

Geologic Resources Inventory Scoping Summary Wilson's Creek National Battlefield, Missouri

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US Department of the Interior



The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a Geologic Resources Inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

The National Park Service held a GRI scoping meeting for Wilson's Creek National Battlefield on April 5, 2011 at park headquarters. Jason Kenworthy (NPS Geologic Resources Division) presented an overview of the Geologic Resources Inventory and led the discussion regarding geologic issues, features, and processes at Wilson's Creek National Battlefield. After Bill Duley (Missouri Department of Natural Resources) presented an overview of Missouri's geology, Tim Connors (NPS Geologic Resources Division) facilitated the discussion of map coverage at the park. In addition to Bill Duley, other geologists who were familiar with the local geology included Jerry Prewett (Missouri Department of Natural Resources) and Doug Gouzie (Missouri State University). Participants at the meeting also included Superintendent Ted Hillmer and Resource Manager Gary Sullivan. In the afternoon, Gary Sullivan led the participants on a field trip throughout the park. A complete list of participants and contact information is included in Table 2 at the end of this report. This scoping summary highlights the GRI scoping meeting for Wilson's Creek National Battlefield including the geologic setting, the plan for providing a digital geologic map, a description of geologic resource management issues, a list of significant geologic features and processes, and a record of meeting participants.

Park and Geologic Setting

Wilson's Creek National Battlefield lies southwest of Springfield, Missouri, and commemorates the first battle of the Civil War fought west of the Mississippi River. This battle, fought in 1861, initiated the fierce fighting, mostly by guerrilla warfare that would consume Missouri for the next three and a half years. At Wilson's Creek, Brigadier General Nathaniel Lyon became the first Union general to lose his life in the Civil War.

The battlefield's landscape is part of a geological province known as the Springfield Plateau, a region primarily underlain by relatively flat-lying layers of limestone, dolomite, and chert. These layers were that deposited approximately 350 million years ago (during the geologic period known as the Mississippian) when southwestern Missouri was covered by a shallow sea. The Springfield Plateau forms a subprovince of the Ozark Plateau that includes most of southern Missouri and contains the most extensive outcrop area of Ordovician-age (488 to 461 million years ago) rocks in the country. Ordovician rocks are exposed east of the Wilson's Creek area, primarily east of Greene and Christian counties.

Glacial deposits from the Pleistocene Ice Ages carpet northern Missouri but do not extend into southern Missouri. However, at least two glacial advances farther north produced Pleistocene loess (wind-blown silt) that was transported and deposited into southwestern Missouri (Castillon 1984).

Dissolution of the limestone on the Ozark Plateau produced a “karst” topography, characterized by sinkholes, caves, and underground drainage systems. The park contains caves, whose locations are not shared with visitors, and the following springs that are included in the Missouri Department of Natural Resources database: Short Spring, Ray Spring, Pipeline Spring, and Skeggs Branch Spring.

Radar Spring, one of the more notable springs in southwestern Missouri, lies northeast of the park. Discharging from a series of joints in the Burlington-Keokuk Limestone, Radar Spring empties into Wilson’s Creek. In the past, about half of the flow of the spring came from treated sewage effluent from the Springfield Southwest Treatment Plant. Subsequent improvements have eliminated this effluent and improved the water quality of the spring (Thomson 2003). Dye traces indicate that groundwater flow through underground caves and conduits is relatively rapid (Doug Gouzie, Assistant Professor of Geology, Missouri State University, personal communication, April 5, 2011). A dye trace done by Bill Duley in 1985 showed that groundwater traveled the 4.0 km (2.5 mi) from the waste water treatment plant near the Whispering Lanes Mobile Home Park to Radar Spring in 8 to 15 days (Thomson 2003).

The Mississippian Burlington-Keokuk Limestone is the dominant bedrock exposed in the park (fig. 1). Layers of limestone are interbedded with thin layers of chert. Chert nodules are also present within the limestone layers. The layers were originally deposited in a warm, shallow sea when the area was near the equator. The sea was an ideal environment for marine invertebrates, especially crinoids (fig. 2), brachiopods, and bryozoans now found as fossils throughout the region. Fossils of these invertebrates may be found within the Burlington-Keokuk Limestone as well as the underlying Elsey Formation, exposed along the banks of Wilson’s Creek, and Reeds Spring Formation, exposed near the southern boundary of the park.

The Elsey Formation may be difficult to differentiate from the Reeds Spring Formation, especially in Wilson’s Creek National Battlefield. Both contain thin beds of fossiliferous limestone and chert, although the Reeds Spring Formation typically contains abundant chert nodules concentrated along bedding planes. Horizontal fractures along bedding planes and vertical fractures have created conduits for groundwater flow through all three formations. Limestone dissolution along vertical fractures has formed impressive cutters (solution-widened fractures) and pinnacles in the Reeds Spring Formation. Excellent examples of these features are exposed on the west side of Missouri Highway 13, approximately 1.3 km (0.8 mi) south of the intersection with Missouri Highway 76 (Plymate et al. 2003; Bill Duley, Assistant State Geologist, Missouri Department of Natural Resources, geology presentation, April 5, 2011).

Bedrock in southwestern Missouri has also been fractured by regional faults. These northwest-to-southeast trending faults may have originated during a mountain-building episode at the end of the Paleozoic era, approximately 253 million years ago, that gave rise to the Ouachita Mountains (Plymate et al. 2003). One of these regional faults, known as the Battlefield Fault Zone, cuts through the northeastern corner of Wilson’s Creek National Battlefield.

Geologic Mapping for Wilson's Creek National Battlefield

During the scoping meeting, GIS Facilitator Tim Connors (NPS GRD) showed some of the main features of the GRI Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRI Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRI Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, a Windows HelpFile that captures ancillary map data, and a map document that displays the map, and provides a tool to access the HelpFile directly from the map document. Final data products are posted at the NPS Natural Resource Information Portal at <http://nrinfo.nps.gov/Home.mvc>. The data model is available at <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>.

When possible, the GRI Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest. Because of the influence of karst features and processes in the area of the park, the 7.5-minute quadrangles that would be useful to resource managers at Wilson's Creek National Battlefield include the Republic quadrangle, which contains the park lands, and the surrounding Brookline, Springfield, and Nixa quadrangles (fig. 3). Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). Table 1 lists the existing geologic maps that were identified by the scoping participants as appropriate source maps for the digital geologic data.

Useable maps appear to be available for the Republic Brookline, and Springfield 7.5' quadrangles, but useful geologic maps may not exist for the Nixa 7.5' quadrangle. There is coverage of the Nixa 7.5' quadrangle from GMAP 75457. The Nixa area consists of mostly upland with few bedrock exposures. It was suggested to compare the mapped units of this map with the units appearing on the other three quadrangles to get a feeling for the reliability of this map to adequately portray the geology here based upon confidence in the quality of the mapping for the other quadrangles.

Table 1. GRI Mapping Plan for Wilson's Creek National Battlefield

Covered Quadrangles	GMAP ¹	Citation	Scale	Format	Assessment	GRI Action
Republic, Missouri 7.5'	75521	Work, D.M. and C.E. Robertson. 1991. Geologic map of the Republic 7.5' quadrangle, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, unpublished.	1: 24,000	paper	Provides bedrock geology. Bill Duley recommends as best available map for this quadrangle.	Digitize this map.
Brookline, Missouri 7.5'	75524	Robertson, C.E. 1990. Geologic map of the Brookline 7.5' quadrangle, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, unpublished.	1: 24,000	paper	Provides bedrock geology. Bill Duley recommends as best available map for this quadrangle.	Acquire and evaluate this map.
Springfield, Missouri 7.5'	75533	Fellows, L.D. 1970. Geologic map of the Springfield 7.5' quadrangle, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, unpublished.	1:24,000	paper?	Provides bedrock geology. Bill Duley recommends as best available map for this quadrangle.	Acquire and evaluate this map.
Nixa, Missouri 7.5'	75527	Thomson, K.C. 1981. Geologic map of the Nixa 7.5' quadrangle, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, unpublished.	1:24,000	paper?	Might be useable; edge-match with other three quadrangles to see if common units and evaluate for utility.	Acquire and evaluate this map.
Nixa, Missouri 7.5'	75457	Thomson, K.C. 1981. Geologic map of the Brookline, Republic, Springfield, and Nixa 7.5' quadrangles, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, unpublished.	1:62,500	paper	Might be useable; edge-match with other three quadrangles to see if common units and evaluate for utility.	Evaluate vs other gmaps for matching.

¹GMAP numbers are unique identification codes used in the GRI database.

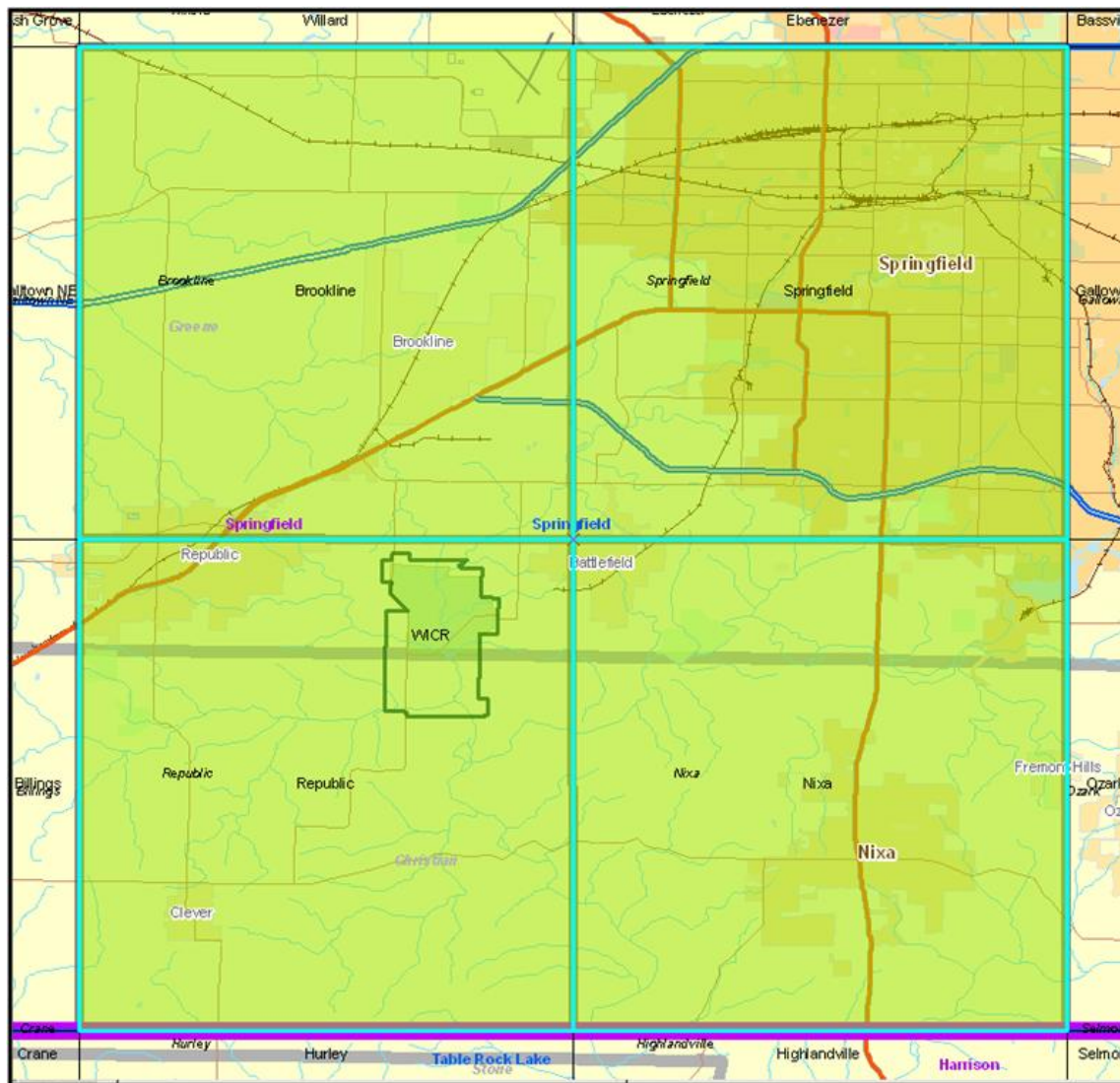


Figure 3. Area of interest for Wilson's Creek National Battlefield, Missouri. The 7.5-minute quadrangles are labeled in black. Green outlines indicate monument boundaries.

Thus, for the immediate mapping completion plan for Wilson's Creek National Battlefield, GRI staff plan to obtain the best available base copies of the Republic, Brookline and Springfield 7.5' quadrangles from the Missouri Department of Natural Resources, Division of Geology and Land Survey and digitize those maps. From there, GRI staff will compare the polygons on those maps with those of the two potential Nixa 7.5' quadrangle sources and make a decision on the utility of using the existing Nixa data.

Geologic Resource Management Issues

The development of sinkholes, which are common in karst terrain, is the dominant geologic issue at Wilson's Creek National Battlefield. Sigel's Sinkhole (fig. 4), for example, formed between late 2010 and early 2011. Sinkholes in this area are known as "cover collapse" sinks in contrast to "roof

collapse” sinkholes in which the roof of a cave suddenly collapses and leaves a large hole in the ground. Development of a “cover collapse” sinkhole begins with the dissolution of limestone along fractures in the bedrock that produces subterranean openings and caves. The overlying “cover” of weathered bedrock and soil, called residuum, begins to collapse into these openings and is subsequently washed away by groundwater. The openings expand upward in a process known as stoping. Residuum continues to collapse, and groundwater continues to transport the collapsed residuum away from the opening until the surficial residuum finally collapses, resulting in a sinkhole. Sinkholes vary considerably in size. Sigel’s Sink, for example, is only about 0.6-0.9 m (2-3 ft) in diameter whereas in 2007, a sinkhole in Nixa engulfed an entire garage. Sinkholes may be quite shallow or quite deep, and they seem to occur in areas where groundwater is rapidly replenished by water from the surface. Consequently, they are also areas of potential groundwater contamination.

New sinkholes, such as Sigel’s Sink, pose potential visitor safety issues. The park has covered Sigel’s Sink with a steel grate and surrounded the site with a safety fence. A sign to keep out visitors was suggested as an additional safety measure. The Missouri Department of Natural Resources website contains information concerning the formation and remediation of sinkholes (<http://www.dnr.mo.gov/geology/geosrv/geores/sinkholeformation.htm>, accessed April 12, 2011).

Paradoxically, dye traces indicate that groundwater flow through these underground systems is quite rapid and may flush any contaminants relatively quickly. Groundwater quality in the karst region of southern Missouri remains superior to any other region in the state. Dye traces have also shown how difficult it is to map and predict groundwater flow in fractured bedrock. At Wilson’s Creek National Battlefield, some sinkholes may be associated with the Battlefield Fault Zone, but more research is needed to establish this relationship.

Locally, surface water quality may be impacted by sewage flowing into Wilson’s Creek from caves and springs. With improved sewage treatment, however, the water quality has improved over the last few years.

Lateral erosion of the banks along Wilson’s Creek is a natural process for a meandering stream but presents a minor issue for park management. In a meandering stream, the stream’s current flows faster around the outside bend of a meander, cutting into the unconsolidated material and forming a steep bank, known as a “cutbank.” Opposite the cutbank, channel velocity decreases and becomes unable to transport heavier material such as sand and gravel. These heavier materials accumulate to form a “point bar.” Currently, no known cultural resources are being threatened by bank erosion.

The only energy-related issue noted at the scoping meeting was the nearby power plant, which affects the viewshed of the park.

Features and Processes

The following table lists geologic features and processes that were identified at the scoping meeting. These features and processes will be further explained in the GRI report.

Feature/Process	Brief Description
Bedrock Features	Limestone, invertebrate marine fossils, chert, fractures, and regional faults suggest depositional environments in southwest Missouri during the Mississippian period and subsequent deformation during the Ouachita mountain-building episode.
Caves/Karst	As noted above, caves and sinkholes are common features in this region. Springs are associated with these sinkholes and caves.
Stream (Fluvial)	Wilson's Creek National Battlefield contains features associated with meandering streams, such as cutbanks and point bars, as well as features associated with straight channels, such as riffles.
Paleontological Resources	Crinoid fossils are the principal invertebrate fossil in the park's bedrock formations. Extinct Pleistocene fauna have been discovered in caves outside the park's boundaries (Hunt et al. 2008).
Seismic (faults)	The inactive Battlefield Fault Zone intersects the northeast corner of the park and may have a bearing on groundwater flow. Wilson's Creek National Battlefield, however, should not be impacted by any new movement in the New Madrid earthquake zone of southeast Missouri.
Windblown (aeolian)	Loess (wind-blown silt) may be present in the residuum, but its presence on upland topography is unknown.
Hillslope (rockfall or landslide hazards)	Rockfall or landslide hazards are minor issues for resource management. Rocks occasionally fall from the vertical exposure of limestone beds near the park road, south of the Ray House (fieldtrip stop 4), but this exposure is scheduled to be modified to slope away from the road.
Other significant or unique geologic features	1. Soldiers were buried in sinkholes and along the creek after the battle. 2. American Indians found that the chert from these bedrock formations made excellent points, tools, and other artifacts and was often traded.
Disturbed lands (mining, grazing, logging) or severe erosion	The one abandoned quarry (c. 1880s) could be restored, but in a sense, the entire park has been "disturbed" by logging, farming, and troop movements during the Civil War.

Field Trip

Some of the geologic features, processes, and potential issues at Wilson's Creek National Battlefield were identified on the afternoon field trip that was led by Gary Sullivan. The field trip stops are plotted on the National Park Service map for Wilson's Creek National Battlefield (fig. 5).

Stop 1: Gibson's Mill Site

Both geomorphic and bedrock features are present at the Gibson's Mill site. Bedrock that outcrops along the river bank has been mapped as Elsey Formation, but the fractured, fossiliferous limestone and interbedded chert are similar to both the overlying Burlington-Keokuk Limestone and underlying Reeds Spring Formation. Crinoids are the dominant fossil in the limestone. Burlington-Keokuk Limestone forms the ridge along the western bank of Wilson's Creek, and two caves with openings approximately 1.8-3 m (6-10 ft) wide could be seen in the limestone cliffs.

Upstream from the site, Wilson's Creek forms a meander bend with an erosional cutbank on the western bank opposite a broad, well-vegetated point bar. A mid-channel gravel bar has formed

immediately downstream from the point bar. Downstream from the old Gibson's Mill, Wilson's Creek forms a relatively straight channel containing riffles.

Stop 2: Ray House

The chimney at the Ray House is made of sandstone blocks, some of which are iron-stained. Exposures of sandstone such as this are not common to this region. Coincidentally, sandstone slabs at the Wildcat Glades and Audubon Nature Center outside Joplin, Missouri, appear similar, and according to Nature Center staff, may have originated from quarries in Arkansas. The concrete mortar cementing the sandstone blocks together suggests that the Ray House chimney may be a relatively new addition or renovation.

Stop 3: Abandoned Quarry southwest of the Ray House

Evidence of previous quarry operations (c. 1880s) has disappeared, leaving an exposure of Burlington-Keokuk Limestone (fig. 2). The limestone contains abundant crinoid debris as well as a groundwater seep. The myriad of horizontal (bedding) and vertical fractures throughout the limestone provide evidence for how difficult it is to determine groundwater flow in the subsurface.

Stop 4: Roadcut along the park road approximately 0.8 km (0.5 mi) south of the Ray House turnoff

Because of potential rockfall issues, this exposure of Burlington-Keokuk Limestone will be sloped back from the road (fig. 1). Until then, the roughly 6 m (20 ft) high cliff exposes the characteristic fossiliferous limestone and chert nodules present in the Burlington-Keokuk Limestone. Some of the limestone beds are coarsely crystalline, and the bed at the base of the outcrop contains abundant crinoid stem fragments. A perched groundwater seep emerges from the southern end of the outcrop.

Stop 5: Sigel's Sink (unofficial name)

Sigel's Sink (fig. 4) is a recently discovered sinkhole that lies west of Sigel's Second Position and south of Sigel's Final Position (fig. 5). Discovered about 3-4 months ago, the sinkhole is roughly 0.6-0.9 m (2-3 ft) in diameter and formed from the progressive upward stoping (collapse) of residuum. The depth of the sinkhole was estimated to be approximately 6 m (20 ft) and contained a coiled, black snake resting amidst the thick, reddish residuum. Located on the side of a hill rather than in a valley, Sigel's Sink provides credence to the hypothesis that sinkholes form from water percolating through fractured bedrock rather than being controlled by surface drainage. The park has covered the sinkhole with a steel grate and surrounded the site with a safety fence. A sign to keep out visitors was suggested as an additional safety measure. The Missouri Department of Natural Resources website contains information concerning the formation and remediation of sinkholes (<http://www.dnr.mo.gov/geology/geosrv/geores/sinkholeformation.htm>, accessed April 12, 2011).

Stop 6: South Cave

A stream flows from the mouth of South Cave (fig. 6). The cave extends approximately 6 m (20 ft) into an exposure mapped as Burlington-Keokuk Limestone by Work and Robertson (1991). No bats have been reported from this cave.

Stop 7: Confluence of Wilson's Creek and Terrell Creek, southern boundary of the park

Outcrops of fossiliferous limestone and chert nodules at this location have been mapped as either Elsey Formation or Reeds Spring Formation. Thicker chert layers suggest that these beds are not

Burlington-Keokuk Limestone. Crinoids remain the dominant macro-invertebrate fossil in the limestone beds. The meandering pattern of Wilson's Creek has formed a cutbank and corresponding point bar upstream from the confluence of the two creeks.

Stop 8: Bloody Hill Sinkhole and Glade

A ravine carved into Bloody Hill was used by Confederate soldiers to advance upon federal troops during the Civil War. Located near the head of this ravine, the sinkhole at Bloody Hill appears to be the result of roof collapse into a cave rather than the process of upward stoping through residuum, which typically forms the area's sinkholes. Following the battle at Wilson's Creek, bodies were buried in the sinkhole. The sinkhole has been excavated at least twice, the last excavation occurring in 1973.

The limestone glade on Bloody Hill is an unusual feature for this area. Naturally dry, glades contain shallow soils and areas of exposed bedrock. Burlington-Keokuk Limestone forms the exposed bedrock at the Bloody Hill glade. Open limestone glades are also the preferred habitat of the threatened Missouri bladderpod (*Lesquerella filiformis*). The glade contains the names of Civil War soldiers carved in the exposed limestone as well as General Lyon's memorial granite marker.

Stop 9: Double Spring

Double Spring is located along the southern boundary of the recently acquired acreage west of highway ZZ. The springs emerge from either the Elsey Formation or the Reeds Spring Formation, and they discharge into Terrell Creek (fig. 7). The discharge rate illustrates the rapid groundwater flow through some of these underground systems.

Literature Cited

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Table 2. Scoping Meeting Participants

Name	Affiliation	Position	Phone	E-Mail
Connors, Tim	NPS Geologic Resources Division	Geologist	303-969-2093	tim_connors@nps.gov
Duley, Bill	Missouri Department of Natural Resources, Division of Geology and Land Survey	Assistant State Geologist	573-368-2101	Bill.Duley@dnr.mo.gov
Gouzie, Doug	Missouri State University	Associate Professor	417-836-5228	douglasgouzie@missouristate.edu
Graham, John	Colorado State University	Geologist	970-225-6333	rockdoc250@comcast.net
Hillmer, Ted	NPS Wilson's Creek National Battlefield	Superintendent	417-732-2662	T_John_Hillmer@nps.gov
Kenworthy, Jason	NPS Geologic Resources Division	Geologist	303-987-6923	jason_kenworthy@nps.gov
Prewett, Jerry	Missouri Department of Natural Resources, Division of Geology and Land Survey	Geological Survey Program Director	573-368-7152	jerry.prewett@dnr.mo.gov
Sullivan, Gary	NPS Wilson's Creek National Battlefield	Resource Manager	417-732-2662	Gary_P_Sullivan@nps.gov



Figure 1. Outcrop of Burlington-Keokuk Limestone along the park road near the East Battlefield Overlook. The relatively horizontal layers (bedding) consist of limestone and chert. Note overhanging ledges of rock, which may constitute a rockfall hazard. Photograph by John Graham (Colorado State University).



Figure 2. Crinoid columns in the Burlington Limestone. Crinoids, which may still be found in today's oceans, consist of a mouth and feeding arms attached to a column of disk-like segments, which often disarticulate upon death. Individual disks and articulated disks (near pencil tip) are visible in this photograph, taken at an abandoned quarry southwest of the Ray House. A crinoid (*Delocrinus missouriensis*) is the state fossil of Missouri. Photograph by John Graham (Colorado State University).



Figure 4. Geologists ponder the recently discovered Sigel's Sinkhole at Wilson's Creek National Battlefield. Located on the side of a hill, Sigel's Sink illustrates how sinkholes develop as a result of fractures in the bedrock rather than being controlled by surface drainage. The 0.6-0.9 m (2-3 ft) diameter hole formed in a thick residuum of weathered soil and bedrock. The fencing was installed by the park for visitor safety and encircles the area surrounding the sinkhole. View is to the southeast. Geologists (left to right): Jerry Prewett and Bill Duley from the Missouri Department of Natural Resources and Tim Connors and Jason Kenworthy from the Geologic Resources Division of the National Park Service. Photograph by John Graham (Colorado State University).

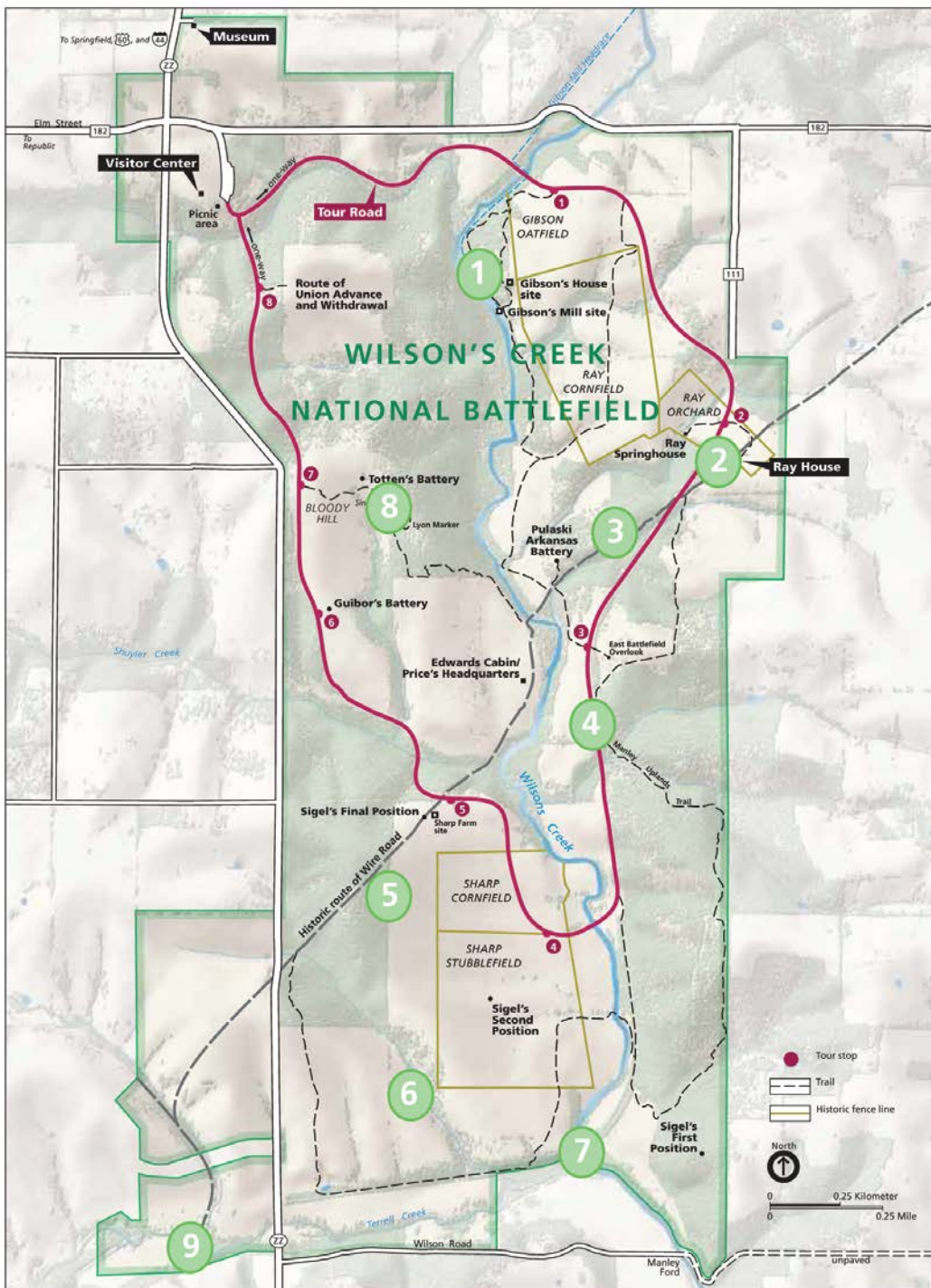


Figure 5. Location of field trip stops (labeled 1-9).



Figure 6. A geologist peers into the depths of South Cave, field trip stop 6, Wilson's Creek National Battlefield. A stream emerges from the mouth of the cave, formed in Burlington-Keokuk Limestone. Photograph by John Graham (Colorado State University).

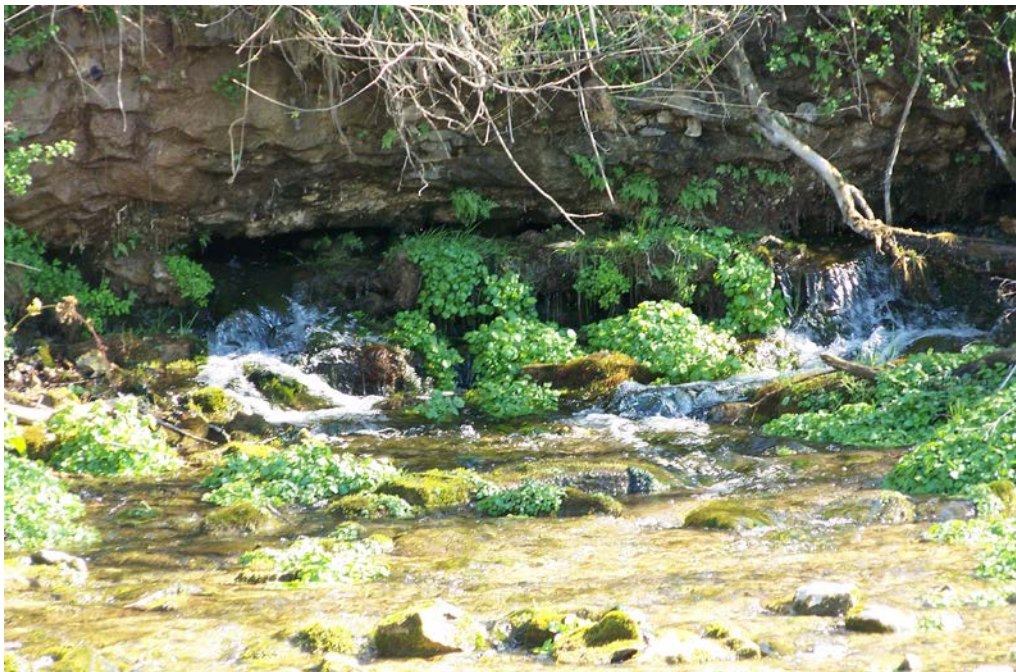


Figure 7. Double Spring, field trip stop 9, showing the high discharge rate from the fractured limestone and chert. Photograph by John Graham (Colorado State University).