DNR-237

Final Report

Characterization of the geology and hydrogeology of the Rountree Formation in southwestern Wisconsin

Administrative Report to the Wisconsin Department of Natural Resources
Wisconsin Geological and Natural History Survey
Division of Extension
University of Wisconsin-Madison

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INTRODUCTION

Project Objectives

The objectives of this project were as follows:

(1) to evaluate the geographic distribution and thickness of the Rountree Formation in Grant, Iowa, and Lafayette Counties, WI;

(2) to characterize the physical properties of the Rountree Formation, focusing on properties most relevant to water infiltration and groundwater vulnerability (hydraulic conductivity, grain size, clay mineralogy, spatial variability);

(3) to evaluate the Rountree Formation's ability to buffer groundwater from contamination by comparison to direct measurement of groundwater quality taken from wells in the study area; and

(4) to compare the evolving understanding of the Rountree Formation as developed on the Sinnipee Group dolomite from this study with similar data collected by the WGNHS for the Rountree Formation where it is developed on the Prairie du Chien Group dolomite in Crawford, southern Monroe, Richland, and Vernon Counties to assess its role in buffering groundwater there.

Relation to Other Projects

This project complements the recently completed SWIGG Project (Stokdyk and others, 2022; Muldoon and other, 2021) by assessing the role that the Rountree Formation plays protecting the groundwater system from contamination. Because the Rountree is not exposed at the surface, relatively little is known about its distribution and hydrogeologic properties (grain-size distribution, porosity, permeability, etc…). An understanding of the distribution of the Rountree is important for understanding the role the unit plays in buffering and protecting the groundwater system, for explaining the patterns and extent of well water contamination in the study area as identified by the SWIGG Project, and for predicting the likelihood of contamination in other areas of the Driftless Area of southwestern Wisconsin where the Rountree Formation occurs.

Background

Geologic Setting

The Driftless Area of southwestern Wisconsin, unlike the rest of the state, was not overridden by ice sheets during the Pleistocene Epoch. The resulting landscape is quite distinctive and consists of bedrock uplands with deeply incised, steep-walled, stream valleys. The character of the bedrock uplands varies within the SWIGG study area. North of Military Ridge, also called the Platteville Cuesta by Trewartha and Smith (1941), the landscape is more deeply dissected and the uplands are thin ridges, capped by the cherty lower member of the Galena Formation. South of Military Ridge, the landscape is more of a broad upland capped by the non-cherty upper unit of the Galena Formation (Figure 1).

Bedrock in the SWIGG study area consists of unexposed Precambrian-aged crystalline rocks that are overlain by a thick package of Paleozoic sedimentary rocks that outcrop in steep-sided stream valleys and hillslopes. A generalized stratigraphic column for the lead zinc district (Figure 2) illustrates that Cambrian-age units are primarily sandstones, whereas the Ordovician is dominated by carbonate deposition. After deposition of the Lower Ordovician Prairie du Chien dolomite, sea level fell and there was a period of erosion and karstification. As sea levels rose at the start of the Middle Ordovician, the St Peter Sandstone and Glenwood Shale (now included in the Ancell Group) were deposited prior to the deposition of the carbonate-dominated Sinnipee Group, which consists of the Platteville, Decorah, and Galena Formations. The Sinnipee Group is the uppermost bedrock unit in the majority of the study area south of Military Ridge and the younger Maquoketa Shale and Silurian dolomite are restricted to scattered “mounds” in the area. The lithostratigraphy of the Sinnipee Group is heterogeneous and consists of a mixture of dolostone, limestone, and shale (Figure 3). This sequence of rocks has been well characterized as it serves as the host rock for the lead-zinc deposits in the region.

The surficial sediments in the study area consists of the Rountree Formation, a residual weathering product that forms from dissolution of underlying carbonate rock, and which is the focus of this project. Quaternary sediments above the Rountree consist primarily of wind-blown loess on the bedrock uplands; colluvium and rare landslide deposits occur over bedrock on valley sides; and alluvium occurs in the valley bottoms.

The Rountree Formation

The Rountree Formation is a reddish-brown clay deposit found throughout the Driftless Area of southwestern Wisconsin. It is a residual material formed by chemical alteration of underlying carbonate rock, and is overlain by loess of the Peoria and Roxana Members of the Kieler Formation (Knox et al., 1990). Because it is a bedrock weathering product with late

Quaternary loess blanketing it, there are few or no natural surface exposures of the Rountree Formation; most commonly, it is exposed in excavations associated with quarries and road construction (Figure 4). In fact, the type section was in a now-defunct dolomite quarry adjacent to the Rountree Branch of the Little Platte River near Platteville, WI. The deposit ranges in color from reddish-brown (5YR 4/3) to strong brown (7.5 YR 4/4 to 4/6), and contains as much as 70 – 80% clay, imparting a characteristic sticky texture. At the type section, montmorillonite and mixed-layer intergrades dominate the clay fraction, with lesser amounts of kaolinite, mica, and vermiculite (Frolking, 1978). Residual clays similar to the Rountree Formation, are often referred to as *terra rosa*. Traditionally, these deposits were believed to form either by (1) the complete dissolution of the underlying carbonate by the very groundwater processes that form karst weathering also associated with carbonate, leaving behind the insoluble fraction (*e.g.*, Thornbury, 1954; Bardossy, 1982; Moresi and Mongelli; 1988); or by (2) detrital accumulation of material, often interpreted to be of aeolian origin (*e.g.*, Yaalon and Ganor, 1973; Durn et al, 1999; Muhs et al., 2007). However, the thicknesses often observed for *terra rosa* is often unrealistic to represent solely dissolution, and the geochemistry is incompatible with solely detrital origin (Ruhe et al., 1961; Comer, 1974; Mee et al., 2004). Field observations and geochemical analyses from various sites in the U.S. Midwest, including the Driftless Area, both suggest that the *terra rosa* in general and the Rountree Formation in particular develop by a volume-per-volume replacement of the underlying dolomite, aided by contributions Al, Fe, and Si from aeolian dust (Knox et al., 1990; Merino and Banerjee, 2008; Stiles and Stensvold, 2008).

At the type section, the Rountree Formation is approximately 2.1 m thick; across the study area the thickness and geographic distribution of the unit is poorly understood, although it is thought to be related to the abundance of chert in the parent dolomite (which produces an armoring lag that protects the weathering product from erosion) and slope. It is presumed to be ~1.5 to 3 m thick throughout Grant, Iowa, and Lafayette Counties, with greater thicknesses correlating to areas where the lower Galena Dolomite is the parent material and where slopes are negligible. However, this is supported by very little data, precisely because the deposit has only been observed in limited locations (mostly quarry excavations).

Hydrogeology

The topography and geology of the Driftless Area affect the groundwater flow systems of the region. Recharge occurs on ridgetops and hillslopes; streams in the deeply incised valleys serve as local discharge locations for groundwater with some diffuse discharge and some focused at discrete spring orifices. Several lines of evidence suggest that there are multiple aquifers in the study area that are separated by shale layers. The distribution of springs can provide important information about aquifer heterogeneities and stratigraphic controls on the distribution of high-permeability features. DeGeoffrey and others (1969) noted that springs occur throughout the stratigraphic sequence in the study area but were more common along outcrops of shale beds and other zones of low permeability as well as in stratigraphic units that were densely fractured, such as portions of the Prairie du Chien dolomite. Swanson and others (2009) noted that springs in Iowa County could occur throughout the stratigraphic section but occurred most frequently in the Sinnipee Group, near the St. Peter contact, and near the upper contact of the Cambrian sandstones. While many springs emerge near the bottom of the incised stream valleys, some springs occur at mid-slope positions along the valley walls. Work by Swanson and others (2014) noted that the Spechts Ferry Shale, located at the base of the Decorah Formation, appears to be the unit responsible for perching two tufa-depositing springs in Grant County (Figure 5).

The distribution of springs is one line of evidence that the aquitards in the stratigraphic sequence are effective barriers to vertical groundwater flow and serve to direct flow more laterally. Large discrepancies in hydraulic head between wells completed at different depths also suggest a multi-aquifer system in the SWIGG study area. Previous work in Iowa County (Gotkowitz, 2010; Carter and others, 2011) suggests that there are at least two distinct aquifers in the area with the upper aquifer consisting of the Sinnipee Group and the deeper, more regional aquifer, consisting of the St Peter sandstone and underlying Prairie du Chien (PdC) Group. In other parts of the SWIGG study area, specifically at Pioneer Farm discussed below, we were also able to document significant head differences between the upper Sinnipee Group aquifer and the deeper St. Peter-PDC aquifer.

Existing Water-quality Data

While the area was known to have groundwater quality concerns prior to the SWIGG study, the available data were somewhat limited and patchy in distribution. Figure 6 shows the county-wide estimates for private wells testing positive for coliform bacteria (top) and the section-level data (bottom). Data are from the UW Stevens Point Well Water Quality Data viewer https://gissrv3.uwsp.edu/webapps/gwc/pri_wells/. Data densities were similar for nitrate samples.

Impacts of COVID-19 Pandemic

The COVID-19 pandemic which began in March 2020, directly impacted the progress and scope of this work. At the outset of the pandemic, the University of Wisconsin-Madison enacted a close-down of facilities; staff at the WGNHS were transitioned to working 100% remotely, and through the bulk of calendar year 2020, prior approval from Division of Extension administration was required to enter any UW-Madison facility. On-campus laboratories that were expected to provide geochemical and hydraulic conductivity analyses were similarly closed; once those laboratories began to reopen in 2021, priority was understandably given to research projects and graduate students on the Madison campus.

In response to these realities, resources available from this grant were shifted away from quantifying the hydraulic conductivity, grain size, and clay mineralogy of the Rountree Formation and towards evaluating its spatial distribution and thickness in the study area, evaluating its buffering ability, and comparing it to the Rountree Formation as it has been mapped and understood in Crawford, Richland, Vernon, and southern Monroe Counties.

METHODS

Characterization of Rountree Formation

Regional Characterization of Rountree Distribution

Regional characterization of the Rountree Formation was modeled from previous and current federally funded 1:100,000-scale surficial geologic mapping projects that staff at the WGNHS have been conducting in Crawford, Grant, Iowa, Monroe, Richland, and Vernon Counties. Mapping is generated entirely in GIS (Geographic Information System) ArcMap software. Data are compiled in geodatabases in the US Geological Survey's GeMS (Geologic Mapping Schema) format. Computer mapping incorporates high-resolution LiDAR topography & digital elevation models, aerial photography, available bedrock geology data, and soils mapping data. Initial mapping is confirmed by field investigation and observation in the mapping area. Additional stratigraphic information is provided by 4.5-cm diameter Geoprobe cores. The final mapping is able to be queried in ArcMap to ascertain various parameters and statistics of interest, and is publicly available.

The Rountree Formation occurs only in the subsurface in the mapping area. It may be found on upland surfaces underlain by carbonate bedrock, and published literature suggests that it is most closely associated with areas capped by the lower portions of both the Galena Formation and the Prairie du Chien Group dolomites (Syverson et al., 2011). It is also surmised to be largely eroded from upland surfaces with slopes greater than 3 to 5 percent (Syverson et al., 2011). This by default limits the areal distribution of the Rountree Formation to nearly flat upland surfaces. Because these upland surfaces are ubiquitously mantled by loess, previous and on-going surficial geologic mapping in southwestern Wisconsin divides upland areas based on the material underlying the loess. This determination is based on known geomorphic expression of discrete bedrock units and an aggressive campaign of spot verification of presence/absence of Rountree Formation from Geoprobe cores that collect sediment from the ground surface to the buried bedrock surface.

In surficial geologic mapping in the Driftless Area prior to and during this project, we have identified five different loess-on-upland map units based on the underlying material; all map units contain variable thicknesses of Kieler Formation loess at the surface, dependent on landscape position and distance from the source of loess (principally, the Mississippi River corridor). These have been applied in Grant and Iowa Counties as part of this project and are as follows:

(1) '*Loess on residuum*' is interpreted to represent the Rountree Formation as encountered in the subsurface. Residuum is typically red to reddish-orange clay or silty clay, sometimes with manganese nodules, often with white or gray chert clasts (Figure 7a). Residuum is almost always less than 3 m thick, very often less than 1 m.

(2) '*Loess on Readstown Member*' is identified because of the unique weathering characteristics of the Readstown Member of the St. Peter Formation. This lower member of the formation weathers to mixed sands and clays in a spectacular array of colors ranging between white, yellow, orange, red, dark gray, black, and (especially with weathered clay) pale green (Figure 7b). Because of the unconformable contact between the St. Peter Formation and the underlying Prairie du Chien Group dolomite, the thickness of the weathered Readstown Member in the subsurface can range from greater than 10 m to absent. We suspect that north of the Wisconsin River, where the Readstown Member most frequently subcrops, that it has historically often been mistaken for the

Rountree Formation. In areas north of the Wisconsin River, the Readstown Member is often identifiable in high-resolution LiDAR hillshade imagery due to a distinctive cauliflower-shaped form on the land surface at stream headwaters.

(3) '*Loess on Maquoketa Formation*' is defined by the presence of weathered shale from this Late Ordovician formation in the subsurface. Weathered Maquoketa Formation shale often appears as pale yellow silt or silty clay. Thickness can exceed 5 m; geographically confined in the Driftless Area to southern Grant and southwestern Lafayette County.

(4) '*Loess on till*' represents subsurface deposits from a Pre-Illinoian (> 500 ka) glaciation that advanced from the northwest in extreme western Grant County and one limited area in southwesternmost Crawford County. The relict till presents as extremely dense and compact medium gray clay with few small clasts of weathering-resistant lithologies. Thickness is typically less than 1.5 m, deposit is patchy (based on closely-spaced Geoprobe coring in western Grant County), and due to proximity to the Mississippi River the till is typically overlain by 10 m or more of loess.

(5) '*Loess on undifferentiated bedrock*' represents areas where the bedrock unit underlying surficial loess is unlikely to produce any clay-rich residuum. This includes limited areas with the Late Cambrian Jordan Sandstone, Middle Ordovician Glenwood Formation, and relatively extensive areas through the Driftless Area with the Middle Ordovician Tonti Member of the St. Peter Formation. The Tonti Member is a resistant sandstone that typically and prominently produces topographic scarps on the landscape (Figure 7c), thus creating an obvious stratigraphic marker.

Confirmation of Presence/Absence of Rountree Formation

Because the Rountree Formation is a subsurface unit, information regarding its distribution across the landscape has previously been absolutely minimal and anecdotal. Prior to this study, the only information on the distribution of the Rountree Formation was based on exposures of the unit revealed in bedrock quarry walls, road construction, building foundation excavations, and the like. Several of these were confirmed during field reconnaissance (Figure 8). Using methodologies developed during surficial geologic mapping in Crawford, Monroe, Richland, and Vernon Counties, we collected at total of 123 Geoprobe cores targeted on upland surfaces throughout Grant, southern Iowa, and western Lafayette Counties, and augmented that collection with descriptions from 94 Geoprobe cores previously collected for mapping projects in western Grant and northern Iowa Counties (Table 1; Figures 9 and 10). Cores were distributed across the landscape on upland surfaces with the exception of 12 cores that were collected on the property of Pioneer Farm to compare with geophysical data collected in association with this work.

Rountree Characterization at Pioneer Farm

We conducted an electrical resistivity survey in late June 2020 at Pioneer Farm to gain a better understanding of how the thickness of the Rountree varies across the landscape. Dave Hart and Grace Graham of the WGNHS collected over 1 kilometer of geophysical data along several transects (Figure 10). Data from those transects are presented in Figures 11a to 11f. The areas of high resistivity (red) are bedrock, the areas of low resistivity (blue) are unconsolidated sediment, and the areas of intermediate resistivity (green) are likely altered rock. Preliminary interpretation suggests that the uplands have little altered rock, the hillslopes have greater thickness of altered rock and unconsolidated sediment, and the lowlands near the stream have little altered rock. Twelve Geoprobe cores, varying in depth from 4.5 to 15 feet, were collected along the same transect lines as the electrical resistivity survey described above. Core locations are shown in Figure 10; descriptions, and photos can be found in Appendix 1. These data provide information on how the thickness of the surficial sediment varies across the site and indicate that the distribution of the Rountree is quite patchy, ranging from 0 to 2.3 m in thickness.

During this project, two soil pits were dug for Dr. Chris Baxter's soil class at UW-Platteville (see location in Figure 10). We examined those pits in early October 2020 and noted that the Rountree appeared quite fractured. Since those pits had been open for several weeks, it is possible that these were recent desiccation cracks and not representative of the unit. We consulted with Dr. Baxter to determine whether it was worthwhile to dig additional backhoe pits at the Farm and he recommended against doing so since the distribution of the Rountree is so patchy and it would be quite likely that we would dig pits that did not encounter it.

Table 1. Base statistics on Geoprobe cores used to support this project

Cores collected for this project			
	County	**No.**	**Purpose**
	Grant	61	Upland distribution (presence/absence) of Rountree Formation
	Iowa	28	Upland distribution (presence/absence) of Rountree Formation
	Lafayette	22	Upland distribution (presence/absence) of Rountree Formation
	Lafayette	12	Targeted coring to support geophysical data collection at Pioneer Farm

	County	**No.**	**Purpose**
	Grant	59	Distribution of old (Pre-Illinoian) till underlying loess
	Iowa	35	Upland distribution (presence/absence) of Rountree Formation

Hydrogeologic Characterization

Recharge is the process that moves contaminants from the ground surface and into an underlying aquifer and the presence or absence of the fine-grained Rountree Formation could influence recharge processes in the study area. There were limited historic data that would allow us to develop a good understanding of recharge to the uppermost aquifer in the study area and so we proposed to install a transect of three instrumented observation boreholes from a ridge crest to a valley bottom where we could continuously record water levels and observe recharge processes. Early in the project, we identified an existing network of monitoring wells at UW-Platteville's Pioneer Farm that had been installed by George Kraft back in 2006 (Kraft and Mechanich, 2008) and that fit the criteria outlined in the proposal. The network was much more extensive than what we had proposed and the research staff at the farm were willing to let us use the wells. We thought it would be an ideal site because the farm, located in northwestern Lafayette County (Figure 1), is 1) in terrain typical of uplands in the majority of the SWIGG study area in terms of geology and having agricultural land use and 2) preliminary geoprobe cores indicated that the Rountree was present on the ridge crest.

Pioneer Farm Monitoring Network

The existing groundwater-monitoring network at the Pioneer Farm consists of 12 monitoring wells; 11 wells are instrumented with piezometer nests and one well has a FLUTe multi-level monitoring system with 8 ports. During this project, we found that the FLUTe multi-level monitoring system is no longer functional. Without the FLUTe, there are 36 monitoring points completed at varying depths within the bedrock (Figure 12). Borehole geophysical logs, collected by the WGNHS prior to the installation of the piezometers, provide data on the geology of the bedrock underlying the farm. Existing hydraulic head data (collected approximately monthly from October 2006 to May 2007) indicate that groundwater flow is to the southwest, toward the Upper Fever River.

Instrumentation

Our approach to characterizing the recharge processes at the Pioneer Farm site was to monitor temporal changes in water levels, temperature, and electrical conductivity using Solinst^{TM} Leveloggers capable of measuring those parameters (TLC Leveloggers). When we first visited the site in November 2019 to assess the condition of the wells, we discovered existing Solinst^{TM} LTC Leveloggers in several piezometers. We learned that these had been installed in January 2010 and had been recording water levels, fluid temperature, and conductivity at 4-hour intervals until their batteries died. We returned the Leveloggers to Solinst in Canada where they recovered the data and replaced the batteries in those that were still operable. Several had had water seep into the datalogger and the electronics were destroyed. Water-level data recovered from the Leveloggers are plotted in Figure 13 along with daily precipitation data from Lancaster, WI. These previously collected data suggested that recharge at the site is rapid, as water-level responses can be noted in piezometers within days of precipitation or snow melt events.

The repaired dataloggers were returned to the WGNHS in February 2020 but we were unable to re-install them into piezometers until June 2020 due to Covid-19 travel restrictions. Prior to reinstalling them, we decided to pump the piezometers to remove any sediment or other debris that may have accumulated. Piezometers were pumped in May and Leveloggers were reinstalled in mid-June. Three of the Leveloggers failed upon installation and another failed in September 2020. Based on the previously collected data and the data collected from June to October 2020, we redistributed the remaining Levleoggers so that we were monitoring the shallowest piezometers in each borehole except for borehole LF-469 and LF-465 where we continued to monitor two piezometers completed at varying depths. Table 2 gives the specifics of which piezometers were monitored over the duration of the project.

Table 2. Information on Leveloggers installed in piezometers at Pioneer Farm

Borehole	Piezometer	Elev TOC (ft AMSL)	Depth Open Interval (ft)	Average Depth Water (ft)	Notes
LF-461	LF-461-1	1113.36	117.02 - 122.02		
Ridge top	LF-461-2	1113.33	103.00 - 108.00		
	LF-461-3	1113.39	74.05 - 84.05	67.61	Monitored June 2020-June 2022
LF-463	LF-463-1	1057.08	52.45 - 57.45		
Near manure pit	LF-463-2	1057.08	43.53 - 48.53	35.86	Monitored June to October, 2020. Moved to LF-469-2 on Oct 8
	LF-463-3	1057.08	14.25 - 24.25	Often dry	
LF-464	LF-464-1	1024.715	50.30 - 55.30		
Near Fever River	LF-464-2	1024.715	37.00 - 42.00		
	LF-464-3	1024.715	26.94 - 31.94		
	LF-464-4	1024.715	11.26 - 21.26	14.85	Monitored June 2020-June 2022
LF-465	LF-465-1	1036.32	222.0 - 232.0	116.76	Monitored June 2020-June 2022
Deep wells in pasture	LF-465-2	1036.32	154.4 - 164.4	24.85	Monitored June 2020-June 2022
LF-466	LF-466-1	1072.625	71.92 - 76.92		
Across divide to East	LF-466-2	1072.625	60.87 - 65.87	26.58	Monitored June to October, 2020. Moved to LF-469-1 on Oct 8
	LF-466-3	1072.625	42.89 - 47.89		
	LF-466-4	1072.625	27.87 - 37.87	28.28	Monitored June 2020-June 2022
LF-468	LF-468-1	1060.82	69.85 - 74.85		
Mid-slope North	LF-468-2	1060.96	57.6 2- 62.62		
	LF-468-3	1060.96	37.85 - 42.85		
	LF-468-4	1060.96	24.97 - 34.97	21.32	Monitored June 2020-June 2022
LF-469	LF-469-1	1030.72	46.97 - 51.97	7.80	Failed upon installation. Moved different logger here on Oct 8.
Toe-of-slope	LF-469-2	1030.90	27.92 - 37.92	9.05	Failed in September 2020. Moved different logger here on Oct 8
LF-470	LF-470-1	1087.045	96.95 - 101.95		
Side of Ridge	LF-470-2	1087.045	80.01 - 85.01		
	LF-470-3	1086.935	54.02 - 64.02	47.38	Monitored June 2020-June 2022
	LF-470-4	1087.045	37.91 - 47.91	Often dry	Barologger Monitored June 2020-June 2022

Installation of Additional Monitoring Well

Because we were able to utilize the existing Pioneer Farm groundwater-monitoring network, we had the necessary funds to drill an additional deep well at Pioneer Farm in order to explore which shale layer was more critical in terms of separating the upper and lower aquifers in the area. Previous work indicated at least two shale units could act as aquitards: the Glenwood Formation which lies atop the St Peter Sandstone and the Spechts Ferry Shale, located at the base of the Decorah Formation within the Sinnipee Group. A new well, LF-493, was drilled using air rotary methods in April, 2021. Grab samples of cuttings were collected every 5 feet. We continued drilling until the hole had advanced several feet into the St. Peter sandstone. The casing extends to 40.6 feet below ground surface. Figure 14 shows the stratigraphic log for the new well. We collected an optical borehole image log as well as both geophysical and spinner flow logs prior to conducting packer tests to define the vertical hydraulic head profile. These logs are included in Appendix 2.

Groundwater Quality Samples (from other projects)

This project did not include any funds for groundwater sampling. Rather we proposed to use existing results from the SWIGG study to assess whether the Rountree provided protection to the underlying aquifer. A second project, funded through the UW Consortium for Extension and Research in Agriculture and Natural Resources (CERANR) provide us the opportunity to collect nitrate samples from the Pioneer Farm Network on an approximately monthly basis. The following paragraphs describe sample collection methods and resulting water-quality results for those two data sets.

SWIGG Sampling: The total number of wells in the SWIGG study area is estimated to be approximately 16,000 based on the WDNR Well Construction Information System. Samples were collected during two synoptic sampling events, November 9-10, 2018 and April 11-12, 2019, to account for seasonal variation in water quality. Recruitment letters were sent to 1250 and 2083 randomly selected well owners for the November 2018 and April 2019 sampling events, respectively. Sample bottles and detailed instructions on proper sample collection techniques were mailed to the well owners by the Water and Environmental Analysis Lab at UW Stevens Point. Samples were collected by the homeowners and taken to designated sample drop-off locations within 24 hours of collection. Project personnel transported the samples to the lab on the day that they were submitted. We received 301 well owner-collected samples for the November 2018 event and 539 samples for the April 2019 event; for a total of 840 samples from 816 randomly selected wells; some wells were sampled twice by random selection. Samples were analyzed for nitrate-N, total coliforms, and *E. coli* bacteria. Maps of the nitrate-N and total coliform results are shown in Figure 15 in relation to the bedrock geology.

Pioneer Farm Sampling: Approximately ten rounds of nitrate-N samples were collected between late August 2020 and August 2021 from 24 piezometers in the Pioneer Farm monitoring network. Nitrate-N concentration at each piezometer did not vary significantly over this time period, however, there was considerable spatial variation in the results (Figure 16).

RESULTS AND DISCUSSION

Regional Distribution of Rountree Formation

Mapping associated with this project has resulted in an entirely new 1:100,000-scale surficial geologic map of Grant County (which was originally mapped in 2009 – 2012, prior to release of high-resolution LiDAR data which merited remapping) and the completion of a 1:100,000-scale surficial geologic map of Iowa County (the northern half of the county was mapped using US Geological Survey mapping grants). It will also provide the start of a new 1:100,000-scale surficial geologic map of Lafayette County (which will be completed using US Geological Survey mapping grants). As a direct result of this grant funding 1:100,000-scale surficial geologic maps of Grant and Iowa Counties are currently in production for publication by the WGNHS (Figure 17).

The geomorphology of Grant and Iowa Counties can be described in broad terms that have then been divided to provide much greater nuance through the new surficial geologic mapping. Broadly speaking, the landscape in the study area can be divided into four main areas: (1) upland surfaces that are mantled in windblown silt with a variety of underlying materials, as has previously been discussed in the Methods section; (2) shallow colluvial slopes that are a mélange of windblown silt and underlying material mobilizing downslope associated with the headwaters of the Grant, Platte, and Pecatonica Rivers; (3) steep colluvial slopes that are dominated by thin, coarse, blocky material derived from local bedrock; and (4) valley bottoms that are primarily composed of toe-slope colluvium, alluvium, and alluvial terraces.

Rountree Formation in Grant and Iowa Counties

The upland surfaces that are mantled by windblown silt are of primary interest to this study, as that is the area where the Rountree Formation can be produced and exist in the subsurface. In Grant and Iowa Counties, the principle areas for this landform is the southern half of each county, where primarily the Galena Formation dolomite of the Sinnipee Group caps the landscape. Geoprobe cores targeted on upland surfaces allowed delineation of the various materials underlying the windblown silt (Rountree Formation, Readstown Member, Maquoketa

Table 3. Absolute amounts of windblown silt in Grant and Iowa Counties

County	Loess on Rountree Fm.	Loess on Readstown Mbr.	All other loess units	All non-loess units
Grant	839.3 km^2 (27.46%)	16.8 km^2 (0.55%)	380.9 km^2 (12.46%)	1819.1 km^2 (59.52%)
Iowa	354.7 km^2 (17.85%)	32.0 km^2 (1.61%)	363.0 km^2 (18.26%)	1237.9 km^2 (62.28%)
Combined	**1194.0 km^2 (23.67%)**	**48.8 km^2 (0.97%)**	**743.9 km^2 (14.75%)**	**3057.0 km^2 (60.61%)**

Table 4. Proportions of windblown silt units isolated from other map units in Grant and Iowa Counties

County	Loess on Rountree Fm.	Loess on Readstown Mbr.	All other loess units
Grant	839.3 km^2 (67.85%)	16.8 km^2 (1.36%)	380.9 km^2 (30.79%)
Iowa	354.7 km^2 (47.31%)	32.0 km^2 (4.27%)	363.0 km^2 (48.42%)
Combined	**1194.0 km^2 (60.10%)**	**48.8 km^2 (2.46%)**	**743.9 km^2 (37.44%)**

Shale, undifferentiated bedrock or Pre-Illinoian till) at the 1:100,000 (Figure 18). Querying the geodatabase created from the mapping provides information on the absolute distribution of the Rountree Formation in Grant and Iowa Counties (Tables 3 and 4).

While the '*Loess on Rountree*' is the most abundant of the various loess map units found on the upland surfaces, the relatively deep incision by streams into the bedrock system—particularly with the north-draining streams that are tributaries of the Wisconsin River—results in all loess units comprising slight less than 40% of the land area of Grant and Iowa Counties. Thus, isolating solely for the '*Loess on Rountree*' shows that only 23.7% of the two counties has Rountree Formation present in the subsurface. Furthermore, the detailed study combining Geoprobe cores and geophysical data at Pioneer Farm demonstrates that even in areas where the Rountree Formation is present, it is in fact patchy in its distribution. Thus, the value of 23.7% of the county with Rountree Formation estimated from the 1:100,000-scale mapping likely over-estimates the actual amount.

Rountree Distribution at Pioneer Farm

Based on the electrical resistivity survey, the Geoprobe cores, and the two soil pits, it is clear that the distribution of the Rountree is quite patchy at the Farm. Geoprobe core IPW-1, drilled in the road right-of-way in front of the swine facility penetrated 22 feet of Rountree, one of the thicker sections encountered within the entire study area. Rountree thicknesses within the 12 Geoprobe cores collected on Farm property varied from 0.0 to 7.5 ft (Figure 19). In general, Rountree thicknesses are lower along the swale that runs from the ridge crest and it is possible that the Rountree may have been eroded along this feature. On the ridge crest and in mid-slope positions, the Rountree is generally greater than 2 feet in thickness, however, cores PFM-1 and PFM-10 do not follow this trend.

These observations highlight the difference between the areas that are mapped at the 1:100,000 scale as being 'loess over Rountree Formation' versus the actual finer-scale distribution of the residual material on the landscape. Preliminary 1:100,000-scale surficial geologic mapping in Lafayette County (underway, will be completed by June 2023) indicates the vicinity of Pioneer Farm is indeed classified as '*Loess on Rountree*'. The closely spaced Geoprobe cores and electrical resistivity surveys on the Pioneer Farm property demonstrate that even in areas mapped as such, the actual distribution of Rountree Formation in the subsurface can be patchy. The patchy, discontinuous distribution of the lower members of the Kieler Formation loess—that being the Roxana, Loveland, and Wyalusing Members—suggests that erosion of upland unconsolidated sediments is a pervasive and cumulative process over time (Syverson et al., 2011). The residual clay of the Rountree Formation would be similarly affected by such erosion.

Recharge Characteristics Pioneer Farm

Precipitation

Climatic data were not recorded as part of this study. Instead, we utilized climatic data available from the Global Historical Climatology Network-Daily (GHCN-Daily) for Lancaster, WI. It is approximately 19.5 miles northwest of Pioneer Farm. Historical climate data were accessed from the National Climate Data Center (https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00474546/detail) and include the following daily data: temperature (maximum, minimum, and time of observation), 24-hr precipitation totals (including the water equivalent of any snow fall), and snow depth.

Water Levels and Barometric Pressure Corrections

The Solinst TLC Leveloggers™ are unvented and the total pressure measured by the transducer is a combination of the pressure due to the height of the overlying water column and the pressure due to the weight of the overlying atmosphere. As such, the readings must be corrected for variations in barometric pressure. Readings from a Solinst Barologger™ suspended in well LF-470 were used to correct the Levelogger readings from all piezometers. The default "barometric compensation" option in the Levelogger 4.4.0 software provided by Solinst™ assumes 1) a barometric efficiency of 100%, 2) that there is no lag time between a change in barometric pressure and response in the aquifer, and 3) that the barometric efficiency is constant. We assumed that this correction was adequate for all water-level records.

Recharge Events

Water levels from the reinstalled loggers are presented in Figure 20. All of the piezometers, other than LF-465-1, are completed within the Galena Formation of the Sinnipee Group. The piezometers located on top and the upper slopes of the ridge (LF-461-3, LF-466-2 and LF466-4, and LF-470-3) show similar water level trends, including a somewhat slower, and more muted response to the March 2021 snowmelt event which is the major recharge event over the monitoring period. Both piezometers in LF-466 show a sharp response to a precipitation event in late June 2020 that is not reflected in other piezometers near the ridge top (LF461-3 and LF-470-3); this is perhaps due to a shallower depth to water in the LF-466 piezometers. Piezometer LF461-3 shows a drop in water level in mid-April 2021, probably in response to a new well being drilled nearby.

Piezometers further down in the flow system (LF-468-4, LF-469-1and 2, LF-464-4 and LF-465-2) all have average depths to water less than 30 feet. These piezometers, except perhaps LF-465-2, show sharp increases in water levels in response to precipitation and snow melt events. In general, precipitation events with daily total rainfall in excess of 1-inch result in groundwater recharge perhaps with the exception of the month of July.

Fluid Temperature Results and Discussion

Variations in fluid temperature at a specific monitoring location are affected by the thickness and thermal conductivity of the unsaturated zone as well as the depth of circulation of groundwater flow (Bundschuh, 1992). In some fractured carbonate aquifers, rapid changes in fluid temperature can be used to identify recharge events (Bradbury and others, 2001; Muldoon and Bradbury, 2010). Variation in fluid temperature, as recorded in the piezometers at Pioneer Farm, appears to be related to depth to water and depth of groundwater circulation and does not seem to be affected by recharge events. The middle graph in Figure 21 shows those piezometers that exhibit little to no seasonal variation in fluid temperature while the middle graph in Figure 22 shows those piezometers that exhibit significant seasonal variation in temperature. The occasional short, spiky, increases or decreases in temperature in Figure 21 are related to sampling events and not correlated to recharge events. Of the piezometers with little to no seasonal variation LF-465-1 is completed in the St Peter sandstone, the deep aquifer, and piezometers LF461-3 and LF-470-3 are located on the ridge where the depth to water is high and the air temperature signal seems to be attenuated by the thick unsaturated zone. The piezometer nests at LF-466 and LF-469 are interesting in that the deep piezometers at each nest (LF-466-2 and LF469-1) show little to no temperature variation, even if the depth to water is moderate to shallow, while the shallow piezometers (LF-466-4 and LF-469-2) do exhibit seasonal temperature variation. This suggests that the upper portion of the Galena aquifer may have more rapid groundwater flow while the deeper portion of the Galena aquifer may exhibit slower flow. For the other piezometers with distinct seasonal variation, we only monitored the shallowest piezometer in nests LF-463, LF-464, and LF-468 and so we cannot compare with the deeper piezometers in these nests. Groundwater temperature in most piezometers peaked in December, with the exception of LF-469-2, which peaked in late January-early February. Peak annual air temperature is typically in late July, suggesting a 5-month lag time between air temperature and groundwater temperature. LF-469-2 also shows less seasonal variation than the other shallow piezometers and this may be due to the upward groundwater gradients at that nest.

Fluid Conductivity Results and Discussion

The fluid conductivity data from the Leveloggers are shown in the top graphs of Figures 21 and 22. Most piezometers show little variation in conductivity over time and there appears to be no correlation between recharge events and changes in fluid conductivity. The records for LF466-2, LF470-3, LF464-4, and LF469-2 show occasional sharp jumps in fluid conductivity that correlate with sampling events during which the logger is removed, and the piezometer is pumped enough to remove three well volumes. It is not uncommon for wells to have differing fluid conductivities before and after pumping as the pumping brings fresh groundwater into the piezometer. Unless there is significant ambient flow in the portion of the aquifer where the piezometer is screened, the water in the piezometer may have water chemistry and fluid conductivity that differs from the surrounding groundwater. The record for LF468-4 is exceptionally variable and we assume that this is instrument error. The Levelogger in this piezometer is one of the refurbished ones and older units are more prone to measurement error. In addition, we noted a white precipitate forming on the ferule that was used to make the end loop in the wire cable that suspends the Levelogger in the hole. It is not clear if this precipitate could have affected readings. Since the precipitate was observed in several holes and none of the others conductivity records are this variable, we are assuming that the record for LF468-4 is not reliable.

Water-quality Results in Relation to Rountree Distribution

As noted previously, we did not collect any groundwater samples as part of this project, however the nitrate data from Pioneer Farm collected for the CERANR project and the results from the SWIGG study suggest that the presence of Rountree Formation is not protective of the underlying Galena aquifer.

Comparison of the nitrate-nitrite data at Pioneer Farm (Figure 16) and the Geoprobe data on the thickness of the Rountree Formation (Figure 17) show little spatial correlation. The Rountree varies in thickness on top of the ridge from 0.2 to 4.7 feet (cores PFM1 to PFM3 in Figure 17). The greatest thickness is at the very top of the ridge, near well LF461 (Figure 16). And yet this well has the highest average NO_3-NO_2-N concentration observed in the piezometers monitored at the Farm. The high NO_3-NO_2-N concentrations at LF461 are consistent with the idea that this well is in a recharge area and has a strong downward component to groundwater flow. The horizontal component of flow in the upper aquifer is to the west-southwest, toward the Upper Fever River. LF468, which is in a midslope position, downgradient from LF461, has the second highest average NO_3-NO_2-N concentration. This well is located near Geoprobe core PFM-7 which has a thickness of 2.64 feet of Rountree. In general, wells show a decrease in average NO_3-NO_2-N concentration with distance along the flow path – or highest on the ridge and lowest near the Upper Fever River. This is opposite the trend in the thickness of the Rountree which is thickest along the ridge and midslope. While this is just one location, the detailed characterization of both the thickness of the Rountree and the nitrate concentrations in the upper Galena Aquifer at Pioneer Farm suggest that the Rountree provides little protection to the aquifer.

Comparison of Rountree formed on Sinnipee Group vs. Prairie du Chien Group

The new surficial geologic mapping conducted with this funding in Grant and Iowa Counties can be compared with previous, recent surficial geologic mapping conducted by the WGNHS in Crawford, Monroe, Richland, and Vernon Counties (2015 – 2022) to compare the regional distribution of the Rountree Formation as mapped at the 1:100,000 scale and to compare to clays produced by weathering of the Readstown Member of the St. Peter Formation (Figure 23).

The landscape in the four counties to the north of the Wisconsin River is fundamentally different than the landscape in the adjacent counties to the south, and this largely reflects a broad-scale difference in the erosion of the landscape into the Paleozoic sedimentary section. In the study area counties south of the Wisconsin River and particularly south of Military Ridge, the landscape largely 'rides' on the dipslope of the Galena Formation of the Sinnipee Group. Coming off the Wisconsin Arch, the sedimentary layers here dip gently to the south and southeast; this is also the general direction of flow of the major tributary streams in the area and the overall slope of the landscape. As a result, there are relatively large areas of the counties that are either uplands capped by the Galena Formation or headwater slopes with relatively moderate incision by the tributary streams. North of the Wisconsin River, in contrast, the landscape is emplaced lower in the Paleozoic section and thus more heavily influenced by the friable Cambrian sandstones. Upland surfaces in the four counties north of the Wisconsin River are capped primarily by either the Prairie du Chien Group dolomites and associated residual clays or residual clays derived from the Readstown Member of the St. Peter Formation. Streams in this area have eroded deeply into the Cambrian sandstones, resulting in a significantly larger proportion of these counties mapped as steep colluvial surfaces and relatively less area (especially outside of Vernon County) as flat-lying upland surfaces that may contain the Rountree Formation.

Residual Clays in Crawford, Monroe, Richland, and Vernon Counties

As within the study areas of Grant and Iowa Counties, surficial geologic mapping in the four counties north of the Wisconsin River provided the means for evaluating the geographic distribution of upland materials underlying the surficial windblown silt. Geoprobe cores targeted on upland surfaces allowed delineation of the various materials underlying the windblown silt (Rountree Formation, Readstown Member, undifferentiated bedrock or Pre-Illinoian till) at the 1:100,000 (Figure 24). Querying the geodatabase created from the mapping provides information on the absolute distribution of the Rountree Formation in Crawford, Monroe, Richland, and Vernon Counties (Tables 5 and 6).

In the four counties to the north of the Wisconsin River, the more pervasive erosion of streams into Cambrian sandstones and more widespread occurrence of steep colluvial slopes results in only 25.5% of these counties covered by windblown silt that may have Rountree Formation under it. And, in fact, only 7.8% of these four counties was mapped at the 1:100,000 scale as '*Loess on Rountree*'. Where that unit was mapped, the residual clays as seen in Geoprobe cores were derived from the Prairie du Chien Group dolomites rather than the Galena Formation dolomite. Slightly more abundant on the landscape, at 8.4%, are areas mapped as '*Loess on Readstown Member*'.

The distribution of the Readstown Member of the St. Peter Formation is dependent on the unconformable nature of the contact between the St. Peter Formation and the underlying Prairie du Chien Group. It has been documented that significant paleo-erosion is preserved in the unconformity. In paleo-lows, the St. Peter Formation as a whole—and the Readstown Member in particular—are thickest; in paleo-highs, the Readstown Member is thinnest and sometimes

Table 5. Absolute amounts of windblown silt in counties north of the Wisconsin River

County	Loess on Rountree Fm.	Loess on Readstown Mbr.	All other loess units	All non-loess units
Crawford	0.0 km^2 (0.0%)	173.6 km^2 (11.20%)	255.0 km^2 (16.45%)	1121.9 km^2 (72.36%)
Monroe	206.0 km^2 (8.76%)	82.0 km^2 (3.49%)	0.0 km^2 (0.0%)	2062.7 km^2 (87.75%)
Richland	143.0 km^2 (9.37%)	195.7 km^2 (12.83%)	3.79 km^2 (0.25%)	1182.6 km^2 (77.55%)
Vernon	236.2 km^2 (11.18%)	184.6 km^2 (8.74%)	443.8 km^2 (21.00%)	1248.6 km^2 (59.09%)
Combined	**585.2 km^2 (7.76%)**	**635.9 km^2 (8.43%)**	**702.5 km^2 (9.32%)**	**5615.7 km^2 (74.49%)**
All 6 counties	**1779.1 km^2 (14.14%)**	**684.7 km^2 (5.44%)**	**1446.4 km^2 (11.50%)**	**8672.7 km^2 (68.92%)**

Table 6. Proportions of windblown silt units isolated from other map units in same northern counties

County	Loess on Rountree Fm.	Loess on Readstown Mbr.	All other loess units
Crawford	0.0 km^2 (0.0%)	173.6 km^2 (40.50%)	255.0 km^2 (59.49%)
Monroe	206.0 km^2 (71.52%)	82.0 km^2 (28.48%)	0.0 km^2 (0.0%)
Richland	143.0 km^2 (41.75%)	195.7 km^2 (57.15%)	3.79 km^2 (1.11%)
Vernon	236.2 km^2 (27.32%)	184.6 km^2 (21.35%)	443.8 km^2 (51.33%)
Combined	**585.2 km^2 (30.42%)**	**635.9 km^2 (33.06%)**	**702.6 km^2 (36.52%)**
All 6 counties	**1779.1 km^2 (45.50%)**	**684.7 km^2 (5.44%)**	**1446.4 km^2 (36.99%)**

absent entirely. Because of this relationship, the Readstown Member and the Prairie du Chien Group can be found laterally adjacent to one another capping the upland surfaces throughout the four counties north of the Wisconsin River. Knox (2019) suggested that the Rountree Formation may be thickest where it is mobilized to fill sinkholes in the carbonate rocks. Geoprobe coring into areas where both the Prairie du Chien Group and Readstown Member are the rock that caps the upland surfaces indicates that residual material is systematically thicker when derived from the Readstown Member than from the Prairie du Chien Group. In areas where the Readstown Member is the cap rock, the residual material underlying the surficial windblown silt is often in excess of 20' thick. In areas where Prairie du Chien Group is the cap rock, the residual material (the Rountree Formation) underlying the surficial windblown silt is less than 10' thick, and often less than 5' thick. The presence of residual material derived from the Readstown Member was not recognized prior to the onset of recent (~2015) surficial geologic mapping in these counties. Thus, it seems possible or likely that anecdotal statements of anomalously thick deposits of Rountree Formation in counties north of the Wisconsin River may have been observations of residual material from the Readstown Member rather than the Rountree Formation.

That being said, the overall distribution of the Rountree Formation in the four counties north of the Wisconsin River is less than one third the percentage area than in counties south of the Wisconsin River (7.8% vs. 23.7%). Even combining Rountree Formation and Readstown Member yields only 16.2% of these counties having residual clay units present in the subsurface. Combined with the high resolution data collected at Pioneer Farm which showed little or no correlation between presence of residual clay and buffering capacity, it is highly unlikely that the combination of residual clays from both the Rountree Formation and the Readstown Member—which together cover less than one sixth of the relevant counties—provide any tangible buffering for the groundwater systems in Crawford, Monroe, Richland and Vernon Counties.

CONCLUSIONS AND SUMMARY POINTS

The core collection, surficial geologic mapping, and site-focused data collection associated with this project have provided new, needed information on the distribution of residual clays of the Rountree Formation in Grant and Iowa Counties, and provided insight into the possibility that those residual material provide buffering capacity to the groundwater system in southwestern Wisconsin.

- A total of 123 Geoprobe cores were collected in Grant, Iowa and Lafayette Counties—111 distributed across upland surfaces throughout the study area, 12 collected on Pioneer Farm in conjunction with geophysical transects. Cores were split, described, and photographed at the WGNHS's Mt. Horeb Core Repository and Education Center. Core descriptions/photos were reviewed to determine presence/absence of Rountree Formation.
- The stratigraphic data from 94 Geoprobe cores that were previously collected by the WGNHS in Grant and Iowa Counties were accessed to provide additional site-specific data on presence/absence of Rountree Formation.
- High-resolution LiDAR digital elevation models, LiDAR-derived shaded hillslope models, soils mapping data, aerial photography, and field observation/verification were used to remap the surficial geology of Grant County and complete surficial geologic mapping of Iowa County at the 1:100,000 scale, all work completed in Arc GIS.
- Electrical resistivity surveys paired with 12 closely spaced Geoprobe cores at Pioneer Farm suggest that, even when mapped as present at the 1:100,000 scale, the actual distribution of the Rountree Formation is quite patchy when considered at finer resolution.
- Field monitoring of water-levels and fluid temperature and conductivity of at Pioneer Farm indicates that recharge to the Galena aquifer can be quite rapid, on the order of days, if the depth to water is less than 30 feet. Both snowmelt and precipitation events in excess of 1 inch/day produced recharge. Water-level records from piezometers completed in Galena and St Peter aquifers differ by more than 90 feet and provide additional evidence of a multi-aquifer system.
- Comparison of nitrate-nitrite data from monitoring wells at Pioneer Farm combined with the understanding of the patchy presence/absence of the Rountree Formation indicates

that the Rountree Formation provide very little, if any, protection to the groundwater system even in areas where it is mapped as present in the subsurface at the 1:100,000 scale.

- 1:100,000 scale surficial geologic mapping indicates that the Rountree Formation is present in no more than 23.7% of Grant and Iowa Counties. Given this limited distribution, there is fundamentally no ability for the Rountree Formation to protect the groundwater system in these counties.
- Comparison of new surficial geologic mapping from this project with recently completed surficial geologic mapping north of the Wisconsin River shows that Crawford, Monroe, Richland, and Vernon Counties have less area covered by Rountree Formation—7.8%--than the study area south of the Wisconsin River. Even accounting for the more widespread presence of residual clays from the Readstown Member of the St. Peter Formation, only 16.2% of the counties north of the Wisconsin River have areas that might have residual clays present in the subsurface. This study provides no direct data on the ability of the Readstown Member to protect the groundwater system.

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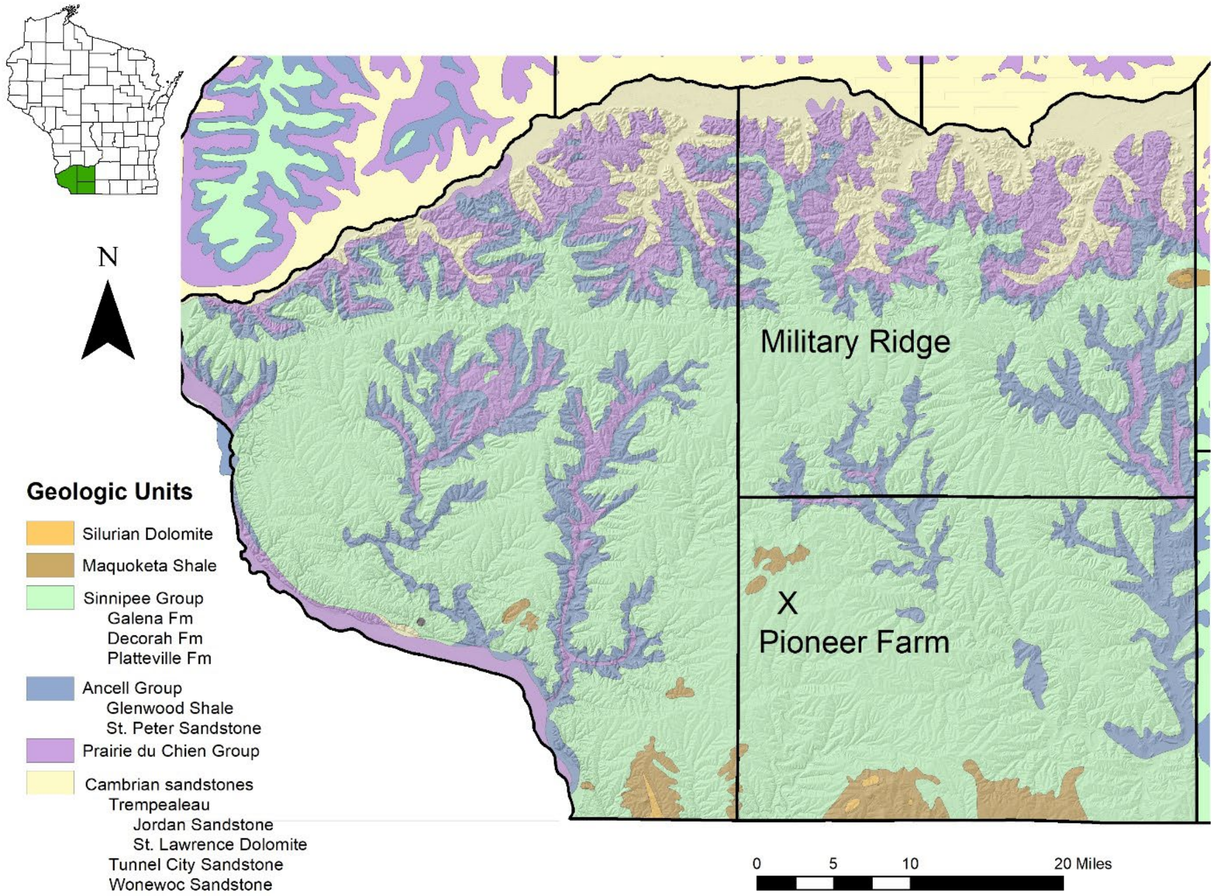
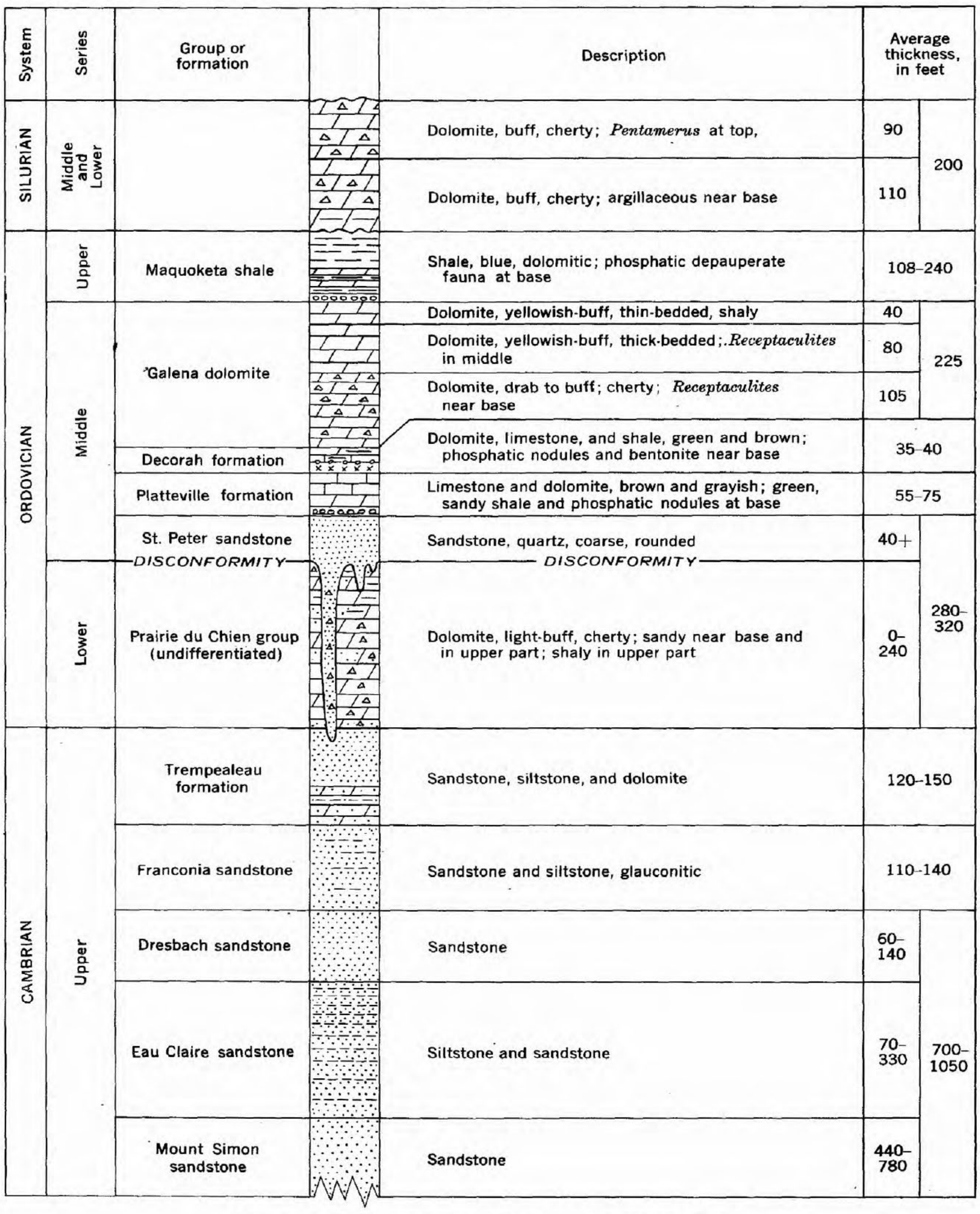


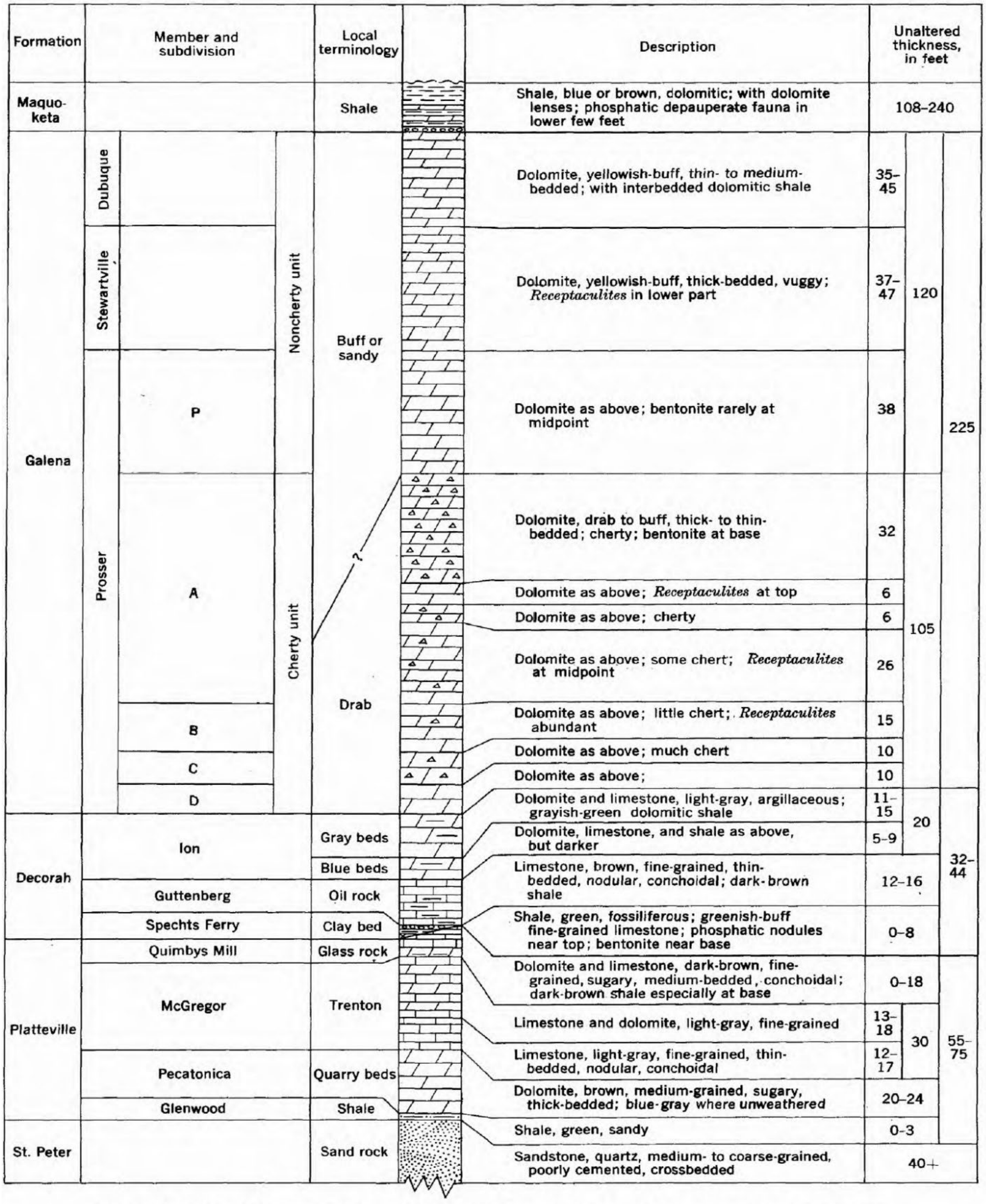
Figure 10. Map of the study area showing bedrock geology (from Mudrey and others, 1982), topography, and the locations of Military Ridge and UW-Platteville Pioneer Farm.



System	Series	Group or formation	Description	Average thickness, in feet	
SILURIAN	Middle and Lower		Dolomite, buff, cherty; *Pentamerus* at top,	90	200
			Dolomite, buff, cherty; argillaceous near base	110	
ORDOVICIAN	Upper	Maquoketa shale	Shale, blue, dolomitic; phosphatic depauperate fauna at base	108–240	
	Middle	Galena dolomite	Dolomite, yellowish-buff, thin-bedded, shaly	40	225
			Dolomite, yellowish-buff, thick-bedded; *Receptaculites* in middle	80	
			Dolomite, drab to buff; cherty; *Receptaculites* near base	105	
		Decorah formation	Dolomite, limestone, and shale, green and brown; phosphatic nodules and bentonite near base	35–40	
		Platteville formation	Limestone and dolomite, brown and grayish; green, sandy shale and phosphatic nodules at base	55–75	
		St. Peter sandstone	Sandstone, quartz, coarse, rounded	40+	280–320
		DISCONFORMITY	*DISCONFORMITY*		
	Lower	Prairie du Chien group (undifferentiated)	Dolomite, light-buff, cherty; sandy near base and in upper part; shaly in upper part	0–240	
CAMBRIAN	Upper	Trempealeau formation	Sandstone, siltstone, and dolomite	120–150	
		Franconia sandstone	Sandstone and siltstone, glauconitic	110–140	
		Dresbach sandstone	Sandstone	60–140	700–1050
		Eau Claire sandstone	Siltstone and sandstone	70–330	
		Mount Simon sandstone	Sandstone	440–780	

FIGURE 2.—Generalized stratigraphic column for zinc-lead district.

Figure 11. Generalized stratigraphic column for southwest Wisconsin, from Heyl and others (1959).



Formation	Member and subdivision		Local terminology		Description	Unaltered thickness, in feet		
Maquoketa				Shale	Shale, blue or brown, dolomitic; with dolomite lenses; phosphatic depauperate fauna in lower few feet	108–240		
Galena	Dubuque		Noncherty unit	Buff or sandy	Dolomite, yellowish-buff, thin- to medium-bedded; with interbedded dolomitic shale	35–45	120	225
	Stewartville				Dolomite, yellowish-buff, thick-bedded, vuggy; *Receptaculites* in lower part	37–47		
	Prosser	P			Dolomite as above; bentonite rarely at midpoint	38		
		A	Cherty unit	Drab	Dolomite, drab to buff, thick- to thin-bedded; cherty; bentonite at base	32	105	
					Dolomite as above; *Receptaculites* at top	6		
					Dolomite as above; cherty	6		
					Dolomite as above; some chert; *Receptaculites* at midpoint	26		
		B			Dolomite as above; little chert; *Receptaculites* abundant	15		
		C			Dolomite as above; much chert	10		
		D			Dolomite as above;	10		
Decorah	Ion			Gray beds	Dolomite and limestone, light-gray, argillaceous; grayish-green dolomitic shale	11–15	20	32–44
				Blue beds	Dolomite, limestone, and shale as above, but darker	5–9		
	Guttenberg			Oil rock	Limestone, brown, fine-grained, thin-bedded, nodular, conchoidal; dark-brown shale	12–16		
	Spechts Ferry			Clay bed	Shale, green, fossiliferous; greenish-buff fine-grained limestone; phosphatic nodules near top; bentonite near base	0–8		
Platteville	Quimbys Mill			Glass rock	Dolomite and limestone, dark-brown, fine-grained, sugary, medium-bedded, conchoidal; dark-brown shale especially at base	0–18		55–75
	McGregor			Trenton	Limestone and dolomite, light-gray, fine-grained	13–18	30	
					Limestone, light-gray, fine-grained, thin-bedded, nodular, conchoidal	12–17		
	Pecatonica			Quarry beds	Dolomite, brown, medium-grained, sugary, thick-bedded; blue-gray where unweathered	20–24		
	Glenwood			Shale	Shale, green, sandy	0–3		
St. Peter				Sand rock	Sandstone, quartz, medium- to coarse-grained, poorly cemented, crossbedded	40+		

FIGURE 3.—Detailed stratigraphic column of Platteville, Decorah, and Galena formations in zinc-lead district.

Figure 12. Detailed stratigraphy of the middle Ordovician Sinnipee Group (Galena, Decorah, and Platteville Formations) from Heyl and others (1959).

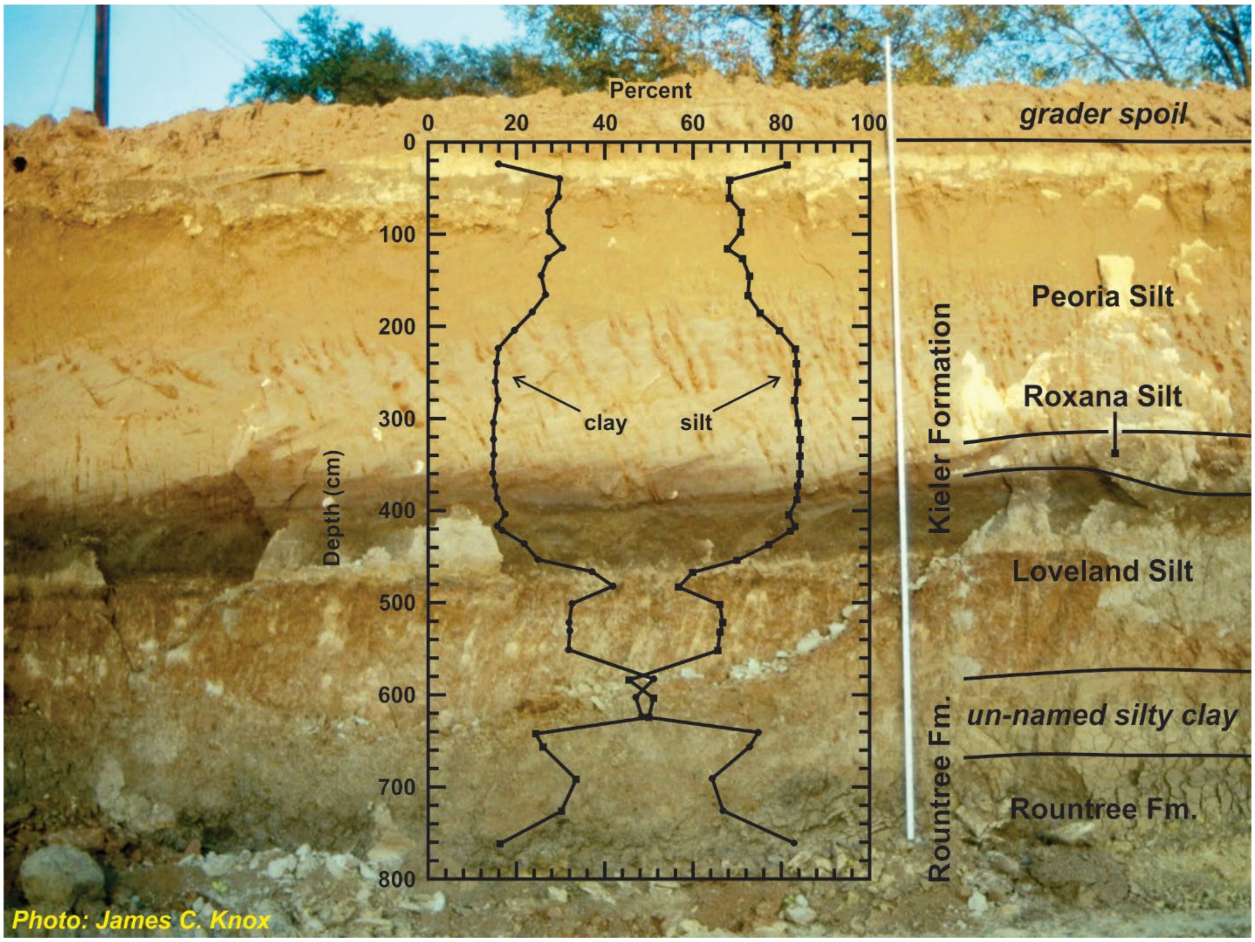


Figure 13. Roadcut exposure near Kieler, WI, of the upper three members of the Kieler Formation windblown silt (loess) and the underlying Rountree Formation. Adapted from Knox (2019).

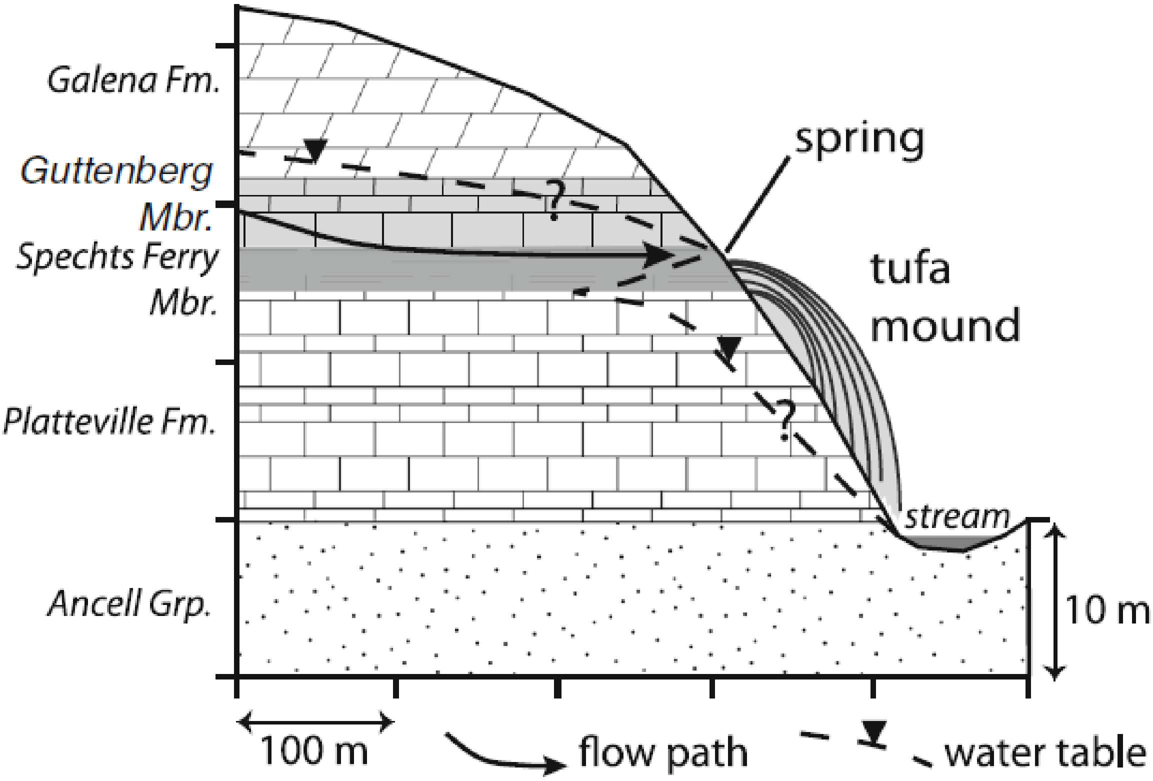


Figure 5. Conceptual model for springs that discharge from a mid-slope position in the bedrock uplands of Grant County. From Swanson and others (2014).

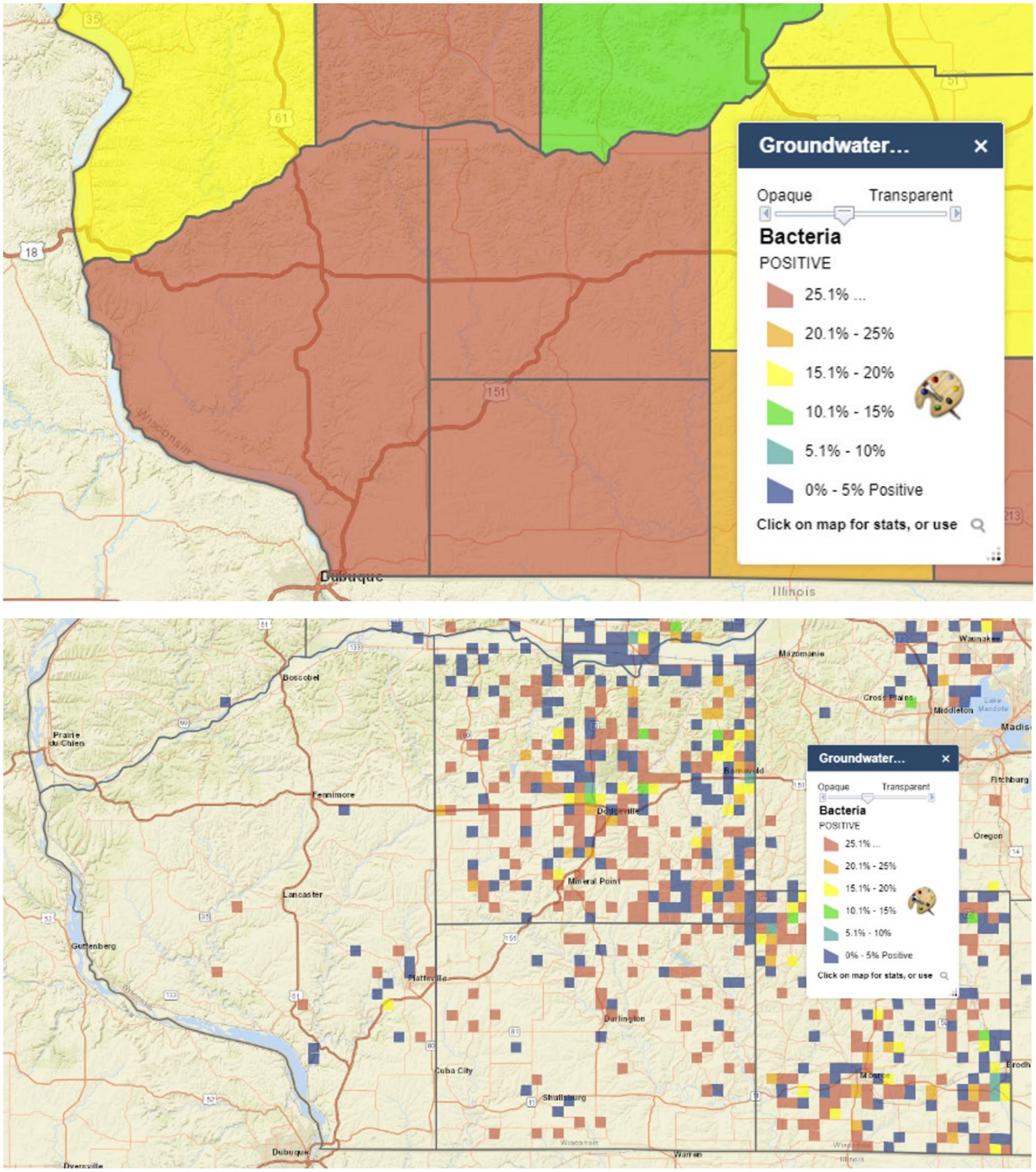
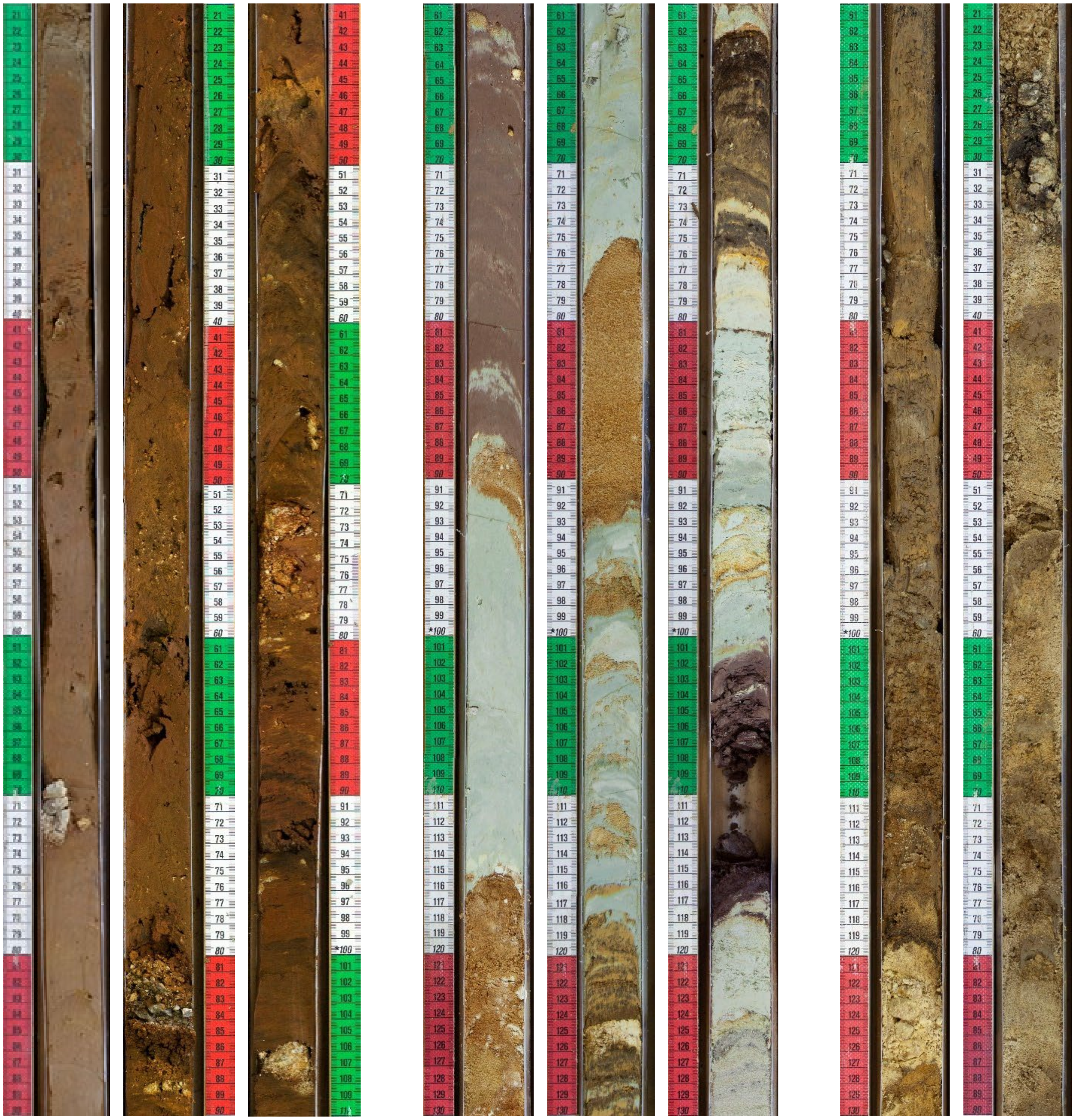


Figure 6. Maps showing existing data for coliform detections in private wells in southwestern Wisconsin prior to the SWIGG study. In the top figure the data are presented at a county-wide scale. The bottom figure shows sample density and results by square-mile section. Data are from the UW Stevens Point Well Water Quality Data Viewer (https://gissrv3.uwsp.edu/webapps/gwc/pri_wells/).



(a.) (b.) (c.)

Figure 7. Representative core photographs showing material underlying windblown silt as revealed in Geoprobe cores. All images show 70 cm of core. (a.) Typical appearance of the Rountree Formation with strong red clay and chert fragments; left image from core collected south of Platteville, WI, center and right images from a core collected near Livingston, WI. (b.) Typical appearance of the weathered Readstown Member of the St. Peter Formation showing orange sand and various colors of clay, including diagnostic pale green color; all three images from a core collected north of Barneveld, WI. (c.) Typical appearance of undifferentiated bedrock, in this case weathered sand of the Tonti Member of the St. Peter Formation; images from a core collected north of Eastman, WI.

Figure 8. Field photographs of the Rountree Formation. (*top*) Along Highway 61 northeast of Lancaster, WI; road cut is ~15’ tall. (*middle*) Along Southwest Rd. south of Platteville, WI. (*bottom*) Along Cty AA northwest of Norwalk, WI, showing removal of Rountree Formation as formed in Prairie du Chien dolomite for new bedrock quarry. All photos courtesy Eric Carson.

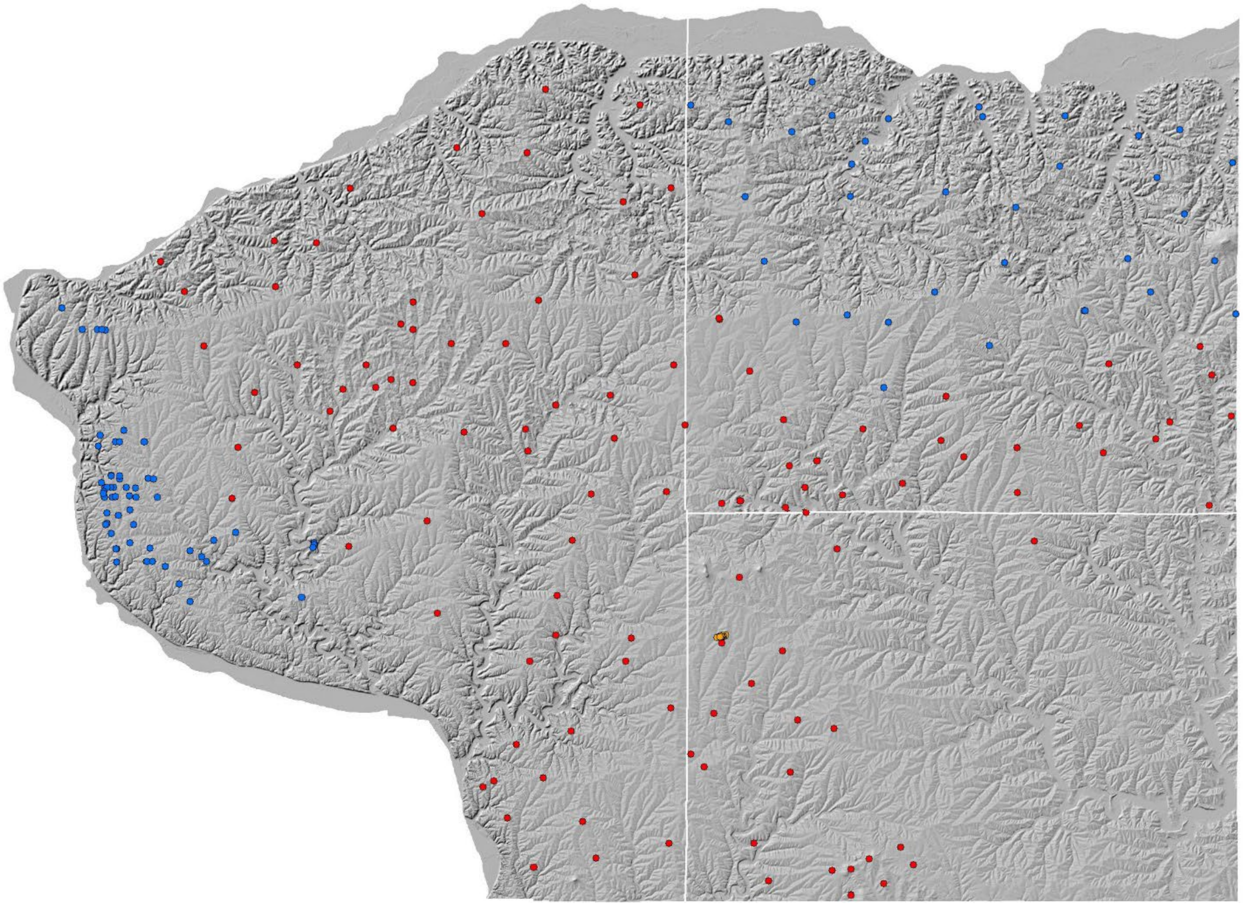


Figure 9. Distribution of Geoprobe cores used in this study: red circles = locations of upland cores collected for this study; blue circles = cores previously collected by the WGNHS that were used in this study; orange circles (concentrated in northwest Lafayette County) = targeted cores on Pioneer Farm. See Figure 10 for detail map of Pioneer Farm cores.

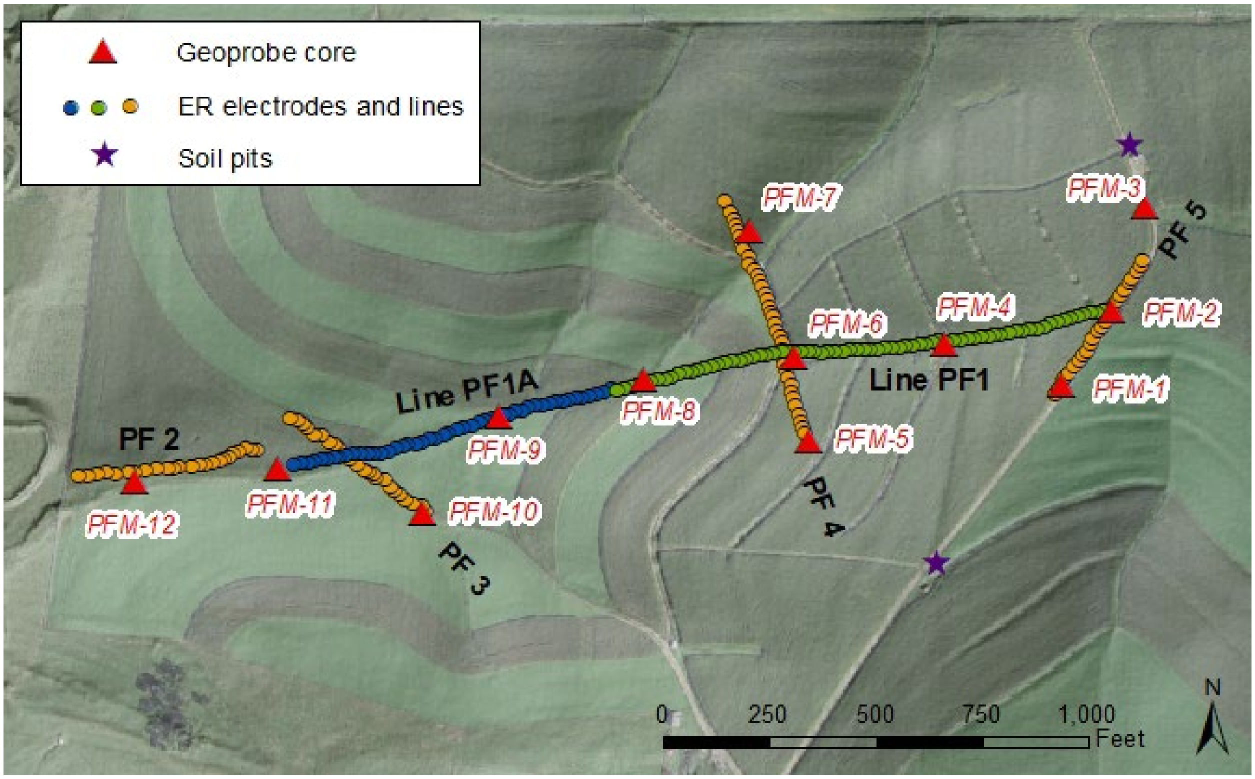


Figure 10. Aerial imagery and LIDAR basemap of Pioneer Farm showing locations of electrical resistivity survey lines, Geoprobe core holes, and soil pits.

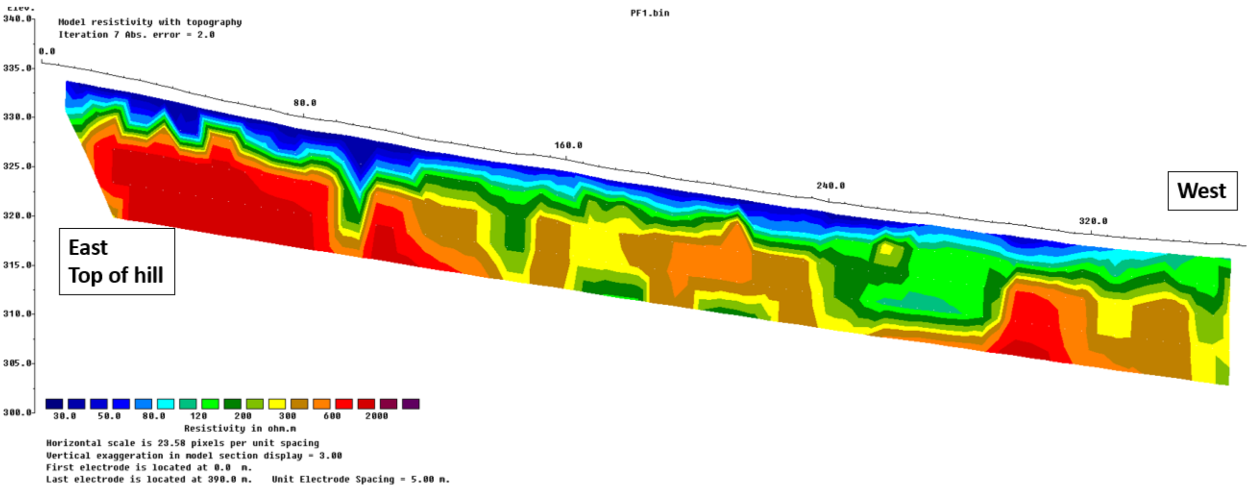


Figure 11a. Survey line PF1. Elevation (in meters) is presented on the left axis. See boxed notes to determine orientation of the line.

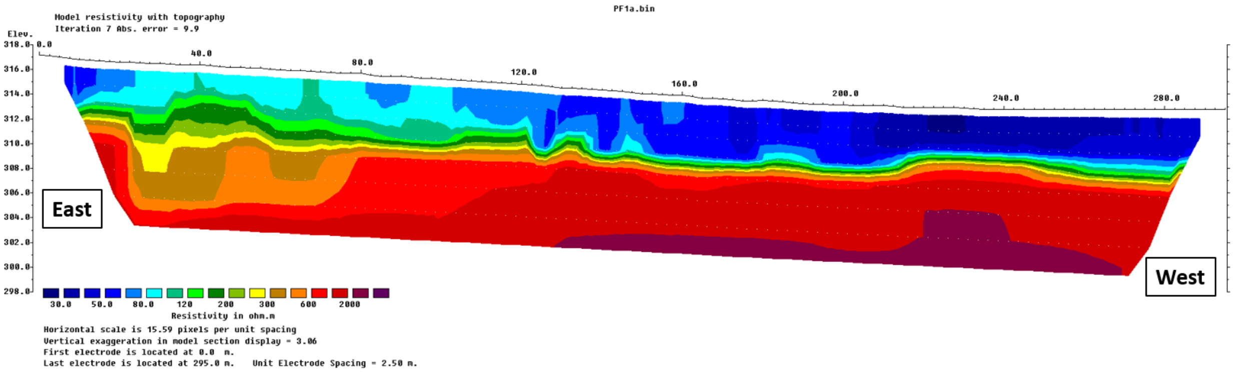


Figure 11b. Survey line PF1a. Elevation (in meters) is presented on the left axis. See boxed notes to determine orientation of the line.

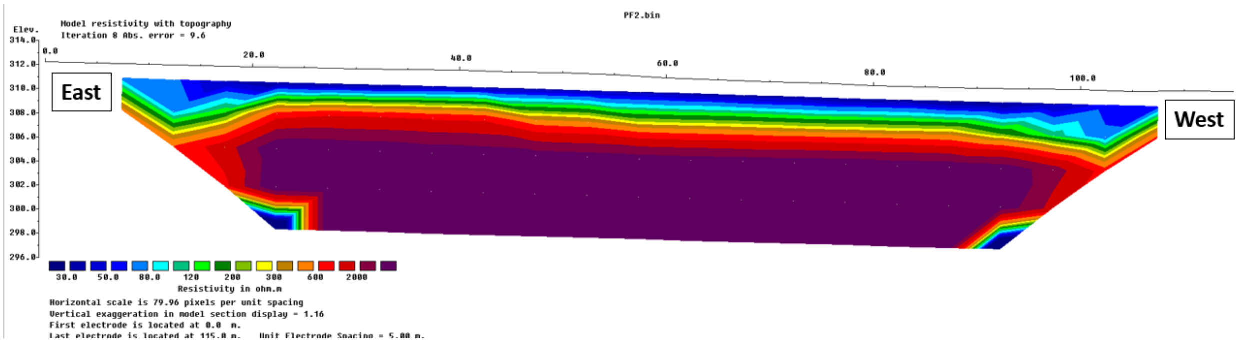


Figure 11c. Survey line PF2. Elevation (in meters) is presented on the left axis. See boxed notes to determine orientation of the line.

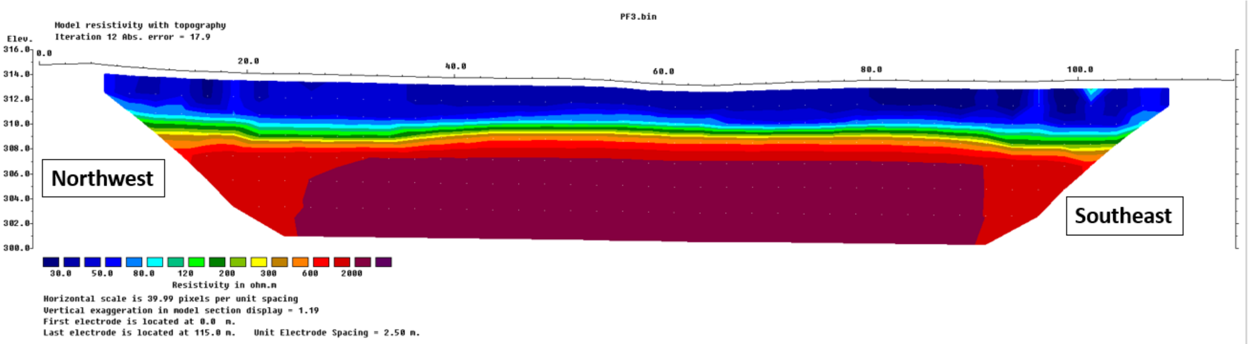


Figure 141d. Survey line PF3. Elevation (in meters) is presented on the left axis. See boxed notes to determine orientation of the line.

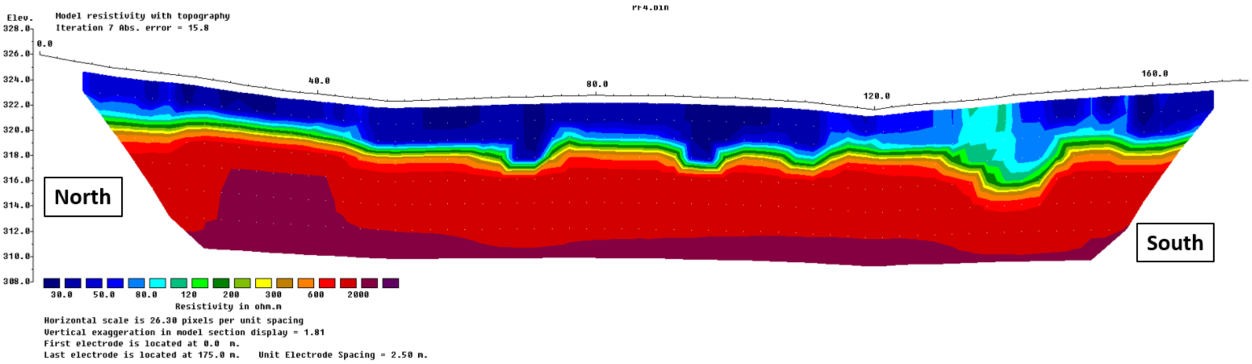


Figure 151e. Survey line PF4. Elevation (in meters) is presented on the left axis. See boxed notes to determine orientation of the line.

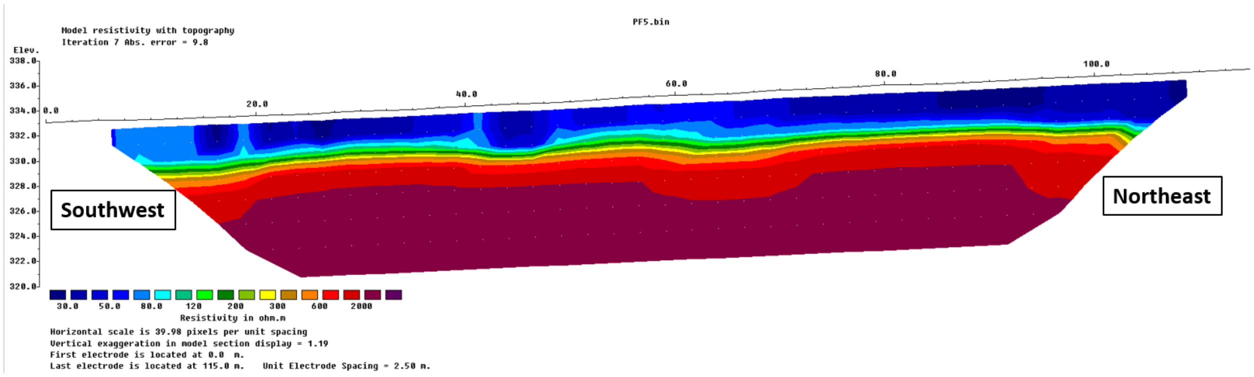


Figure 11f. Survey line PF5. Elevation (in meters) is presented on the left axis. See boxed notes to determine orientation of the line.

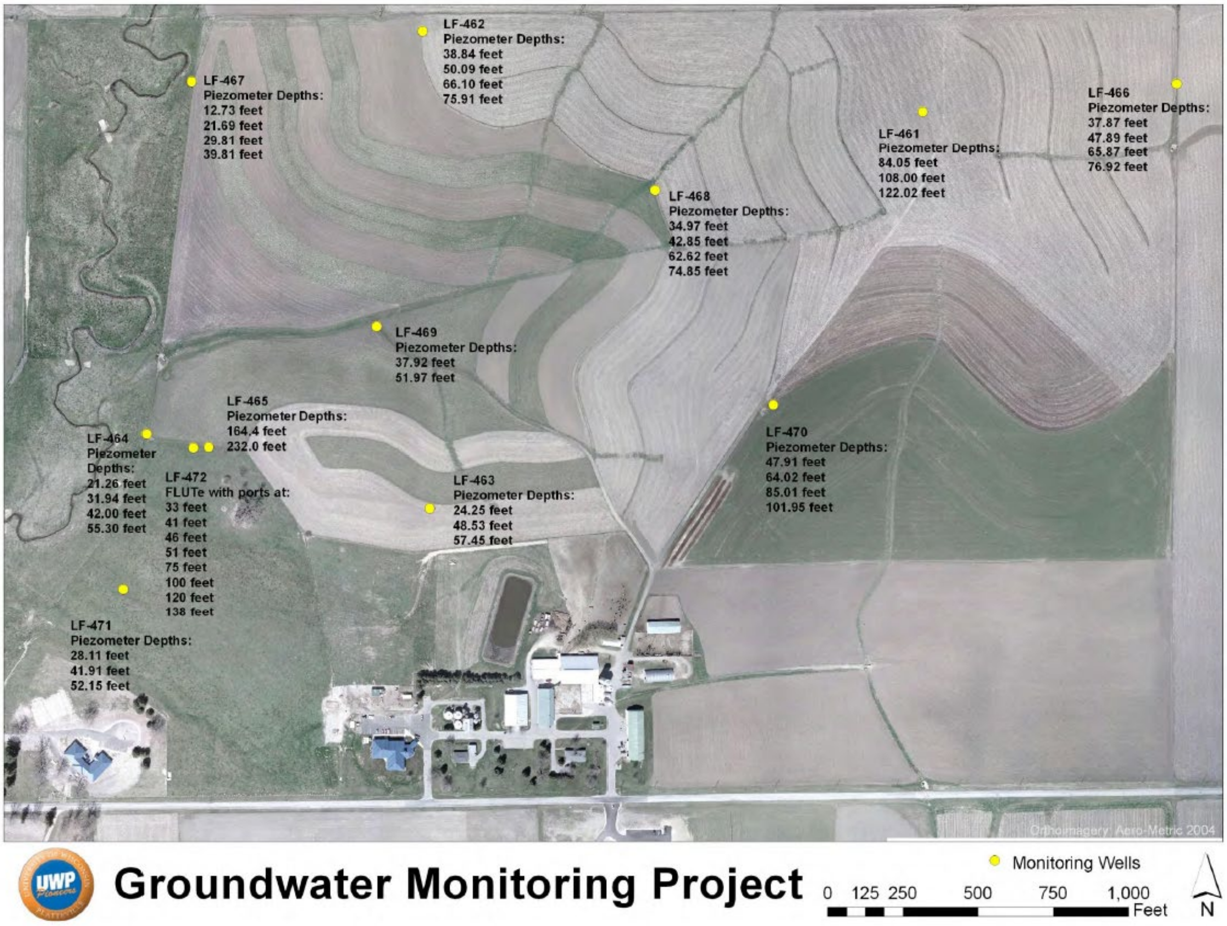


Figure 16. Map of Pioneer Farm showing location of wells and depths of piezometers for each borehole (from slideshow by Dennis Busch).

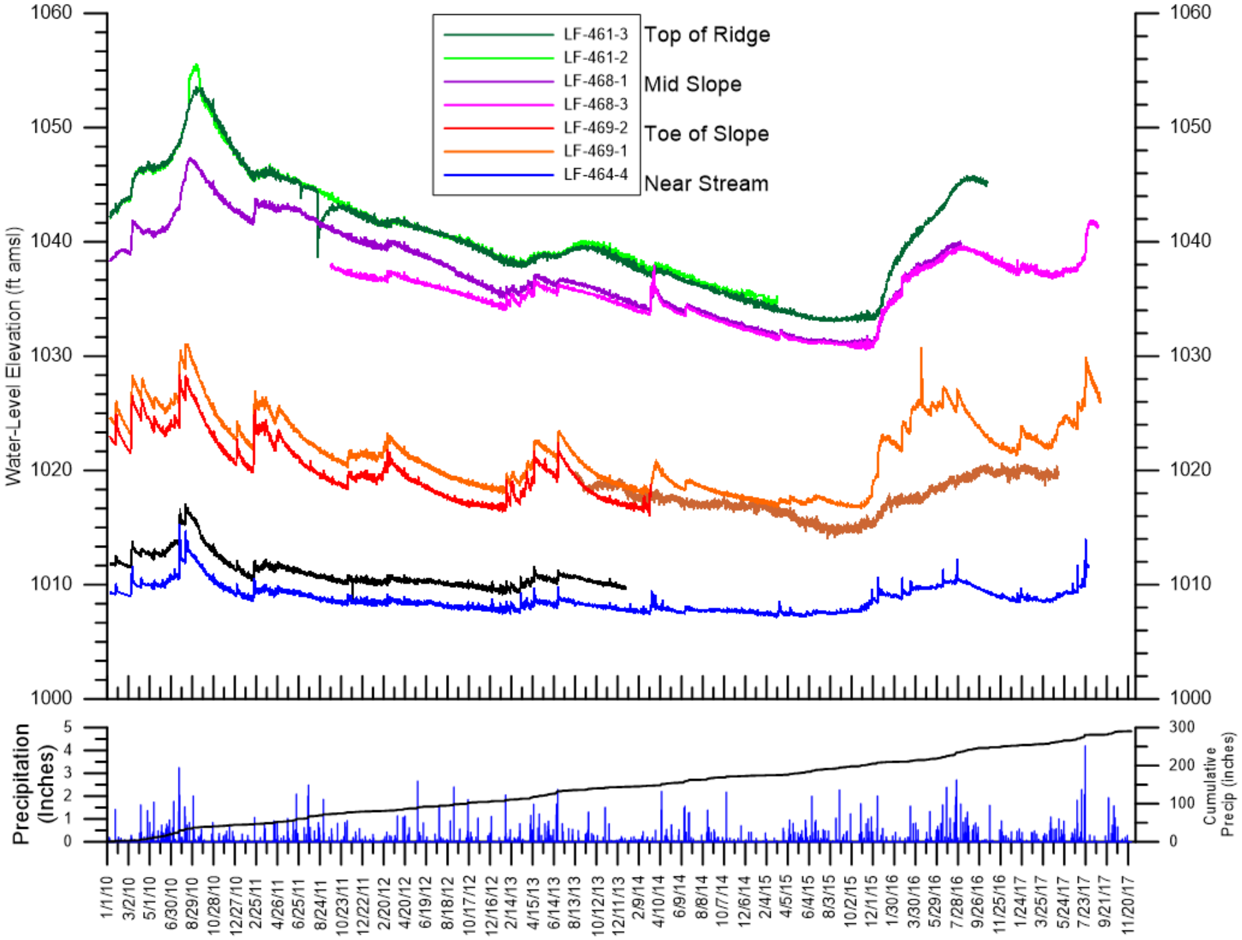


Figure 13. Graph of water levels from recovered Solinst dataloggers for the period January 2010 to November 2017. Bottom graph shows daily precipitation (bars) and cumulative precipitation from NWS station at Lancaster, WI.

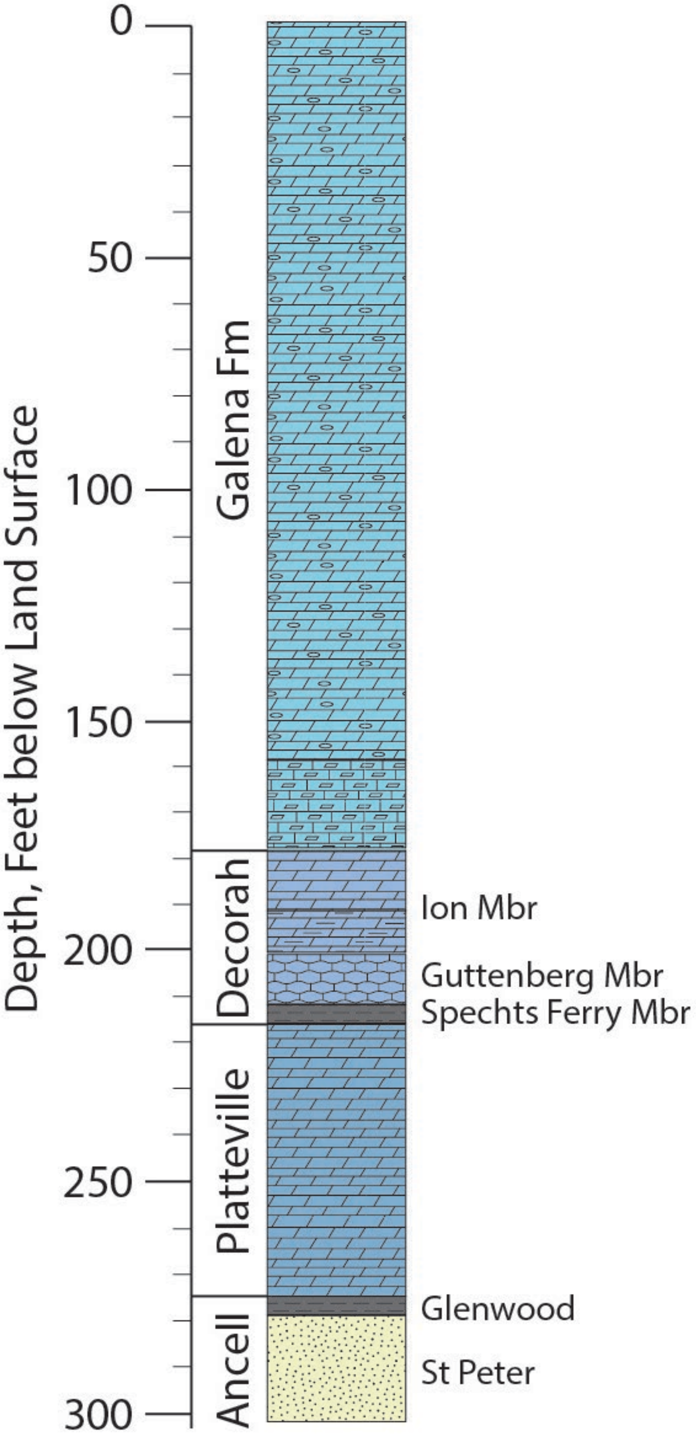


Figure 174. Stratigraphic log for borehole LF-493 which is located on the ridge crest at Pioneer Farm. Total hole depth is 303.5 feet below ground surface.

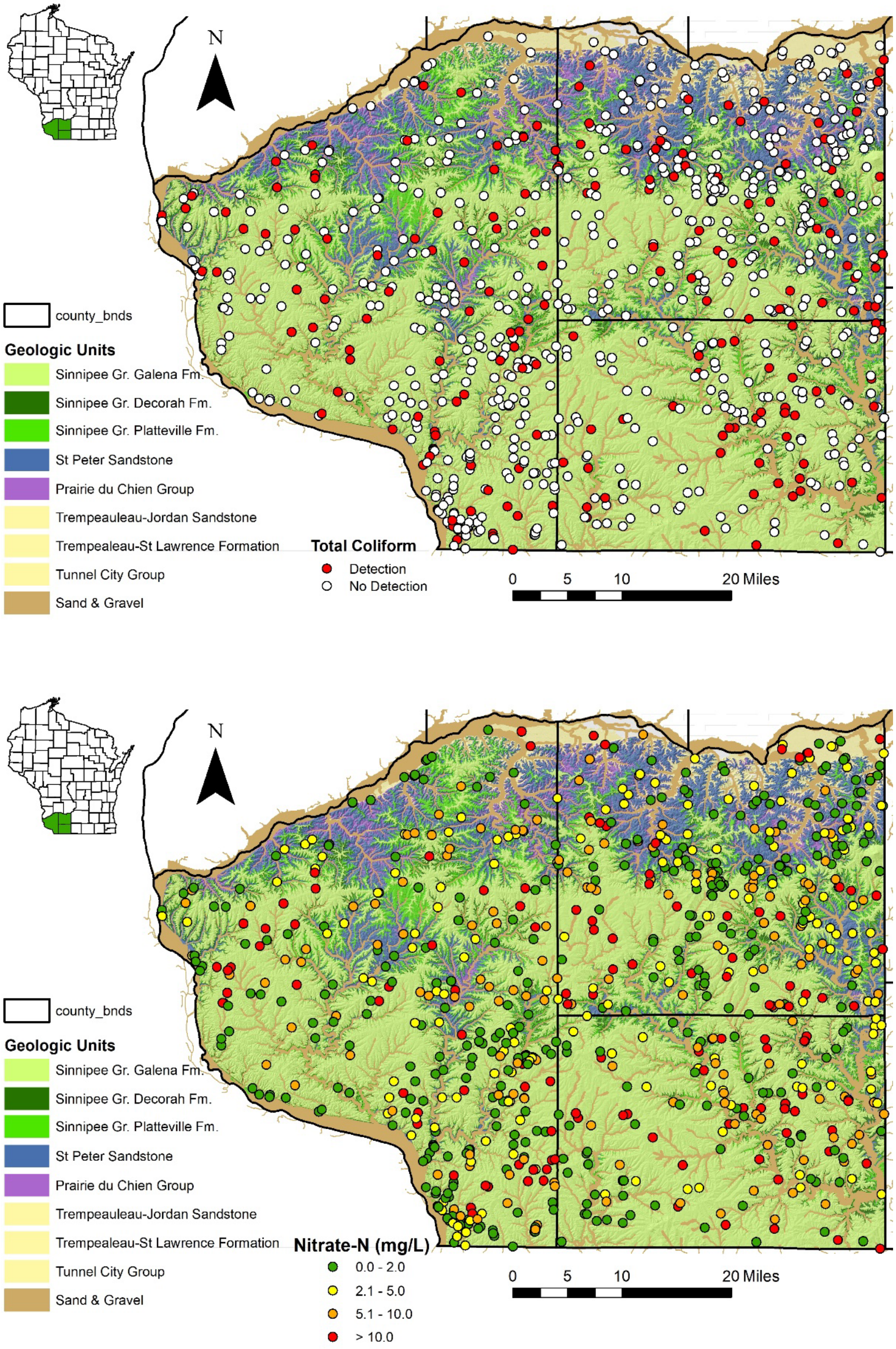
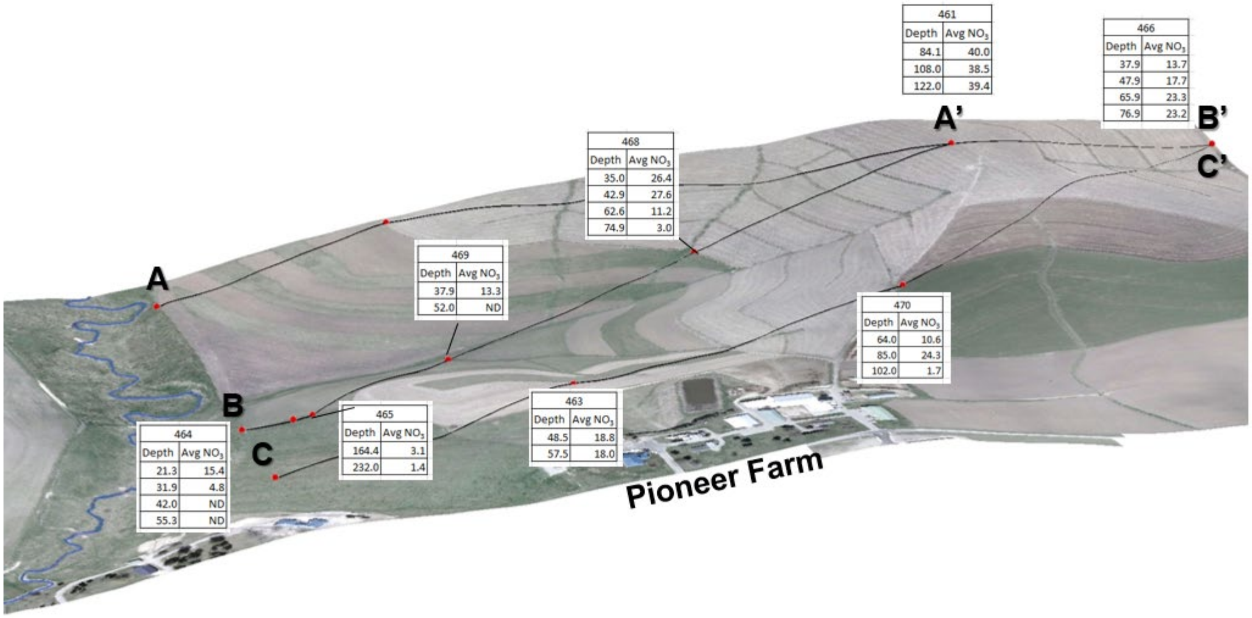


Figure 15. Results from both synoptic sampling events conducted for the SWIGG study. The top map shows total coliform results and the bottom map shows nitrate-N results from 816 domestic wells.



461

Depth	Avg NO_3
84.1	40.0
108.0	38.5
122.0	39.4

466

Depth	Avg NO_3
37.9	13.7
47.9	17.7
65.9	23.3
76.9	23.2

468

Depth	Avg NO_3
35.0	26.4
42.9	27.6
62.6	11.2
74.9	3.0

469

Depth	Avg NO_3
37.9	13.3
52.0	ND

470

Depth	Avg NO_3
64.0	10.6
85.0	24.3
102.0	1.7

464

Depth	Avg NO_3
21.3	15.4
31.9	4.8
42.0	ND
55.3	ND

465

Depth	Avg NO_3
164.4	3.1
232.0	1.4

463

Depth	Avg NO_3
48.5	18.8
57.5	18.0

Figure 16. Average NO_3-NO_2-N based on ten samples collected between August 2020 and August 2021. In general, nitrate-N concentrations (mg/L) are highest at sampling locations near the top of the ridge and decrease toward the Upper Fever River (downgradient flow direction).

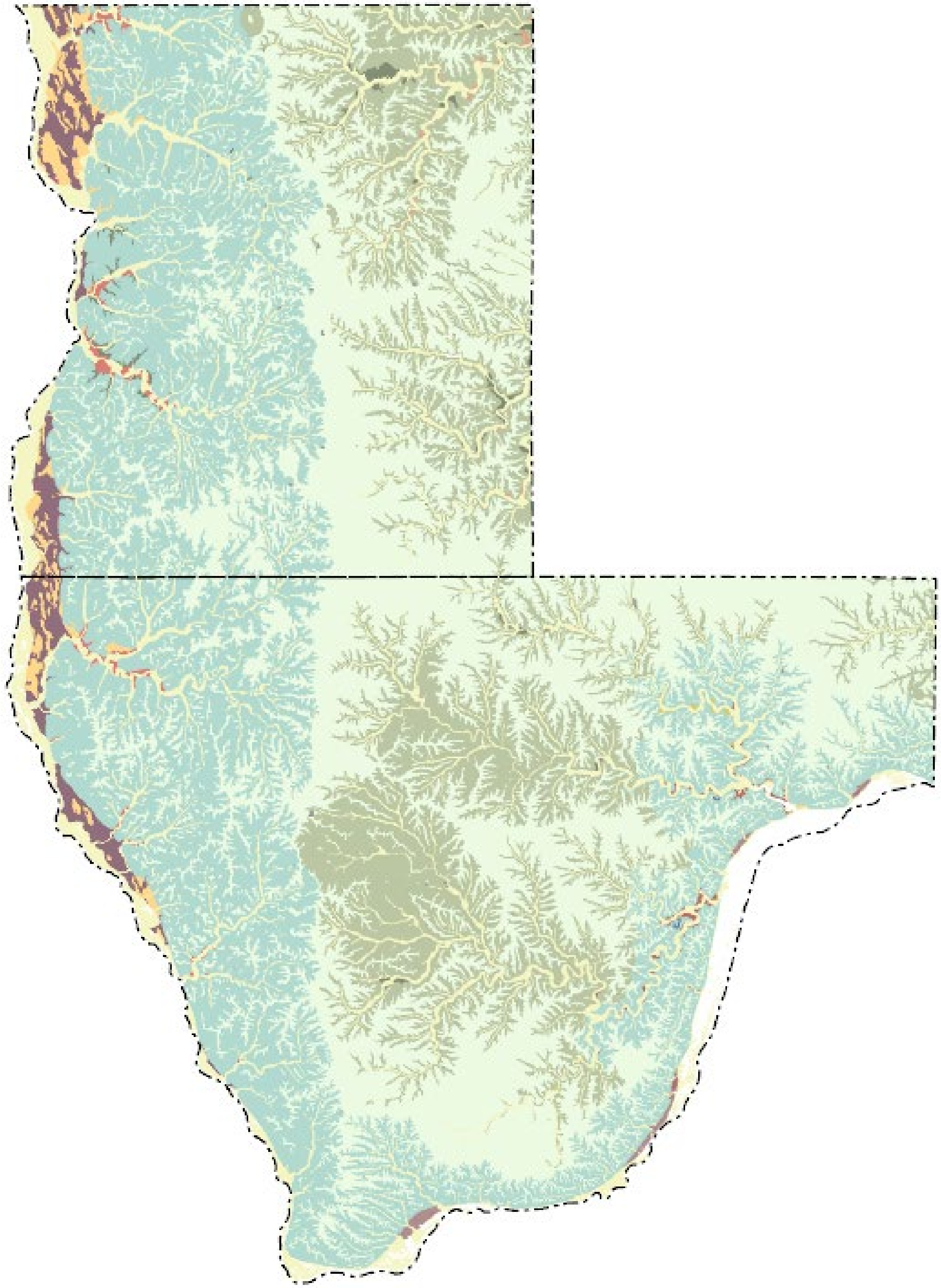
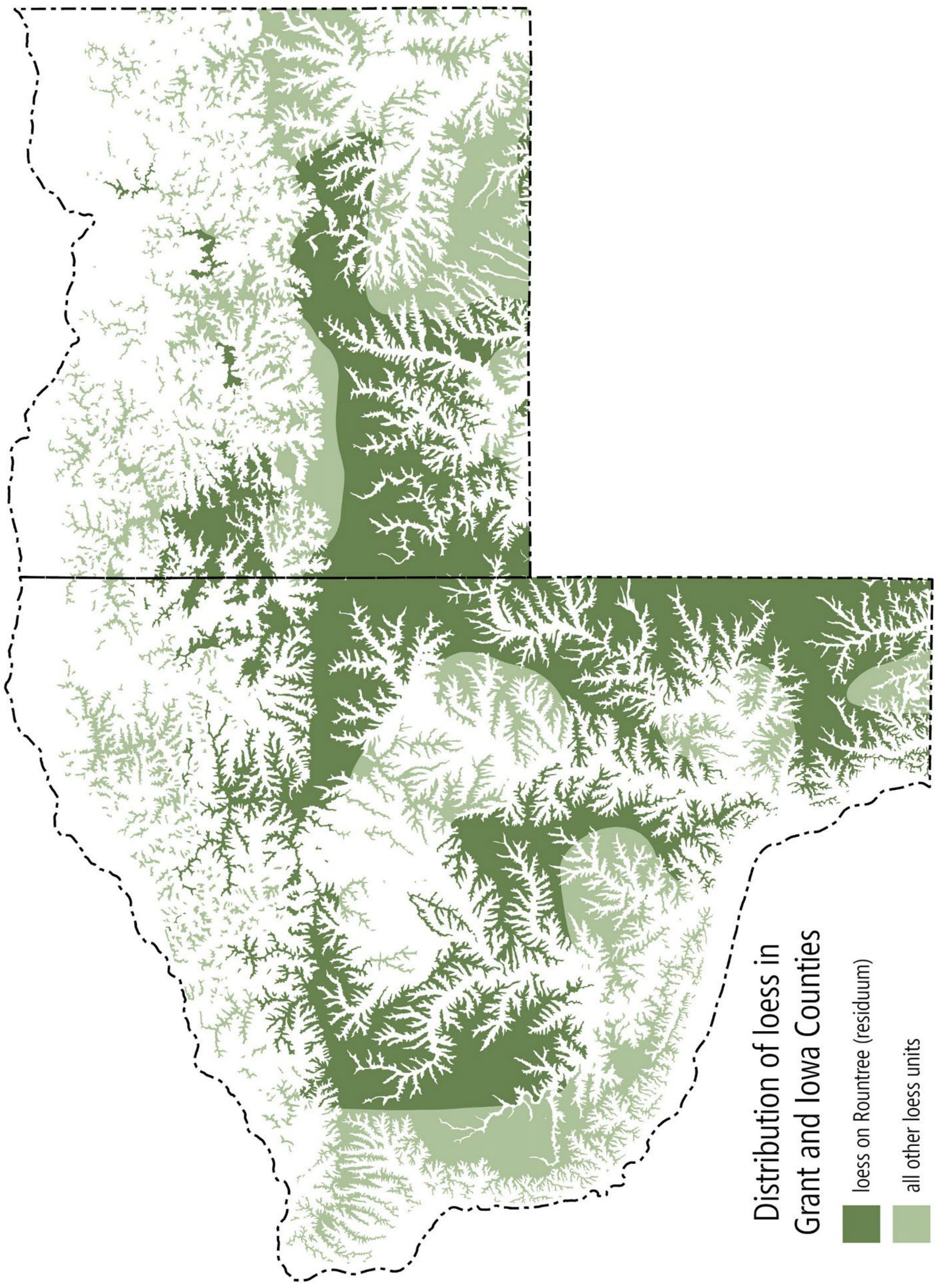


Figure 17 (previous page). Representation of 1:100,000 scale mapping completed for Grant and Iowa Counties as part of this project. Main colors of interest are pale green = upland surfaces that are capped by loess and subdivided base on underlying material of Rountree Formation, Readstown Member, Maquoketa Shale, undifferentiated bedrock, or Pre-Illinoian till; olive green = fine-grained colluvium on moderate slopes; medium green = thin, coarse-grained colluvium on steep slopes.

Figure 18 (next page). Surficial geologic mapping of Grant and Iowa Counties isolating loess on Rountree Formation and all other loess units from any other map unit.



Distribution of loess in Grant and Iowa Counties

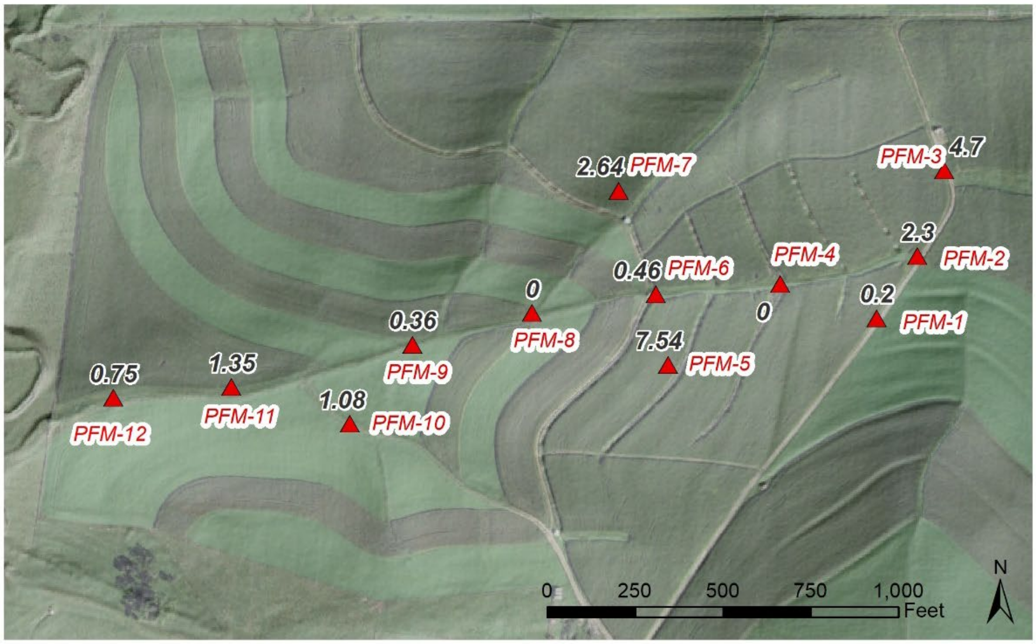


Figure 19. Geoprobe cores (red labels) and observed thickness of the Rountree Formation (black labels) at Pioneer Farm.

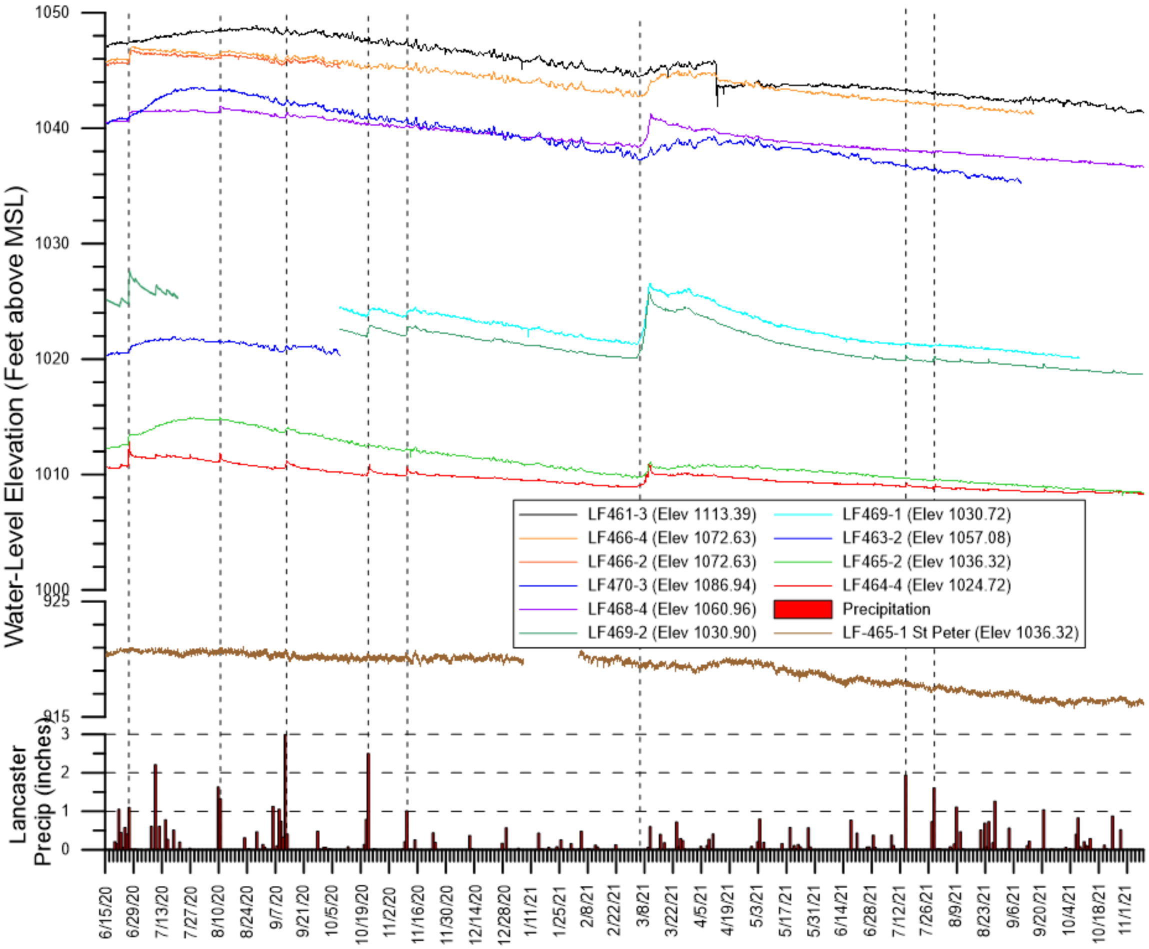


Figure 20. Graph of water levels from the reinstalled Solinst dataloggers for the period June 15, 2020 to August 31, 2021. Piezometer LF465-1 is shown on a different vertical axis than the other piezometers as the hydraulic head is significantly lower and placing all piezometers on the same axis would obscure the details on annual water-level fluctuations. Bottom graph shows daily precipitation (bars) from a weather station at Lancaster, WI. Dashed vertical lines indicate recharge events observed at the site.

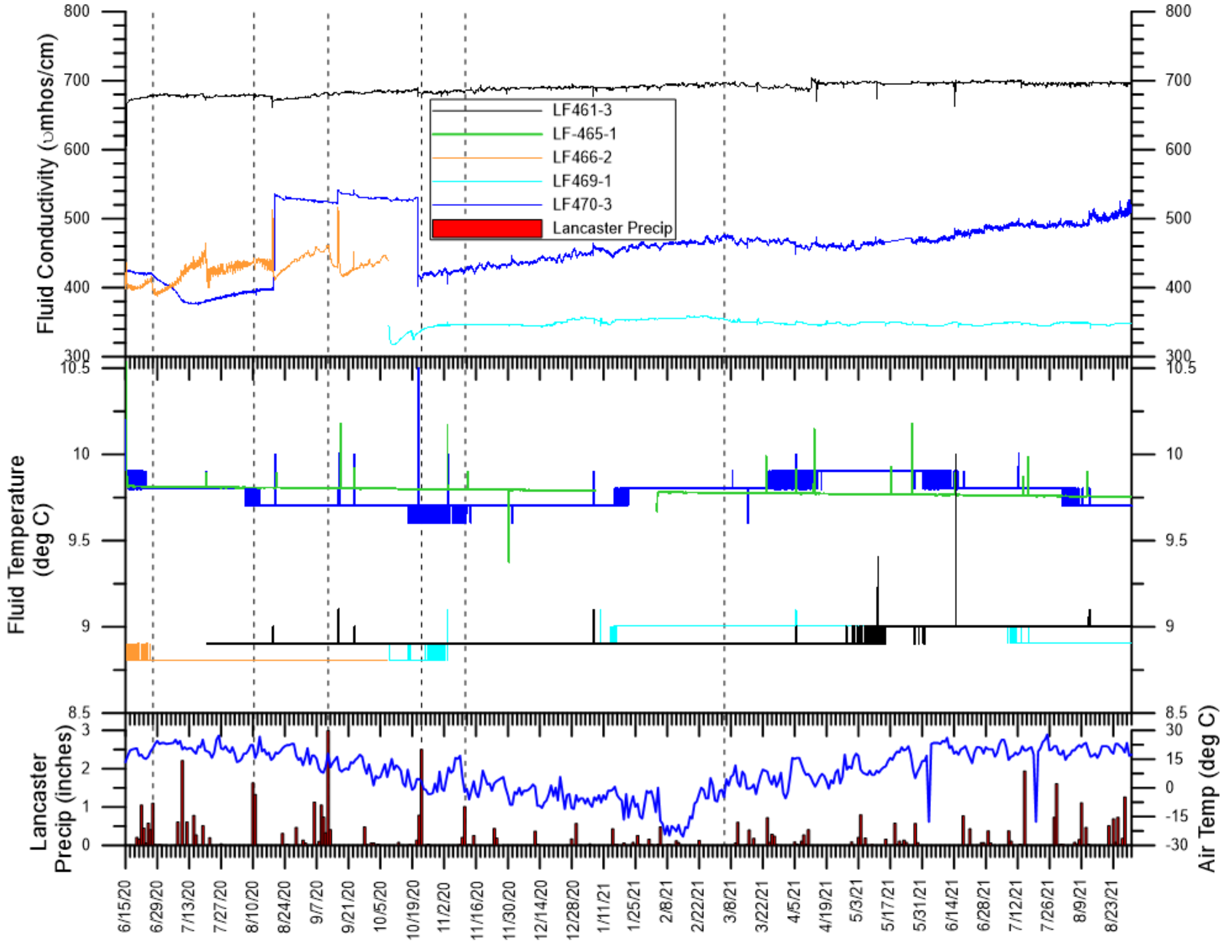


Figure 21. Graph of fluid conductivity (top) and fluid temperature (middle) measurements from piezometers at Pioneer Farm that show little seasonal variation in fluid temperature. The bottom graph shows precipitation and air temperature data from a weather station in Lancaster, WI. The dashed vertical lines are the same as those presented in Figure 19 and represent times when water-levels in the piezometers rose in response to precipitation or snow melt events (recharge events).

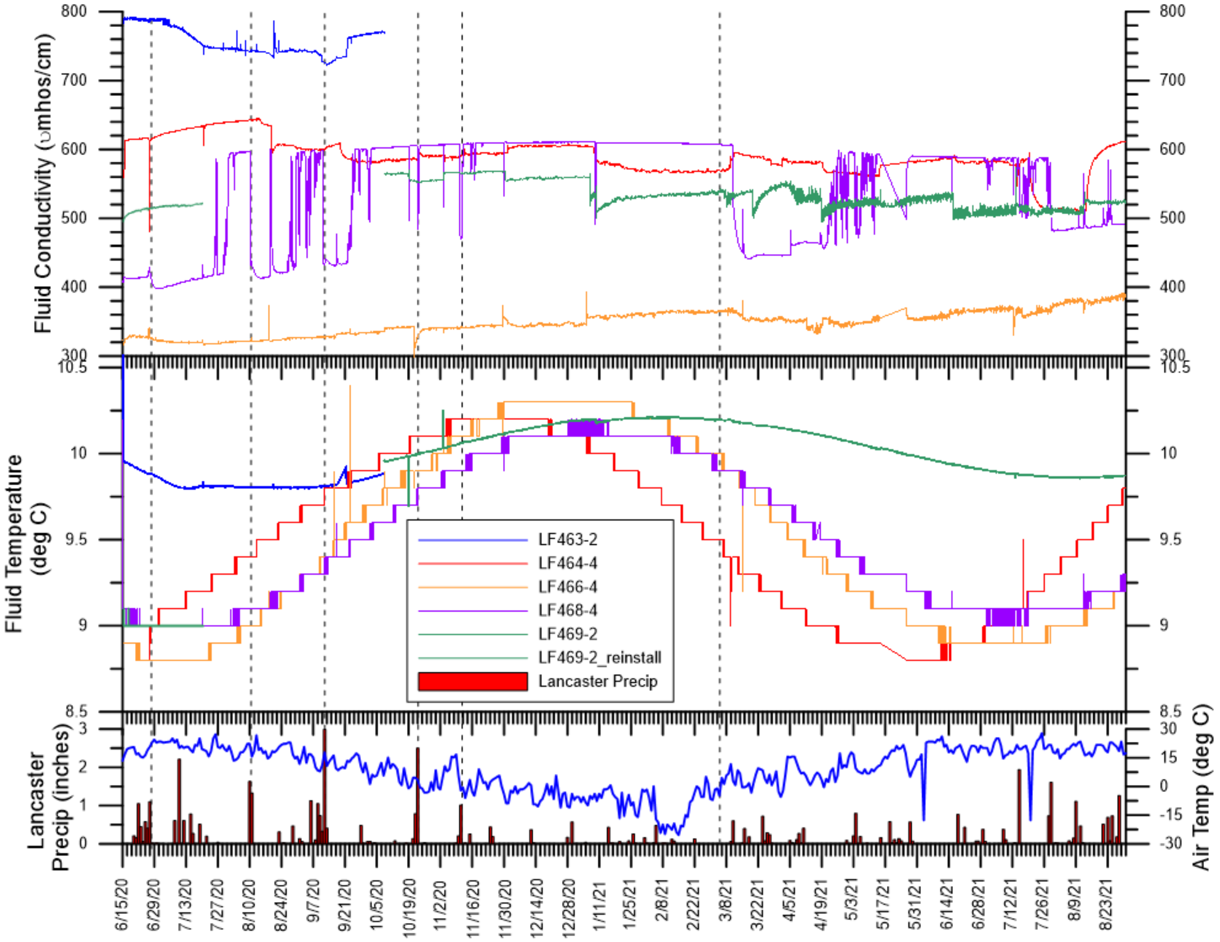


Figure 22. Graph of fluid conductivity (top) and fluid temperature (middle) measurements from piezometers at Pioneer Farm that show seasonal variation in fluid temperature. The bottom graph shows precipitation and air temperature data from a weather station in Lancaster, WI. The dashed vertical lines are the same as those presented in Figure 19 and represent times when water-levels in the piezometers rose in response to precipitation or snow melt events (recharge events).

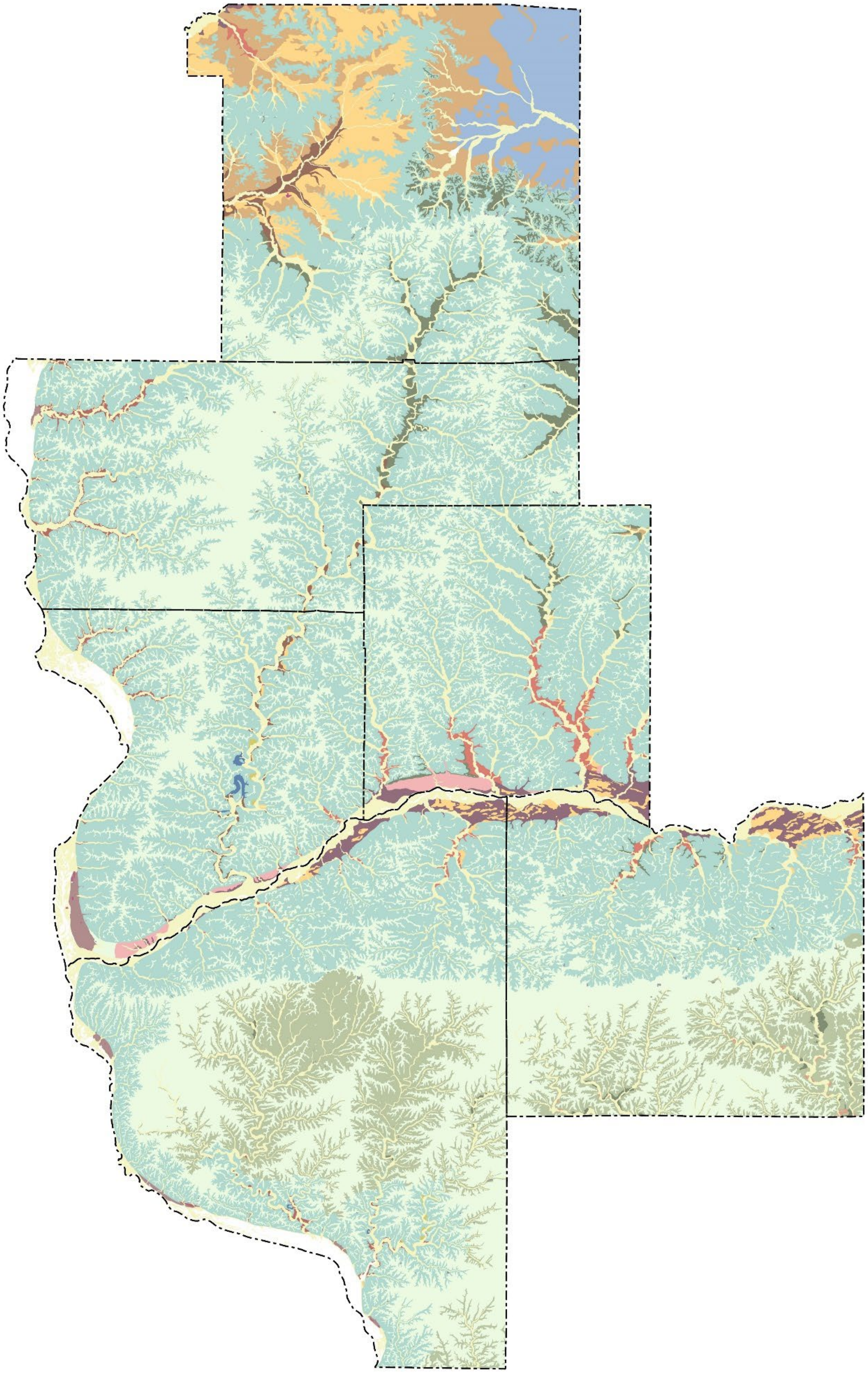
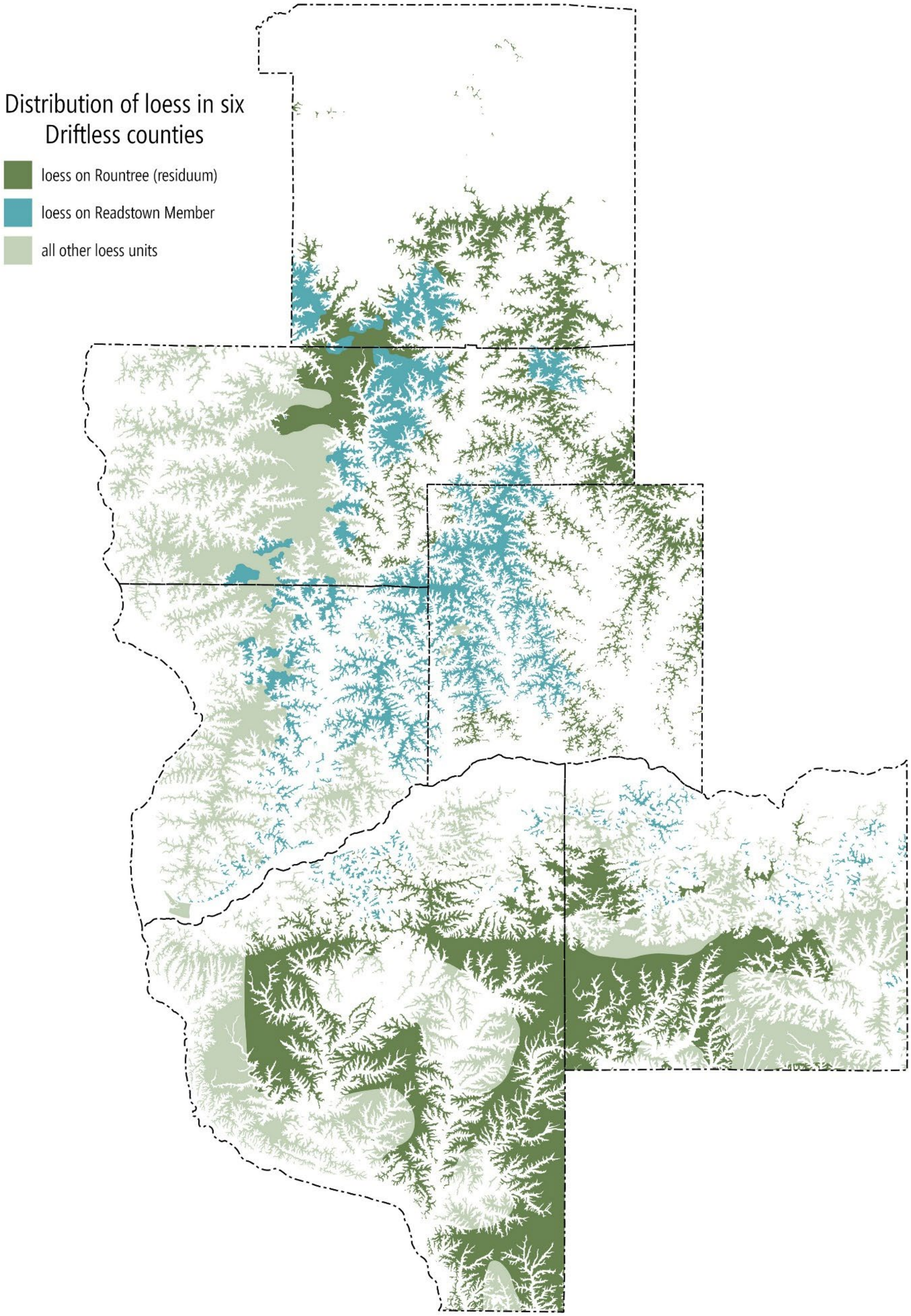


Figure 23 (previous page). Representation of 1:100,000 scale mapping completed for Grant and Iowa Counties as part of this project plus previously completed mapping for Crawford, Monroe, Richland, and Vernon Counties. Main colors of interest are pale green = upland surfaces that are capped by loess and subdivided base on underlying material of Rountree Formation, Readstown Member, Maquoketa Shale, undifferentiated bedrock, or Pre-Illinoian till; olive green = fine-grained colluvium on moderate slopes; medium green = thin, coarse-grained colluvium on steep slopes.

Figure 24 (next page). Surficial geologic mapping of Grant and Iowa Counties compared with Crawford, Monroe, Richland, and Vernon Counties isolating loess on Rountree Formation, loess on Readstown Member, and all other loess units from any other map unit.


Distribution of loess in six Driftless counties
loess on Rountree (residuum)
loess on Readstown Member
all other loess units

APPENDIX 1

Description of Geoprobe Cores from Pioneer Farm

Descriptions of the twelve Geoprobe cores collected at Pioneer Farm are included in this Appendix. The first three pages consist of a spreadsheet summarizing the sediment descriptions. The next 30 pages are the hand-written, detailed core logs. Detailed photos of the core have been placed into a zip file that accompanies this report. The photos are high-resolution and zooming will show the details of the sediment.

Site	drive_topft	drive_base ft	depth2top meters	depth2bottom meters	depth_to_top ft	depth_to_bottom ft	sed_texture	Interpretation
PFM-1	0	5	0.00	0.22	0.00	0.72	topsoil	topsoil
PFM-1	0	5	0.22	1.23	0.72	4.03	clayey silt	loess
PFM-1	0	5	1.23	1.29	4.03	4.23	clay	rountree
PFM-1	0	5	1.29	1.41	4.23	4.61	bedrock	bedrock
PFM-1	5	8	1.52	1.69	5.00	5.56	recore	recore
PFM-1	5	8	1.69	2.44	5.56	8.02	bedrock	bedrock w clay vugs
PFM-2	0	5	0.00	0.25	0.00	0.82	topsoil	topsoil
PFM-2	0	5	0.25	0.54	0.82	1.77	silty clay	loess
PFM-2	0	5	0.54	1.24	1.77	4.07	clay	rountree
PFM-2	0	5	1.24	1.30	4.07	4.26	clayey sand	altered bedrock
PFM-2	0	5	1.30	1.39	4.26	4.56	bedrock	bedrock
PFM-3	0	5	0.00	0.20	0.00	0.66	topsoil	topsoil
PFM-3	0	5	0.20	1.36	0.66	4.46	silt	loess
PFM-3	0	5	1.36	1.38	4.46	4.53	silty clay and gravel	rountree, transitional
PFM-3	5	10	1.52	1.67	5.00	5.49	recore	recore
PFM-3	5	10	1.67	2.79	5.49	9.16	clay	rountree
PFM-3	5	10	2.79	2.96	9.16	9.71	bedrock	bedrock
PFM-4	0	5	0.00	0.62	0.00	2.03	topsoil	topsoil
PFM-4	0	5	0.62	1.46	2.03	4.79	silt	loess
PFM-4	5	10	1.52	1.89	5.00	6.21	recore	recore
PFM-4	5	10	1.89	2.37	6.21	7.79	silt	loess
PFM-4	10	11	3.05	3.39	10.00	11.11	recore	recore
PFM-4	10	11	3.39	3.67	11.11	12.03	bedrock	bedrock
PFM-5	0	5	0.00	0.47	0.00	1.54	topsoil	topsoil
PFM-5	0	5	0.47	1.33	1.54	4.36	silt	loess
PFM-5	0	5	1.33	1.42	4.36	4.66	clay	rountree
PFM-5	0	5	1.42	1.46	4.66	4.77	silt	silty section of rountree
PFM-5	5	10	1.52	1.73	5.00	5.69	recore	recore
PFM-5	5	10	1.73	2.16	5.69	7.10	silt and gravel, clayey	rountree

Site	drive_topft	drive_base ft	depth2top meters	depth2bottom meters	depth_to_top ft	depth_to_bottom ft	sed_texture	Interpretation
PFM-5	5	10	2.16	2.31	7.10	7.59	clay	rountree
PFM-5	10	14	3.05	3.32	10.00	10.88	recore	recore
PFM-5	10	14	3.32	3.63	10.88	11.90	clay	rountree
PFM-5	10	14	3.63	3.79	11.90	12.42	clayey sand/altered bedrock	altered bedrock
PFM-6	0	5	0.00	0.30	0.00	0.98	topsoil	topsoil
PFM-6	0	5	0.30	0.67	0.98	2.20	silt	loess
PFM-6	0	5	0.67	0.70	2.20	2.30	clay	rountree
PFM-6	0	5	0.70	0.81	2.30	2.66	silt	rountree
PFM-6	5	10	1.52	1.77	5.00	5.82	recore	recore
PFM-6	5	10	1.77	2.24	5.82	7.36	bedrock	bedrock
PFM-7	0	5	0.00	0.42	0.00	1.38	topsoil	topsoil
PFM-7	0	5	0.42	0.49	1.38	1.61	silty clay	transitional
PFM-7	0	5	0.49	0.64	1.61	2.10	clayey silt , some gravel	rountree
PFM-7	0	5	0.64	1.30	2.10	4.25	clay, some gravel	rountree
PFM-7	5	8	1.52	1.62	5.00	5.33	recore	recore
PFM-7	5	8	1.62	2.23	5.33	7.33	clayey sand/altered bedrock	altered bedrock
PFM-8	0	4.5	0.00	0.44	0.00	1.44	topsoil	topsoil
PFM-8	0	4.5	0.44	0.83	1.44	2.72	silt	loess
PFM-8	0	4.5	0.83	1.16	2.72	3.80	clayey sand/altered bedrock	altered rock
PFM-9	0	5	0.00	0.60	0.00	1.97	topsoil	topsoil
PFM-9	0	5	0.60	1.05	1.97	3.44	clayey silt	loess
PFM-9	5	10	1.52	1.60	5.00	5.26	recore	recore
PFM-9	5	10	1.60	1.71	5.26	5.62	clay, silt, gravel	transitional, possible rountree

Site	drive_topft	drive_base ft	depth2top meters	depth2bottom meters	depth_to_top ft	depth_to_bottom ft	sed_texture	Interpretation
PFM-9	5	10	1.71	2.57	5.62	8.44	bedrock with clay vugs	bedrock with clay vugs
PFM-9	10	13	3.05	3.21	10.00	10.52	recore	recore
PFM-9	10	13	3.21	3.86	10.52	12.65	bedrock	bedrock
PFM-10	0	5	0.00	0.22	0.00	0.72	road grade	road grade
PFM-10	0	5	0.22	0.64	0.72	2.10	topsoil	topsoil
PFM-10	0	5	0.64	1.15	2.10	3.77	silt	loess
PFM-10	5	10	1.52	1.85	5.00	6.08	recore	recore
PFM-10	5	10	1.85	2.40	6.08	7.89	silt	loess
PFM-10	5	10	2.40	2.73	7.89	8.97	saturated clay, sand, silt	possible rountree
PFM-10	5	10	2.73	2.74	8.97	9.00	bedrock	bedrock
PFM-10	10	15	3.05	3.49	10.00	11.44	recore	recore
PFM-10	10	15	3.49	4.33	11.44	14.20	bedrock w clay vugs	bedrock w clay vugs
PFM-11	0	5	0.00	1.04	0.00	3.39	silt	topsoil/loess
PFM-11	5	10	1.52	1.96	5.00	6.44	silt and clayey silt	transitional
PFM-11	5	10	1.96	2.37	6.44	7.79	silty clay and gravel	rountree
PFM-11	5	10	2.37	2.65	7.79	8.71	bedrock	bedrock
PFM-12	0	5	0.00	0.85	0.00	2.79	silt	topsoil/loess
PFM-12	0	5	0.85	1.31	2.79	4.30	silty clay, gravel at base	transitional
PFM-12	5	7	1.52	1.75	5.00	5.75	silty clay and gravel	rountree
PFM-12	5	7	1.75	1.93	5.75	6.34	bedrock	bedrock

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM-1
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 -- 5
DESCRIBER: Graham
DATE: 11/20/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
		top soil						
22cm	X	10YR 4/4 dark yellowish bawn	Clayey silt	well	none	oxidized	none	chert pebble @ 73 and 93cm
123cm	X	7.5YR 4/4 brown	clay	well	none	oxidized	light	
129cm	X	10YR 4/6 dark yellowish brown	fine sand	well	none	none	med	Dolomite Bedrock
140.5cm								

EDC @ 140.5 cm

PFM-1
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM-1
SECTION ID:
PROJECT NAME: Rowntree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 8
DESCRIBER: Graham
DATE: 11/20/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		Recore						
17cm 20 30 40 50 60 70 80 90		10YR 6/6 brownish yellow	bedrock broken to fine sand + gravel	—	—	ox	med	Dolomite bedrock clay vug @ 88 cm
92cm 100 110 120 130 140 150					EOC@92 cm			

PFM-1
5-8' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-2A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 - 5
DESCRIBER: Graham
DATE: 11/20/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20		Top soil						
25cm 30 40 50	X	10YR 4/4 dark yellowish brown	silty clay	well	none	none	none	
54cm 60 70 80 90 100 110 120	X	7.5YR 4/4 brown	clay	well	none	oxidized	none	
124cm	X	10YR 4/6 dark yellowish brown	clayey sand	well	—	—	med	transitional
130 cm	X	10YR 6/6 brownish yellow	fine sand	well	—	—	med	
139cm 140 150					EOC @ 139cm			

PFM-2
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM-2
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette

WID:
DRILLED INTERVAL (FT): 5 – 7
DESCRIBER: Graham
DATE: 11/20/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		Recor						
15cm 20 30 40 50		10YR 6/6 brownish yellow	Bedrock	well	none	oxidized	med	Dolomite bedrock
58cm 60 70 80 90 100 110 120 130 140 150					EOC @ 58cm			

PFM-2
5-7' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-3A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette

WID:
DRILLED INTERVAL (FT): 0 -- 5
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
0–20								Top soil
20 cm	X	10YR 4/4 dark yellowish brown	silt	well	none	oxidized	none	clayey toward top
136 cm 138cm		7.5YR 4/6 strong brown	silty clay+gravel	well	none	oxidized	none	

EOL @ 138 cm

PFM20-3
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-3A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 10
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		Recore						
15cm								
20		7.5YR 4/6 strong brown	clay	well	none	oxidized	light	
30								
40								
50	X							
60								
70								
80								
90								
100								Silty pockets toward base. Transitional?
110								
120	X							
27cm								
130		10YR 7/6 yellow	fine sand, clay	well	none	oxidized	light	Altered bedrock w/ clay vugs
140	X							
143.5cm								
150					EOC @ 143.5 cm			

PFM20-3
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-3A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 10 --13 BR
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
		Recore						
7cm 10 20 30 40 50 60 70		Sand: 10YR 5/8 yellowish brown Clay: 7.5YR 4/6 strong brown	fine sand and clay	well	none	oxidized	light	Bedrock w/ clay vugs
79cm 80 90 100 110 120 130 140 150					EOC @ 79 cm			

PFM20-3
10-13' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-4A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 -- 5'
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 30 40 50 60		10YR 2/2 v. dark brown						top soil to 62 cm
62cm 70 80 90 100 110 120 130 140		10YR 4/4	silt	well	none	oxidized	none	
146cm	X							
150					EOC @ 146 cm			

PFM20-4
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-4A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 10'
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 30		Recore						
37cm 40 50 60 70 80	X	10YR 4/4 dark yellowish brown	silt	well	none	oxidized	none	C14 sampled @ 66cm Some gravel @ base
85cm 90 100 110 120 130 140 150					EOC @ 85cm			

PFM20-4
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-4A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 10 -- 11
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 30		Recore						
34cm 40 50 60	X	10YR 6/4 light yellowish brown	fine sand + gravel	—	none	—	Med	Dolostone bedrock
62cm 70 80 90 100 110 120 130 140 150					EOC @ 62cm			

PFM20-4
10-11' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-5A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 – 5
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
47cm		10YR 2/2 V. dark brown	clayey silt	well	none	none	none	Topsoil
133cm	X	10YR 4/4 dark yellowish brown	silt	well	none	oxidized	none	
142cm	X	7.5YR 4/4 brown	clay	well	none	oxidized	none	possible ped formation
145.5cm		10YR 4/4	silt	well	none	ox	none	

EOC @ 145.5cm

PFM20-5A
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-5A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -10
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		Recore						
21cm 20 30 40 50 60	X	10YR 4/4 Dark yellowish brown	Silt and gravel w/ clayey streaks	med	none	none	light over dolostone gravel	Chert and dolomite gravels. dolomite (broken to fine sand)
64cm 70	X	7.5YR 4/4 brown	clay	well	none	ox.	light	w/ gravel nede contact w/ above. Breaks into small aggregates
79cm 80 90 100 110 120 130 140 150					EOC @ 79cm			

PFM20-5A
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-5A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 10 -- 14 BR
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
0–27cm		Recore						
27cm–58cm		7.5YR 3/4 dark brown	Clay and sandy clay	med.	none	oxidized	light to med.	clay and altered bedrock
58cm–74cm	X	10YR 6/4 light yellowish brown	clayey fine sand					
74cm					EOC @ 74cm			

PFM20-5A
10-14' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-6A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette

WID:
DRILLED INTERVAL (FT): 0 -- 5'
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
		10YR 2/2 V. dark brown	Clayey silt					top soil
30 cm	X	10YR 4/4	Silt	well	none	oxidized	none	
67cm	x	7.5YR 4/6 strong brown	Clay	well	none	oxidized	none	contains chert gravel
70cm		10YR 4/4	silt	well	none	oxidized	none	
81cm								bedrock contact @ 81cm

PFM20-6A
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-6A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 10
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20		Recore						
25cm 30 40 50 60 70 72cm	X	10YR 6/4 light brown and 10YR 4/6 dark yellowish brown	fine sand & gravel w/ some finer grained where darker.	well	none	—	med	Bedrock
80 90 100 110 120 130 140 150					EOC @ 72cm			

PFM20-6A
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-6A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 10 -- 10.5' BR
DESCRIBER: Graham
DATE: 12/3/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		Recore						
17cm								
20					EOC @ 17cm			
30								
40								
50								
60								
70								
80								
90								
100								
110								
120								
130								
140								
150								

PFM20-6A
10-10.5' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-7A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 - 5'
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 30 40		10YR 4/4 Dark yellowish brown	Clayey silt	well	none	none	none	top soil to 13cm
42cm		7.5YR 4/4 brown	silty clay	well	none	oxidized	none	
49cm 50 60		10YR 4/4	clayey silt, some gravel	well	none	oxidized	light	
64cm 70 80 90 100 110 120	X	7.5YR 4/6 strong brown	clay, some gravel	well	none	oxidized	none	Rountree chert gravel Sandy @ base. Likely BR contact @ 129.5cm
129.5cm 130 140 150					EOC @ 129.5cm			

PFM20-7A
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20 – 7A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 8'
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
		Recore						
10cm 10								
20		10YR 7/3 very pale brown	clayey fine sand + gravel	NA/ poor	none	none	med.	Altered bedrock
30		7.5YR 5/6 strong brown	clayey					
40								
50								
60								
70	X							
71cm								
80					EO.C @ 71 cm			
90								
100								
110								
120								
130								
140								
150								

PFM20-7A
5-8' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20 - 8A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 -- 4.5'
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
		10YR 2/2 v. dark brown	Silt	well	none	none	light	Topsoil to 44cm
44cm	X	10YR 4/4 dark yellowish brown						chert @ 82 cm
83cm	X	10YR 7/3 very pale brown and 7.5YR 5/6 strong brown	fine sand + gravel, clayey	—	—	—	med	Bedrock
116cm					EOC @ 116 cm			

PFM20-8A
0-4.5' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM 20 – 9A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 -- 5
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		10YR 2/2 Very dark brown	silt, clayey silt	well	none	oxidized	none	
20								
30								
40								
50								
60cm 60		10YR 4/4 dark yellowish brown						
70								
80								
90								
100	X							
105cm								
110					EOC @ 105 cm			
120								
130								
140								
150								

PFM20-9A
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20 - 9A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 10
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
8cm		Recore						
10 19cm	X	10YR 3/6 dark yellowish brown	Clayey silt + gravel	poor	none	oxidized	light	possible recore? C14 sampled @ 11cm.
20 30 40 50 60 70 80 90 100 105cm	X	10YR 6/4 light yellowish brown	fine sand + gravel. some clay	—	none	none	Med.	Dolostone Bedrock w/ clay Vugs
110 120 130 140 150					EOC @ 105cm			

PFM20-9A
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-9A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 10 -- 13
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		Recore						
16cm 20 30 40 50 60 70 80	X	10YR 5/6 yellowish brown	fine sand, gravel clay	poor	none	none	med.	Bedrock Facies change @ 65cm? silty @ base
81cm 90 100 110 120 130 140 150					EOC @ 81 cm			

PFM20-9A
10-13' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20- 10A
SECTION ID:
PROJECT NAME: Rowntree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 -- 5
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20		Road	grade					
22cm								
30 40 50 60		10YR 2/2 v. dark brown	Silt	well	none	none	none	
64cm								
70 80 90 100 110 120		10YR 4/4 dark yellowish brown						
115cm	X							
130 140 150					EOC @ 115 cm			

PFM20-10A
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-10
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 10
DESCRIBER: Graham
DATE: 12/04/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 30		Recore						
33cm 40 50 60 70 80		10YR 4/4 dark yellowish brown	silt	well	none	oxidized	none	
88cm 90 100	X	10YR 4/4 + 7.5YR 4/6 strong brown	clay, silt, sand	well	none	oxidized	light	saturated
112cm 110		10YR 4/3	+ gravel	poor				
121cm 120 122cm 130 140 150		10YR 6/4 light yellowish brown	fine sand	well	none	—	light	Bedrock @ base

PFM20-10A
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-10A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette

WID:
DRILLED INTERVAL (FT): 10 -- 15 BR
DESCRIBER: Graham
DATE: 12/4/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10–40		Recore						
44cm–128cm	X	10YR 5/6 Yellowish brown	fine sand, gravel, clay	NA/ poor	none	None	med	Bedrock w/ clay clay vugs
128cm–150					EOC @128cm			

PFM20-10A
10-15' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20 - 11A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 0 -- 5
DESCRIBER: Graham
DATE: 12/10/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		10YR 2/1 black	silt	well	none	none	none	
20								
30								
40								
50								
60								
70								
80								
90								
103.5cm 100	X							
110					EOC @ 103.5cm			
120								
130								
140								
150								

PFM20-11
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-11
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 10
DESCRIBER: Graham
DATE: 12/10/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 30 40 44cm		10YR 2/1 black	Silt + Clayey silt	well	none	oxidized	none	transitional
50 60 70 80 85cm	X	10YR 4/3 brown; 10YR 4/6 dark yellowish brown; 10YR 2/1 black	clay/ silty clay + gravel	poor	mottled	oxidizd	none	
90 100 110 113cm	X	10YR 5/6 yellowish brown	fine sand + gravel	—	none	none	med.	Crushed bedrock
120 130 140 150					EOC @ 113 cm			

PFM20-11
5-10'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM 20-11
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 10 -11 BR
DESCRIBER: Graham
DATE: 12/10/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20			Recore					
22cm 30 40 50		10YR 5/6 yellowish brown	fine sand + gravel	NA well	none	none	med.	Dolostone Bedrock
58cm 60 70 80 90 100 110 120 130 140 150								

PFM20-11
10-11' BR

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-12A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette

WID:
DRILLED INTERVAL (FT): 0 -- 5
DESCRIBER: Graham
DATE: 12/10/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10		10YR 2/1 black	silt	well	none	oxidized	none	
20								
30								
40								
50								
60	X							
70								
80								
85cm								
90		10YR 4/3 brown; 10YR 4/6 dark yellowish brown; 10YR 2/1 black	silty clay	med	mottled possible ped formation	oxidized	none	
100								
110								
120								Chert gravel @ base
130	X							
131cm					EOC @ 131cm			
140								
150								

PFM20-12
0-5'

WGNHS INITIAL SEDIMENT CORE DESCRIPTION

SITE NAME: PFM20-12A
SECTION ID:
PROJECT NAME: Rountree
COUNTY: Lafayette
WID:
DRILLED INTERVAL (FT): 5 -- 7' BR
DESCRIBER: Graham
DATE: 12/10/20

SECTION LENGTH (cm)	SAMPLE	MUNSELL COLOR (Code + Name)	SEDIMENT TEXTURE	SORTING	SEDIMENT STRUCTURE	OXIDATION/ REDUCTION	REACTION w/ HCl	NOTES
10 20 23cm		10YR 4/3 brown; 10YR 2/1 black	Silty clay + gravel	med	mottled?	oxidized	none	Possible Recore
30 40 41cm	X	10YR 4/6 dark yellowish brown	bedrock broken to fine sand + gravel	NA	none	none	med	Dolostone Bedrock
50 60 70 80 90 100 110 120 130 140 150					EOC@ 41cm			

PFM20-12
5-7' BR

APPENDIX 2

Borehole Geophysical Date from Pioneer Farm Monitoring Well

Borehole geophysical data collected from monitoring well drilled on Pioneer Farm property. Higher resolution imagery is available from the Wisconsin Geological and Natural History Survey.

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

BOREHOLE GEOPHYSICAL LOG

WGNHS ID *33000493*
SITE NAME *PF21 DRAFT*
WUWN ______
COUNTY *Grant*
DATE *4/20/21*
LOGGED BY *Chase &Muldoon*

LATITUDE *42.717706*
LOCATION *4250 ft ENE College Farm Rd. @ Galena River, Belmont, WI*
LONGITUDE *-90.385299*
LOC METHOD ______
LOC CONF *+/- 30 ft.*

ELEVATION ______
WELL DEPTH *303.5*
CASING DEPTH *40.6*
ELEV. METHOD ______
DEPTH TO WATER *71.3*
CASING STICK UP *2.0*

Comments:

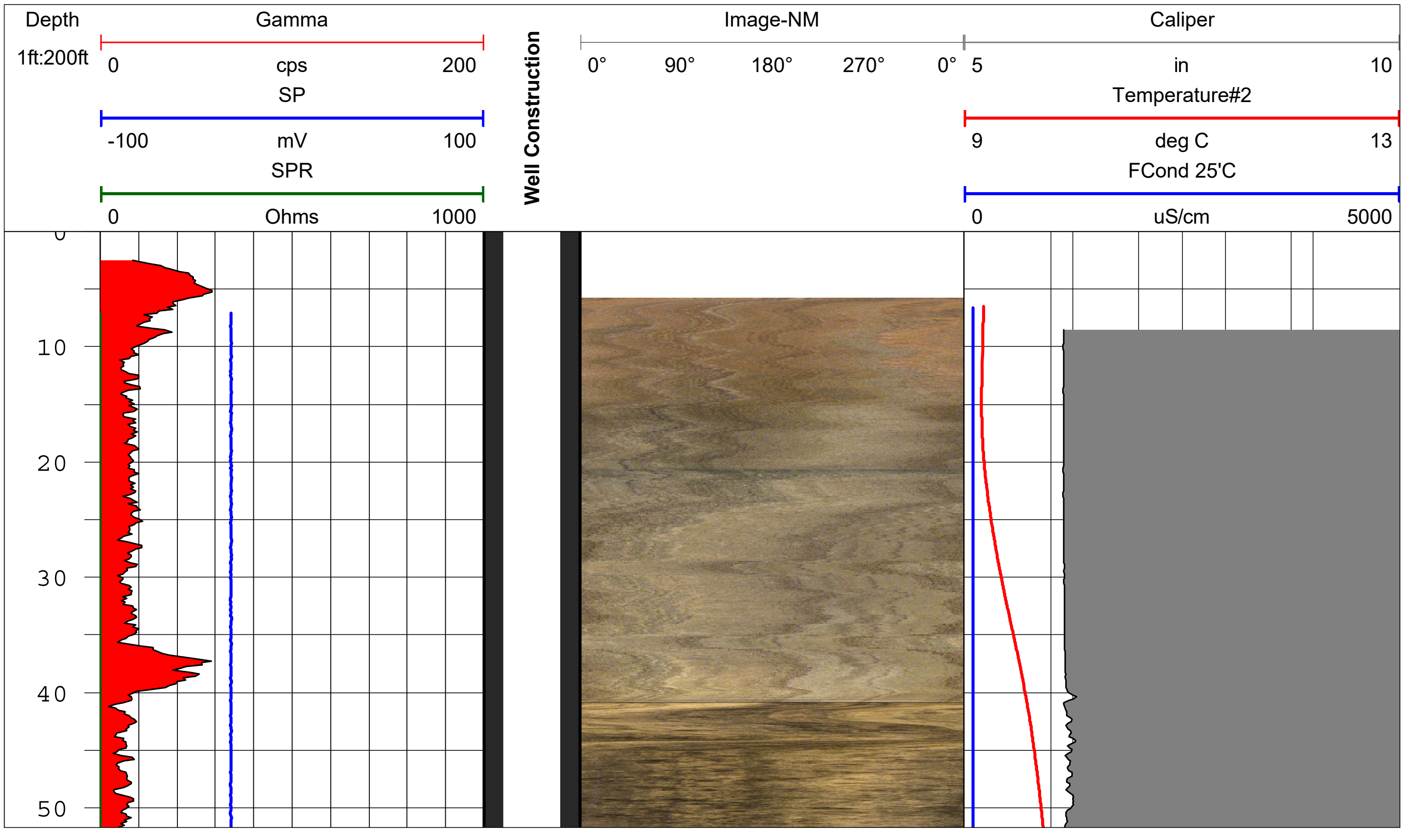
LOGS COLLECTED:

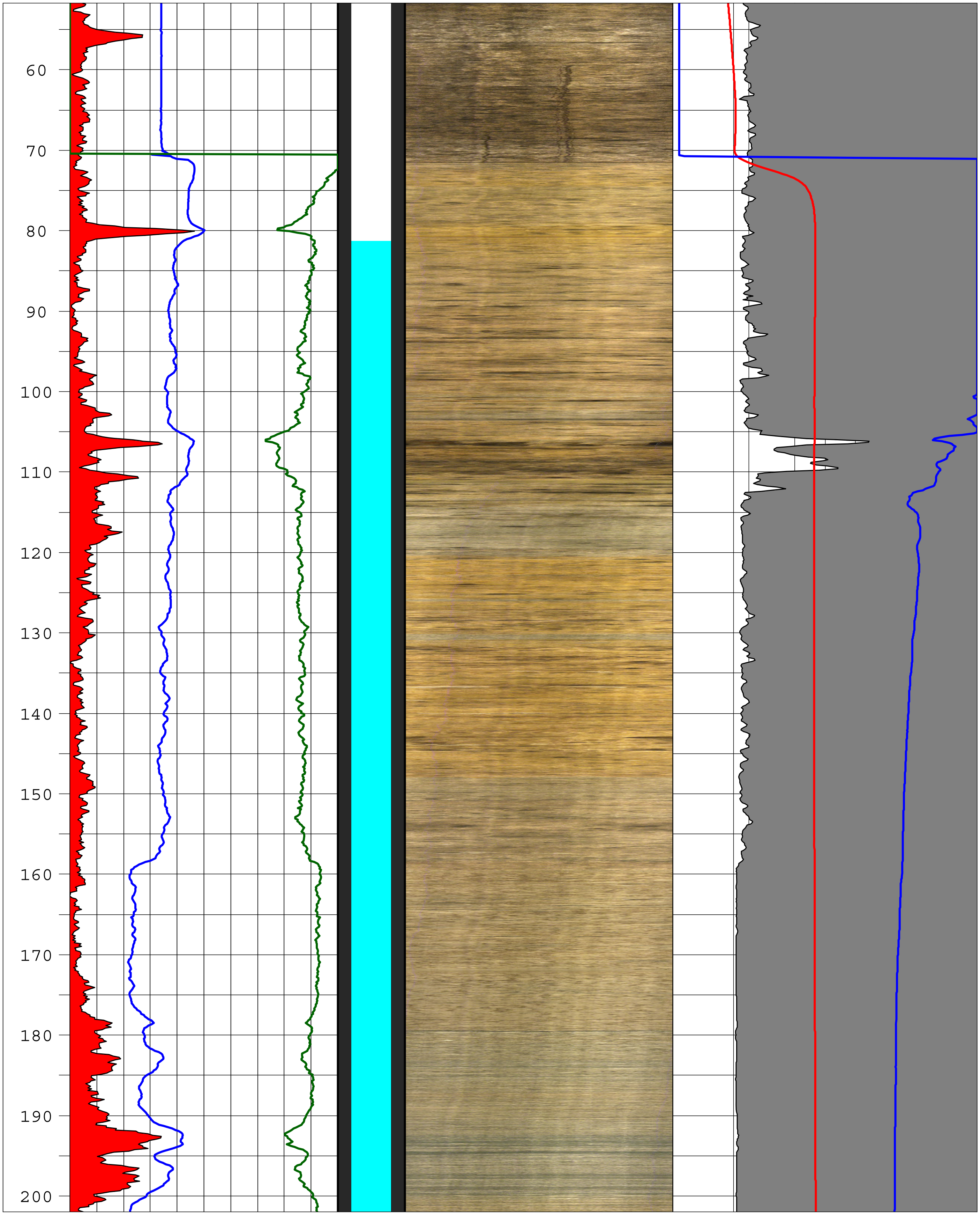
- ☒ **Gamma**
- ☒ **Caliper**
- ☒ **Single Point Resistivity**
- ☒ **Self Potential**
- ☐ **Normal Resistivity**
- ☒ **Fluid Temperature**
- ☒ **Fluid Conductivity**
- ☐ **Flow Meter- HeatPulse**
- ☒ **Flow Meter- Spinner**
  (up is negative; down is positive)
- ☒ **Optical Borehole Imager**
- ☐ **Acoustic Borehole Imager**
- ☐ **OTHER**

Unless noted, (1) all depths are in feet; (2) well depth, casing depth, and depth to water are interpreted from geophysical log; and (3) datum is the top of casing. For more information or to obtain collected data not shown, please contact: ***data@wgnhs.wisc.edu***

File Created on: ______

By: ______

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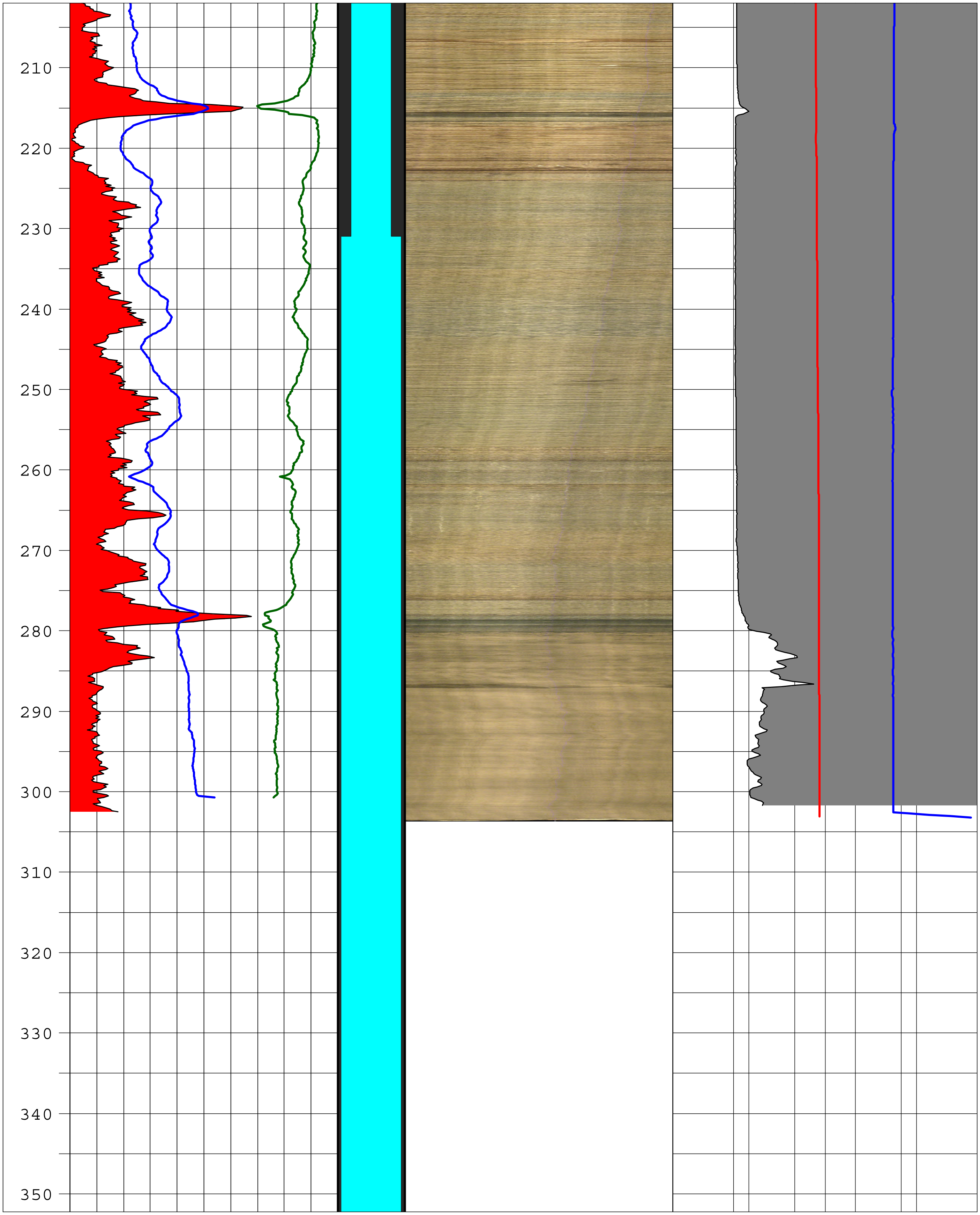

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