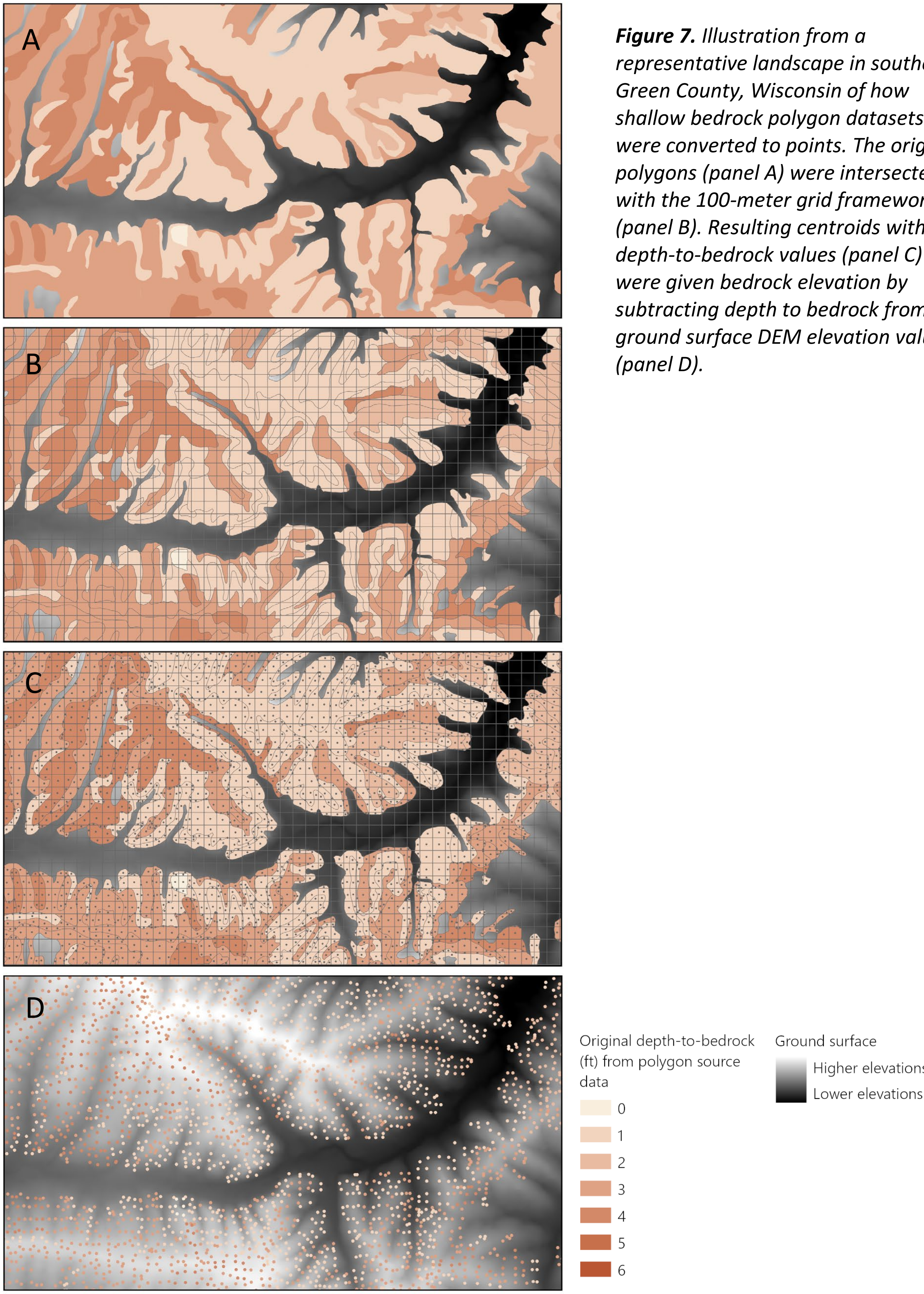

Figure 7. *Illustration from a representative landscape in southern Green County, Wisconsin of how shallow bedrock polygon datasets were converted to points. The original polygons (panel A) were intersected with the 100-meter grid framework (panel B). Resulting centroids with depth-to-bedrock values (panel C) were given bedrock elevation by subtracting depth to bedrock from ground surface DEM elevation values (panel D).*

Raster datasets were resampled to the 100-meter ground surface framework. Rasters were converted to points with 1 point per 100-meter pixel with a bedrock elevation value. An exception was the raster of bedrock elevation in valleys of the greater La Crosse region (WGNHS, unpub. data, 2003) that has 400-meter resolution. This raster was converted directly to points at the center of each pixel. Depth-to-bedrock contours were decomposed to points at each contour line vertex. Bedrock elevation for the points was extracted from NED 10-meter DEM by subtracting depth to bedrock from ground surface. Contours were generally used as-is but edited/edge-matched at adjoining dataset areas where they overlapped and/or disagreed with each other. Nearby bedrock point data were used in cases where contours of different values crossed each other. Barron County contours mis-labeled near the Blue Hills in the northeast corner of the county were corrected (Bell and Hindall, 1975).

The Topo to Raster tool in ArcGIS Pro (ESRI, 2025) was used to generate a continuous bedrock elevation surface because it accepts both point and polyline data inputs. Topo to Raster was run with the consolidated bedrock elevation points dataset, points generated from the bedrock elevation rasters, elevation points generated from the depth-to-bedrock contours, and the combined bedrock elevation contours to generate a raster of bedrock elevation. Default Topo to Raster settings were used, except the discretization error factor was changed from its default of 1 to 0.1, which creates sharper breaks in slopes in areas of steep topography and reduces smoothing of the continuous surface.

The preliminary modeled bedrock elevation surface was compared to wells that did not reach bedrock. Wells with a bottom elevation lower than the preliminary modeled bedrock elevation were selected (fig. 8). The Topo to Raster tool was rerun using the bedrock elevation points and contours, plus the selected well bottom elevations, using the same parameters as above. This second modeled bedrock elevation was compared to the 100-meter raster of ground surface elevation (fig. 9). Where the modeled bedrock surface was above ground surface, cell elevations were replaced with ground surface elevations.

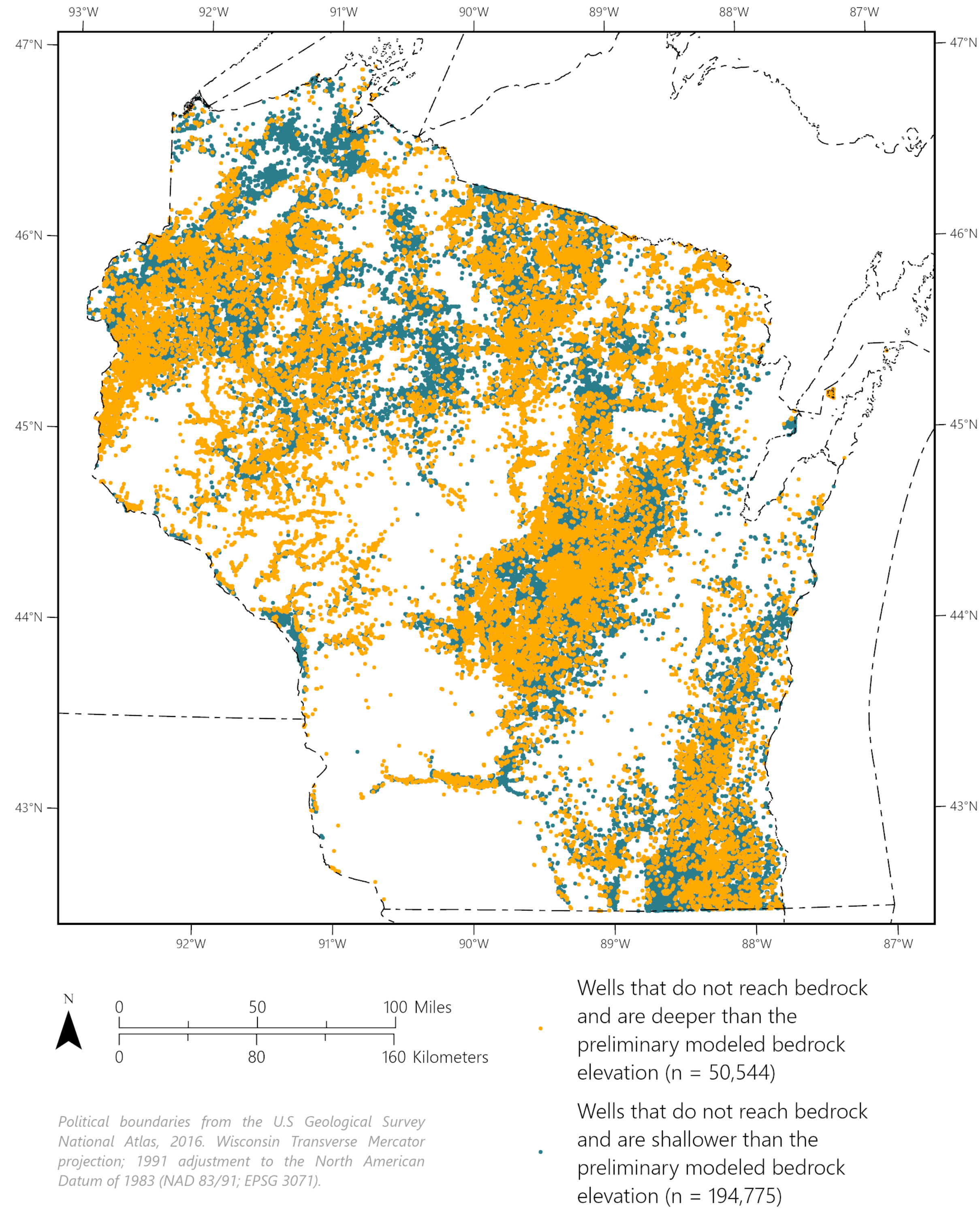

Figure 8. *Spatial distribution of wells that do not reach bedrock. Yellow points indicate wells whose bottoms were deeper than the initial modeled bedrock surface.*

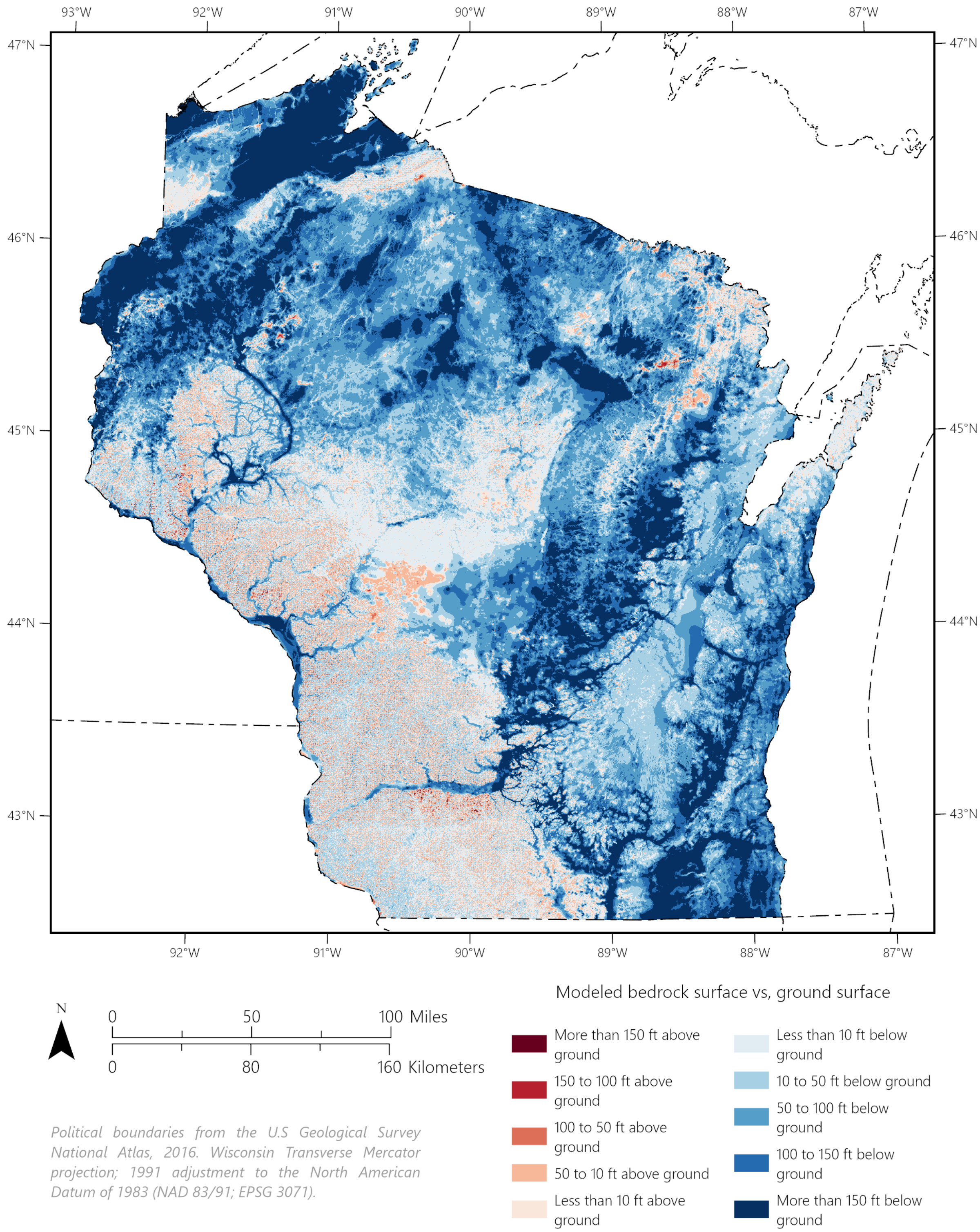

Figure 9. *Comparison of modeled bedrock surface to ground surface. Red zones indicate areas where the modeled bedrock surface was above ground level.*

Results and uncertainty

The final dataset represents Wisconsin's bedrock elevation generalized to a 100-meter resolution (fig. 10, dataset 1) and is intended to be used as a first estimate of the bedrock elevation of the state. The interpolation model can be rerun as new bedrock data become available. Due to the uncertainties discussed below, this product is not intended for site-specific studies.

Accuracy of the modeled bedrock elevation surface is limited by the availability and quality of data points used in its generation. Near-surface bedrock data are readily available through evidence such as outcrops and near-surface investigations/excavations. Information on deeper bedrock relies on well and borehole locations, which have an anthropogenic bias in their distribution and depth. For one, it is more expensive to drill deeper wells, especially if potable water is available from the overlying sand-and-gravel aquifer. Wells are also less likely to be drilled in wetland areas or on steep slopes. In addition, wells are scarcer outside of agricultural areas and population centers. River valleys are another common setting with low data density that impact the modeled bedrock surface. A problematic result of this low data density is evident in western Wisconsin, where the modeled bedrock elevation in some river valleys does not decrease downstream as expected. Additionally, many wells in regions of the state that utilize the near-surface sand-and-gravel aquifer do not reach bedrock. Confidence that this product accurately reflects the true bedrock surface is lower in areas of sparse data away from shallow bedrock.

A recent county-scale depth-to-bedrock mapping effort in Grant County (Mauel and others, 2025) provides a similar, qualitative discussion of uncertainty. Another nearby effort in Lafayette County (Stewart and others, 2025) provides a quantitative, statistical analysis of uncertainty. Due to project timelines, data from these mapping efforts were not included in the new statewide model but will be incorporated in future iterations. Both efforts included manual contouring of depth-to-bedrock based on best professional judgment when available data could not contribute to a geologically reasonable digital interpretation.

Dataset 1 compiles data and professional interpretations from a variety of sources to give a current best estimate of statewide bedrock topography at 100-meter resolution. As data sources are refined, WGNHS mapping efforts proceed to new areas, and interpolation tools are refined, iterative updates to this dataset will improve its accuracy and precision.

Data contents

The data and accompanying materials for this publication are available for download from the WGNHS Publications Catalog at https://doi.org/10.48358/gclw7508.

Dataset 1: Wisconsin bedrock topography, 100-meter resolution

A file geodatabase (.gdb file format) that includes the 100-meter raster dataset, point feature class with bedrock elevation and data source, and line feature class with contours from previous interpretations.

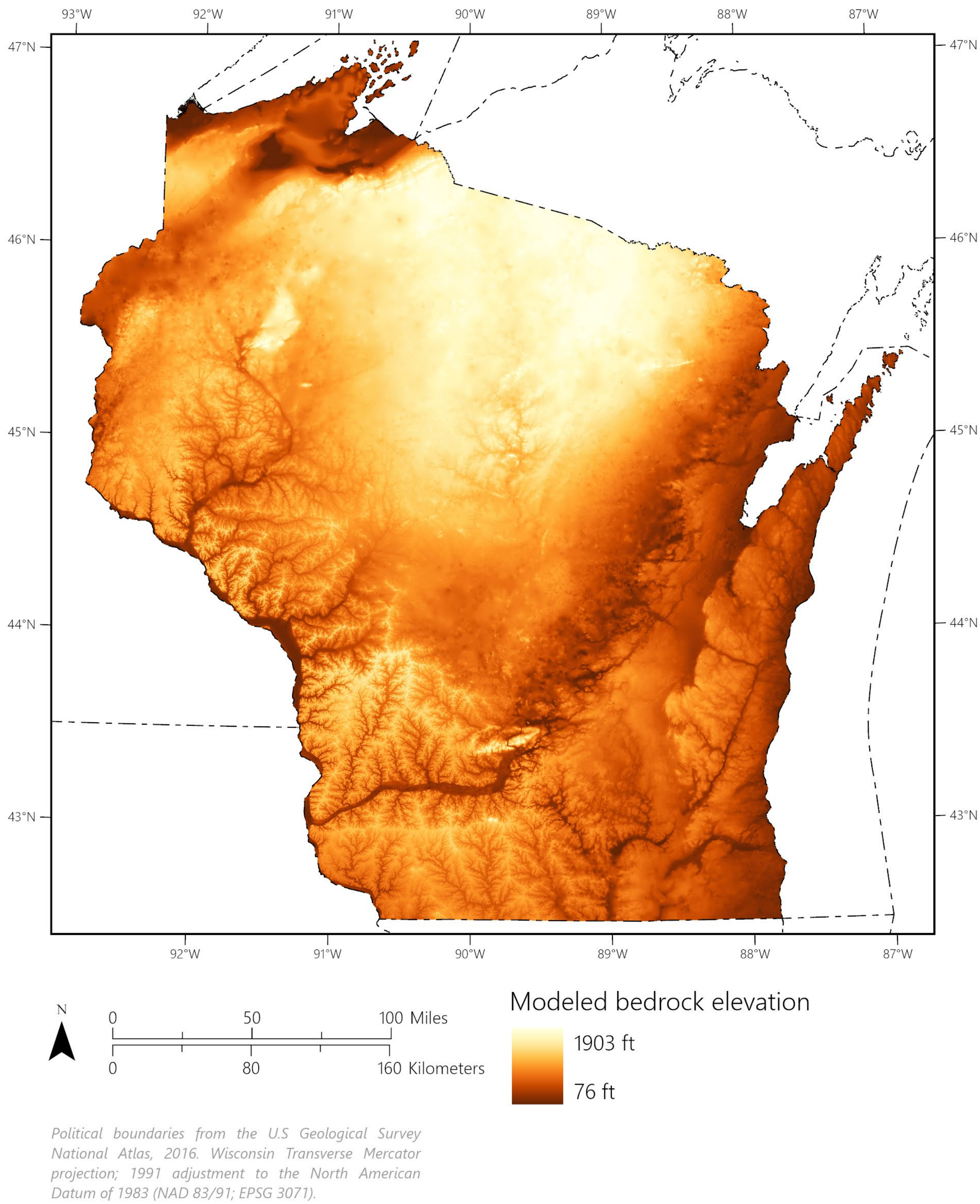

Figure 10. *Wisconsin bedrock topography, 100-meter resolution (dataset 1).*

Acknowledgments

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