

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division



Missouri National Recreational River and Vicinity

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic
Data for Missouri National Recreational River and Vicinity

mnrr_geology.pdf

Version: 6/24/2022

Geologic Resources Inventory Map Document for Missouri National Recreational River and Vicinity

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Geologic Resources Inventory Map Document



Missouri National Recreational River and Vicinity, South Dakota, Nebraska and Iowa

Document to Accompany Digital Geologic-GIS Data

[mnrr_geology.pdf](#)

Version: 6/24/2022

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Missouri National Recreational River and Vicinity, South Dakota, Nebraska and Iowa (MNRR).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

- 1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.
- 2) **GRI Digital Maps and Source Map Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.
- 3) **Digital Geologic-GIS Map of the 39-Mile Reach of Missouri National Recreational River and Vicinity**
 - a) **39-Mile Reach Map Unit List** – A listing of all geologic map units present on the 39-mile reach map for this project, generally listed from youngest to oldest.
 - b) **39-Mile Reach Map Unit Descriptions** – Descriptions for all geologic map units present on the 39-mile reach map for this project.
- 4) **Digital Geologic-GIS Map of the 59-Mile Reach of Missouri National Recreational River and Vicinity**

- a) **59-Mile Reach Map Unit List** – A listing of all geologic map units present on map 59-mile reach map for this project.
- b) **59-Mile Reach Map Unit Descriptions** – Descriptions for all geologic map units present on the 59-mile reach map for this project.
- 5) **Ancillary Source Map Information** – Additional source map information presented by source map.
- 6) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

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About the NPS Geologic Resources Inventory Program

Background

The Geologic Resources Inventory (GRI) provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The GRI is one of 12 inventories funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate administers the GRI. The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. Many additional partners participate in the GRI process by contributing source maps or reviewing products.

The GRI team undertakes three tasks for each park in the Inventory and Monitoring program: (1) conduct a scoping meeting and provide a summary document, (2) provide digital geologic map data in a geographic information system (GIS) format, and (3) provide a GRI report. These products are designed and written for nongeoscientists.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: <https://www.nps.gov/articles/gri-geodatabase-model.htm>

Geologic Reports: GRI reports synthesize discussions from the original scoping meeting, follow up conference call(s), and subsequent research. Chapters of each report discuss the geologic setting of the park, distinctive geologic features and processes within the park, highlight geologic issues facing resource managers, and describe the geologic history leading to the present-day landscape. Each report also includes a poster illustrating these GRI digital geologic-GIS data.

For a complete listing of GRI products visit the GRI publications webpage: <https://go.nps.gov/gripubs>. GRI digital geologic-GIS data is also available online at the NPS Data Store: <https://irma.nps.gov/DataStore/Search/Quick>. To find GRI data for a specific park or parks select the appropriate park(s), enter "GRI" as a Search Text term, and then select the Search button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: <https://www.nps.gov/subjects/geology/gri.htm>. At the bottom of that webpage is a “Contact Us” link if you need additional information. You may also directly contact the program coordinator:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division. Learn more about I&M and the 12 baseline inventories at the I&M webpage: <https://www.nps.gov/im/inventories.htm>.

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps for Missouri National Recreational River and Vicinity, South Dakota, Nebraska and Iowa (MNRR):

Digital Geologic-GIS Map of the 39-Mile Reach of Missouri National Recreational River and Vicinity, Nebraska and South Dakota (*GRI MapCode MRTN*)

The GRI used the full extent of the source digital data presented below, and captured all geologic features within its extent.

Joeckel, R.M., Scofield, N.I., Divine, D.P., and Howard, L.M., 2019, Surficial Geologic Map of Missouri National Recreational River Corridor and Surrounding Areas in Nebraska and South Dakota, Fort Randall Dam and Environs to Springfield, Nebraska and South Dakota: University of Nebraska-Lincoln, unpublished digital data, scale 1:24,000 ([39-Mile Reach of Missouri National Recreational River](#)). (*GRI Source Map ID 76288*).

Digital Geologic-GIS Map of the 59-Mile Reach of Missouri National Recreational River and Vicinity, Iowa, Nebraska and South Dakota (*GRI MapCode MRFN*)

The GRI used the full extent of the source digital data presented below, and captured all geologic features within its extent.

Lundstrom, S.C., Cowman, T., Hanson, P., Holbrook, J., Mahan, S., Moreno-Ward, A., and Paces, J., 2022, Geologic Map Geodatabase of the Valley Corridor of the 59-Mile Reach of the Missouri National Recreational River, South Dakota, Nebraska, and Iowa (Gavins Point Dam to North Sioux City): U.S. Geological Survey, unpublished data release, scale 1:100,000 ([59-Mile Reach of Missouri National Recreational River](#)). (*GRI Source Map ID 76334*).

Additional information pertaining to each source map is also presented in the GRI Source Map Information (MNRRMAP) table included with the GRI digital geologic-GIS data.

Index Map

The following index map displays the extents of the GRI digital geologic-GIS maps produced for Missouri National Recreational River and Vicinity (MNRR). The boundaries for Missouri National Recreational River (as of June 2022) are outlined in green. The extent of the Digital Geologic-GIS Map of the 39-Mile Reach of Missouri National Recreational River and Vicinity is outlined in purple and the extent of the Digital Geologic-GIS Map of the 59-Mile Reach of Missouri National Recreational River and Vicinity is outlined in orange.



Index map by James Winter (Colorado State University).

Digital Geologic-GIS Map of the 39-Mile Reach of Missouri National Recreational River and Vicinity

39-Mile Reach Map Unit List

The geologic units present in the 39-Mile Reach digital geologic-GIS data produced for the Missouri National Recreational River and Vicinity, South Dakota, Nebraska and Iowa (MNRR) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qpi - Pit). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (MRTNUNIT) table included with the GRI geologic-GIS data. Some source unit symbols, names and/or ages may have been changed in this document and in the GRI digital geologic-GIS data. This was done if a unit was considered to be the same unit as one or more units on other source maps used for this project, and these unit symbols, names and/or ages differed. In this case a single unit symbol and name, and the unit's now recognized age, was adopted. Unit symbols, names and/or ages in a unit descriptions, or on a correlation of map units or other source map figure were not edited. If a unit symbol, name or age was changed by the GRI the unit's source map symbol, name and/or age appears with the unit's source map description.

Cenozoic Era

Quaternary Period

[Qpi](#) - Pit

[Qfi](#) - Fill

[Qantd](#) - Niobrara River Tributary delta, subaerial part

[Qf](#) - Alluvial fan sediments

[Qc](#) - Colluvium

[Qanfc](#) - Flood-channel deposits of Niobrara River

[Qal](#) - Alluvium of small streams

[Qalt](#) - Alluvial terrace deposits of small streams

[Qavc1](#) - Verdigre Creek alluvium, ca. 1951-present

[Qavc2](#) - Verdigre Creek alluvium, late 19th and 20th centuries?

[Qavc3](#) - Verdigre Creek alluvium, pre-late 19th century?

[Qapc1](#) - Ponca Creek alluvium, accreted ca. 1961 to present

[Qapc2](#) - Ponca Creek alluvium, accreted ca. 1939-1961

[Qapc3](#) - Ponca Creek alluvium, accreted ca. 1858-1939

[Qapc4](#) - Alluvium of Ponca Creek accreted prior to ca. 1858

[Qapc5](#) - Alluvium of Ponca Creek, oldest

[Qansr](#) - Sand ridges atop alluvium of Niobrara River

[Qan1](#) - Niobrara River alluvium, accreted ca. 1954-present

[Qan2](#) - Niobrara River alluvium, accreted ca. 1938-1951

[Qan3](#) - Niobrara River alluvium, accreted ca. 1858-1938

[Qan4](#) - Niobrara River alluvium, accreted prior to 1858

[Qan5](#) - Niobrara River alluvium accreted prior to 1858, but older than Qan4

[Qam1](#) - Missouri River alluvium, accreted post-ca. 1954-present

[Qam2](#) - Missouri River alluvium, accreted ca. 1939-1954

[Qam3](#) - Missouri River alluvium, mid-19th century-1939

[Qam4](#) - Missouri River alluvium, pre-mid-19th century

[Qalc1](#) - Lost Creek alluvium, ca. 1970-present

[Qalc2](#) - Lost Creek alluvium, pre-ca. 1970

[Qalc3](#) - Lost Creek alluvium, intermediate low terrace

[Qalc4](#) - Lost Creek alluvium, higher low terrace

[Qabc1](#) - Bazile Creek alluvium, ca. 1957 to present

[Qabc2](#) - Bazile Creek alluvium, pre-1957

[Qabc3](#) - Bazile Creek alluvium, oldest

[Qpo](#) - Peoria Loess (thin) atop shallow Ogallala Group

[Qp](#) - Peoria Loess

[Qante](#) - Eolian sands atop Niobrara River high terrace
[Qant](#) - High alluvial terrace sediments of the Niobrara River
[Qtw1](#) - Till, stagnation moraine
[Qtw2](#) - Till, ground moraine
[Qosg1](#) - Younger coarse alluvium, interpreted as glacial outwash
[Qosg2](#) - Older coarse alluvium, interpreted as glacial outwash
[Qapct](#) - High alluvial terrace sands of Ponca Creek
[Qath](#) - High alluvial terrace sand and gravel
[Qtpi](#) - Pre-Illinoian glacial till

Neogene Period

[Nb](#) - Broadwater Formation
[Nofr](#) - Fort Randall Formation of the Ogallala Group
[Nov](#) - Valentine Formation of the Ogallala Group

Mesozoic Era

Cretaceous Period

[Kp](#) - Pierre Shale
[Knsh](#) - Smoky Hill Chalk Member of the Niobrara Formation

39-Mile Reach Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. All unit descriptions from source map: [39-Mile Reach of Missouri National Recreational River](#).

Qpi - Pit (Holocene)

P- Pit

Gravel, sand, or borrow pit (active or inactive).

There are comparatively few active or inactive pits in the mapped area.

Qfi - Fill (Holocene)

F - Fill (Holocene; modern)

Artificial fill and graded areas, including areas extensively disturbed by urban development.

This mapping unit represents significant accumulations of artificial fill and in urban areas, dams, roads, embankments, and other manmade structures. It also includes graded, urbanized areas.

Qantd - Niobrara River Tributary delta, subaerial part (Holocene)

Qantd - Niobrara River tributary delta, subaerial part (Holocene; post-1938)

Fine to coarse sand similar to other units of the Niobrara and mud drapes

The tributary delta of the Niobrara River is an asymmetrical, 200-ha, fan-shaped accumulation of sediment that is partially subaerial and partially subaqueous. Much of the growth of the delta has taken place since 1970. Only the subaerial half of the delta is represented on this map. The subaqueous delta has approximately five main distributary channels and numerous smaller ones are apparent at lower stages of the Missouri River. Gavins Point Dam was completed in 1957, impounding the Missouri River approximately 50 km downstream from the mouth of the Niobrara River. Subaqueous sedimentation at the mouth of the Niobrara River cannot be ascertained in 1938 stereo aerial photographs. Sedimentation at the mouth of the river is apparent, however, in 1957 stereo aerial photographs, as well as an apparent shallowing of the Missouri River in the immediate area. A small, bank-accreted bar remnant that was present immediately upstream of the river's mouth in 1938 gave rise to a large bank-attached bar upstream by 1957. This new bar was the result of deposition by the Missouri River, rather than the Niobrara River. Nevertheless, it appears that a subaerial part of the tributary delta had been accreted alongside the downstream edge of this new bar by ca. 1970. Furthermore, a bank-attached bar had accreted on the downstream side of the mouth of the Niobrara River by 1957, and a small part of the subaqueous delta accreted on the upstream edge of this bar by 1970. The delta was increasingly prominent from the early 1990s onward. It appears to have grown at the expense of Jones Island, a large, compound bar identified adjacent to the mouth of the Niobrara River.

Qf - Alluvial fan sediments (Holocene)

Dominantly grayish brown silty clay, silt, and sand. Sediments in alluvial fans are derived from the erosion of upslope deposits of loess, eolian sands, etc. The sediments of alluvial fans near outcrops or the shallow subcrop of the Niobrara Formation or the Pierre Shale may contain fragments of chalky limestone, shaley chalk, and shale.

Multiple, small (1-46 ha), low-angle alluvial fans exist where smaller streams exit the uplands at the bases of the valley walls of the Missouri River, Niobrara River, Ponca Creek, Verdigre Creek, and Bazile Creek in the mapped area in Nebraska. Alluvial fans mapped in South Dakota are exclusively found where small streams exit the uplands at the base of the valley wall of the Missouri River. Alluvial fans typically lie atop older alluvial units, and those that extend onto the floodplains of the Missouri river overlie mapping units [Qam4](#) or [Qam3](#). Alluvial fans are easily recognizable in LiDAR images. In some cases, they are also discernable at ground level because they are appreciably higher than the surrounding toeslopes or floodplains. Fan deposits consist of colluvium and thin increments of sediment transported from adjacent uplands by overland flow.

Qc - Colluvium (late Pleistocene to Holocene)

Clayey silt to gravelly sand; slope sediments with highly variable compositions.

Colluvium appears on some foot- and toeslopes in the mapped area, but its composition and characteristics vary widely from place to place, depending on the nature of upslope surficial geological materials. In the mapped area of Nebraska, colluvium derived in part from the Pierre Shale and the Niobrara Formation and in part from Quaternary sediments is widespread on lower slopes along Ponca Creek, the north and east sides of the Niobrara River, on some slopes along the Missouri River, and in a few other places. In these cases, mapping unit [Qc](#) may include weathered, *in-situ* Pierre Shale or Niobrara Formation. Upland colluvium south of the Niobrara River is derived from loess, sand, and gravel deposits. In the mapped area of South Dakota, colluvium derived in part from the Pierre Shale and the Niobrara Formation and in part from Quaternary sediments is widespread along the lower slopes of the valley wall of the Missouri River. Mapping unit [Qc](#) merges downslope with, or overlies, the alluvium of major streams, the alluvium of lower-order streams (e.g., mapping unit [Qal](#)), or fan deposits (mapping unit [Qf](#)). It may be difficult to distinguish colluvium from the latter two types of sediments at any given point of transition. Moreover, alluvial fan deposits may themselves contain a component of colluvium.

Qanfc - Flood-channel deposits of Niobrara River (Holocene)

Qanfc - Flood-channel deposits of Niobrara River (Holocene, modern)

Pale brown and light brownish gray silty sand, fine to coarse sand.

Areas mapped as Qanfc are slightly sinuous to sinuous channels of the Niobrara River that flow only when the river exceeds flood stage. These areas may cut across, or be bordered by the following mapping units of Niobrara River alluvium: [Qan2](#), [Qan3](#), [Qan4](#), and [Qan5](#). Channels mapped as Qanfc are uniformly more sinuous than the Niobrara River itself. They range in width from approximately 10 to 120 m and attain a maximum length of approximately 6 km.

Qal - Alluvium of small streams (Holocene)

Alluvial sediments of varied texture and composition; includes combinations of clay, silt, fine to coarse sand, and gravel.

Mapping unit Qal encompasses alluvium of lower-order streams generally in direct association with extant ephemerally to permanently flowing drainages. Most of these lower-order streams are unnamed. The composition of materials encompassed by Qal is determined by local surficial geology. Areas mapped as Qal may be prone to flash flooding.

Qalt - Alluvial terrace deposits of small streams (late Pleistocene to Holocene)

Alluvial sediments of varied texture and composition; includes combinations of clay, silt, fine to coarse sand, and gravel.

Mapping unit Qalt is directly associated with mapping unit [Qal](#) and it shares general characteristics with the latter. Qalt represents terraces of lower-order streams that remained after very recent entrenchment or channel engineering. Some areas of Qalt may still be inundated by major flash floods.

Qavc1 - Verdigre Creek alluvium, ca. 1951-present (Holocene)

Qavc1 - Verdigre Creek alluvium, ca. 1951-present (Holocene; modern)

Gray to brown fine sand.

Mapping unit Qavc1 is very young channel deposits of Verdigre Creek, predating any channel engineering in the last half of the 20th century. Areas mapped as Qavc1 are prone to flooding.

Qavc2 - Verdigre Creek alluvium, late 19th and 20th centuries? (Holocene)

Dark grayish brown silt and sandy silt, with gray to brown fine sand.

Mapping unit Qavc2 represents alluvium that had accreted prior to the first aerial photograph year of 1938. Nevertheless, these deposits are young enough that they still exhibit accretion topography and channel forms. Areas mapped as Qavc2 may be prone to flooding.

Qavc3 - Verdigre Creek alluvium, pre-late 19th century? (Holocene)

Dark grayish brown silt loam, gray to brown fine sand.

The distal alluvium of Verdigre Creek, which has a smooth surface and lacks accretion topography and channel forms, is mapped as Qavc3. Small alluvium fans (mapping unit [Qf](#)) lie atop Qavc3 in a few places. In aerial photographs from the early 1950s, there are splays on channel-proximal parts of areas mapped as Qavc3.

Qapc1 - Ponca Creek alluvium, accreted ca. 1961 to present (Holocene)

Qapc1 - Ponca Creek alluvium, accreted ca. 1961 to present (Holocene; modern)

Gray, light brownish gray, very pale brown, and brown sandy silt and silty fine to coarse (but dominantly medium) sand.

This mapping unit consists of channel and point bar sediments postdating aerial photograph year 1961. Meander scrolls are very common in Qapc1. It appears that attempts were made to straighten the channel of Ponca Creek in some places prior to the first aerial photograph year of 1939. Many of these apparently straightened stretches, however, had formed meanders again after 1961. Other than these changes, there has been very little migration of the active channel of Ponca Creek since 1858 as indicated by the General Land Office (GLO) surveys of that year and aerial photographs from 1939 and 1961.

Qapc2 - Ponca Creek alluvium, accreted ca. 1939-1961 (Holocene)

Qapc2 - Ponca Creek alluvium, accreted ca.1939-1961 (Holocene; historic)

Gray, light brownish gray, very pale brown, and brown sandy silt and silty fine to coarse (but dominantly medium) sand.

Qapc2 covers the least total area of the five alluvial units ([Qapc1](#), Qapc2, [Qapc3](#), [Qapc4](#), [Qapc5](#)) of Ponca Creek. It was identified from stereo aerial photograph series dating to 1939 and 1961.

Qapc3 - Ponca Creek alluvium, accreted ca. 1858-1939 (Holocene)

Qapc3 - Ponca Creek alluvium, accreted ca.1858-1939 (Holocene; historic)

Gray, light brownish gray, very pale brown, and brown sandy silt and silty fine to coarse (but dominantly medium) sand.

Qapc3 appears to have been accreted between the time of the 1858 General Land Office survey and the first aerial photo year (1939). Nevertheless, the accuracy of the mapped course of Ponca Creek in some of the 1858 GLOs is questionable, so the boundaries of this unit are mere approximations.

Qapc4 - Alluvium of Ponca Creek accreted prior to ca. 1858 (Holocene)

Qapc4 - Alluvium of Ponca Creek accreted prior to ca. 1858 (Holocene; historic)

Gray, light brownish gray, very pale brown, and brown sandy silt and silty fine to coarse (but dominantly medium) sand.

Qapc4 is the most expansive alluvial unit of Ponca Creek and it is distal to the active channel in most places. Overall, surfaces mapped as [Qapc5](#) have smoother topography than those of areas mapped as [Qapc1](#), [Qapc2](#), and [Qapc3](#), but flood channels and down-valley splays also appear on areas mapped as Qapc4 in stereo aerial photographs from 1939 and 1961. Most alluvial fans (mapping unit [Qf](#)) in the valley of Ponca Creek lie atop surfaces mapped as Qapc4. Most areas mapped as Qapc4 are under long-term agricultural cultivation.

Qapc5 - Alluvium of Ponca Creek, oldest (late Pleistocene to Holocene)

Gray, light brownish gray, very pale brown, and brown sandy silt and silty fine to coarse (but dominantly medium) sand.

Qapc5 is a flat terrace on the downstream part of Ponca Creek. It lies 1 to 1.5 m above mapping unit [Qapc4](#). Thus, it is relatively older than that widespread mapping unit. Some alluvial fans (mapping unit [Qf](#)) extend from the uplands onto Qapc5. Areas mapped as Qapc5 are generally under long-term agricultural cultivation.

Qansr - Sand ridges atop alluvium of Niobrara River (Holocene)

Pale brown and light brownish gray silty sand, fine to coarse sand.

Sand ridges are anomalous, elongate, positive features atop alluvial surfaces (mapping units [Qan2](#), [Qan3](#) and [Qan4](#)) alongside the Niobrara River. At least 20 of these sand ridges have been identified in the mapped area. Sand ridges attain 84 m to 625 m in length, but they are 6 m or less in height. The interpretation of these features is problematic in the absence of additional data. They may be

remnants of levees along old channels of the river. The largest examples of these features show evidence for eolian erosion in the form of roughly circular blowouts.

Qan1 - Niobrara River alluvium, accreted ca. 1954-present (Holocene)

Qan1 - Niobrara River alluvium, accreted ca. 1951–present (Holocene; modern)

Pale brown and light brownish gray silty sand, fine to coarse sand.

This mapping unit represents very young, channel-proximal alluvium of the Niobrara River that accreted after photography year 1951. On the basis of stage measurements at U.S. Geological Survey gaging stations, areas mapped as Qan1 are subject to floods at higher flow stages. Thus, it is inferred areas mapped as Qan1 were inundated, or very nearly so, during flood crests almost every year during the period 2010 to 2019.

Qan2 - Niobrara River alluvium, accreted ca. 1938-1951 (Holocene)

Qan2 - Niobrara River alluvium, accreted ca. 1938-1951 (Holocene; historic)

Pale brown and light brownish gray silty sand, fine to coarse sand.

This mapping unit is slightly older than mapping unit [Qan1](#). Areas mapped as Qan2 have uneven surfaces and locally exhibit scroll bars. Sand ridges (mapping unit [Qansr](#)) appear in some places atop areas mapped as Qan2. Areas mapped as Qan2 are subject to flooding at higher flow stages of the Niobrara River.

Qan3 - Niobrara River alluvium, accreted ca. 1858-1938 (Holocene)

Qan3 - Niobrara River alluvium, accreted ca.1858-1938 (Holocene; historic)

Pale brown and light brownish gray silty sand, fine to coarse sand.

This mapping unit represents Niobrara River alluvium that accreted between the time of the first General Land Office surveys in the area and the time of the first aerial photography. Areas mapped as Qan3 have uneven surfaces and locally exhibit scroll bars. Sand ridges (mapping unit [Qansr](#)) appear in some places atop areas mapped as Qan3. Areas mapped as Qan3 may be subject to flooding at the highest flow stages of the Niobrara River.

Qan4 - Niobrara River alluvium, accreted prior to 1858 (Holocene)

Qan4 - Niobrara River alluvium accreted prior to 1858 (Holocene; prehistoric to historic)

Pale brown and light brownish gray silty sand, fine to coarse sand.

Areas mapped as Qan4 predate the 1858 General Land Office surveys. These areas exhibit a few remnant channels. Surfaces mapped as Qan4 have elevations similar to those of surfaces mapped as [Qan1](#), [Qan2](#), and [Qan3](#), but Qan4 tends to be distal to the active river channel. Nevertheless, there are examples of areas mapped as Qan4 abutting the present channel of the river.

Qan5 - Niobrara River alluvium accreted prior to 1858, but older than Qan4 (Holocene)

Qan5 - Niobrara River alluvium accreted prior to 1858, but older than Qan4 (Holocene; prehistoric)

Pale brown and light brownish gray silty sand, fine to coarse sand.

Areas mapped as Qan5 are the oldest alluvial surfaces of the present Niobrara River. Such areas have notably smooth surfaces in comparison to younger alluvial mapping units ([Qan1](#), [Qan2](#), [Qan3](#), [Qan4](#)). Qan5 forms a low terrace standing approximately 0.6 m higher than mapping unit [Qan4](#). Many alluvial fans (mapping unit [Qf](#)) lie atop areas mapped as Qan5. Areas mapped as Qan5 are exceedingly rarely, if ever, flooded.

Qam1 - Missouri River alluvium, accreted post-ca. 1954-present (Holocene)

Qam1 - Missouri River alluvium, accreted post-ca. 1954–present (Holocene; modern)

Silt, sandy silt, fine to coarse sand, and gravel.

Mapping unit Qam1, which represents recently accreted bars of the Missouri River, was identified through the comparison of aerial photos dating from 1954 onward. Vegetation has stabilized these accreted bars to varying degrees. Meander scrolls appear in several areas mapped as Qam1. Although trees are present in some areas mapped as Qam1, the unit is generally less heavily wooded than the heavily wooded areas mapped as [Qam3](#) and [Qam4](#). Areas mapped as Qam1 experience frequent flooding.

Qam2 - Missouri River alluvium, accreted ca. 1939-1954 (Holocene)

Qam2 - Missouri River alluvium accreted ca. 1939–1954 (Holocene; historic)

Silt, sandy silt, fine to coarse sand, and gravel.

Mapping unit Qam2 was identified through the comparison of aerial photos dating from 1939 to 1954. Meander scrolls and small channels appear in several areas mapped as Qam2. Although trees are present in some areas mapped as Qam2, the unit is generally less heavily wooded than the heavily wooded areas mapped as [Qam3](#) and [Qam4](#). Areas mapped as Qam2 experience frequent flooding.

Qam3 - Missouri River alluvium, mid-19th century-1939 (Holocene)

Qam3 - Missouri River alluvium, mid-19th century–1939 (Holocene; historic)

Silt, sandy silt, fine to coarse sand, and gravel.

Mapping unit Qam3 was identified through the comparison of General Land Office surveys and the earliest aerial photos (1939). Meander scrolls appear in some areas mapped as Qam3. Some heavily wooded areas mapped as Qam3 are stabilized and accreted parts of former in-channel bars. Areas mapped as [Qam2](#) may experience frequent flooding.

Qam4 - Missouri River alluvium, pre-mid-19th century (Holocene)

Qam4 - Missouri River alluvium, pre-mid-19th century (Holocene; modern)

Silt, sandy silt, fine to coarse sand, and gravel.

Mapping unit Qam4 encompasses older historic alluvium of the Missouri River that were stable parts of the floodplain at the time of the first General Land Office (GLO) surveys in the late 1850s. The cumulative area mapped as Qam4 is larger in comparison with the other mapped alluvial units of the Missouri River. Areas mapped as Qam4 are characterized by a widespread surficial layer of dark grayish brown sand silt with common very coarse sand grains and granules and/or brown weakly stratified silt. Most areas mapped as Qam4 have been under cultivation for decades, although they may still exhibit traces of channels that hold water during rainy periods and floods. Other areas mapped as Qam4 are heavily wooded, and these areas can be identified as stabilized and accreted parts of former in-channel bars. Regardless, all areas mapped as Qam4 may be partial or completely inundated during major flood events.

Qalc1 - Lost Creek alluvium, ca. 1970-present (Holocene)

Qalc1 - Lost Creek alluvium, ca. 1970–present (Holocene; modern)

Dark gray to light brownish gray silt and sand.

This mapping unit encompasses the active channel and zone of overbank deposition of Lost Creek. Examination of stereo aerial photograph series and orthophotos indicates marked change along Lost Creek since ca. 1970. Trees around the permanent channel of the creek have progressively died off within a belt approximately 40-70 m in width, and widening to as much as 150 m near the mouth of the creek, since ca. 1970. The active channel has maintained a roughly constant width, but the zone of flood deposition around that channel appears to have widened to include the aforementioned belt of tree die-off. Areas mapped as Qalc1 are prone to flooding.

Qalc2 - Lost Creek alluvium, pre-ca. 1970 (Holocene)

Qalc2 Lost Creek alluvium, pre-ca. 1970 (Holocene; late prehistoric to modern)

Dark gray to light brownish gray silt and sand.

Mapping unit Qalc2 is alluvium of Lost Creek that is slightly older than that of mapping unit [Qalc1](#). Qalc2 includes areas where fluvial erosion and alluvial deposition have been active since ca. 1900. Areas mapped as [Qalc1](#) exhibit channel forms and are prone to flooding.

Qalc3 - Lost Creek alluvium, intermediate low terrace (Holocene)

Dark gray to light brownish gray silt and sand.

Areas mapped as Qalc3 are generally smooth-surfaced and have been under cultivation for many decades. It is assumed that Qalc3 is a low Holocene terrace predating Euramerican settlement in the 1850s.

Qalc4 - Lost Creek alluvium, higher low terrace (late Pleistocene to Holocene)

Dark gray to light brownish gray silt and sand.

Areas mapped as Qalc4 may be as much as 1.8 m higher in elevation than those mapped as [Qalc3](#) and they also tend to be farther from the present active channel of that stream. Like [Qalc3](#), areas mapped as Qalc4 are generally smooth-surfaced and have been under cultivation for many decades. It is assumed that Qalc4 is a low Holocene and/or latest lower Pleistocene terrace.

Qabc1 - Bazile Creek alluvium, ca. 1957 to present (Holocene)

Qabc1 - Bazile Creek alluvium, ca. 1957 to present (Holocene; modern)

Dark gray to grayish brown silt, light gray to grayish brown, fine to coarse sand and gravel.

Mapping unit Qabc1 represents very recent alluvium of Bazile Creek deposited after aerial photo year 1957 by channel migration and point-bar accretion. Areas mapped as Qabc1 are prone to flooding.

Qabc2 - Bazile Creek alluvium, pre-1957 (Holocene)

Qabc2 - Bazile Creek alluvium, pre-1957 (Holocene; late prehistoric to historic)

Dark gray to grayish brown silt, light gray to grayish brown, fine to coarse sand and gravel.

Mapping unit Qabc2 represents alluvium of ages intermediate between those of [Qabc1](#) and [Qabc3](#).

Qabc3 - Bazile Creek alluvium, oldest (Holocene)

Dark gray to grayish brown silt, light gray to grayish brown, fine to coarse sand and gravel.

Mapping unit Qabc3 represents the oldest surficial alluvium of Bazile Creek. Surfaces on which Qabc3 is mapped are typically smooth. When the 1858 General Land Office (GLO) surveys of the area are rectified, the course of Bazile Creek mapped on those surveys overlaps surfaces mapped as Qabc3 in only a few places. Such few overlaps do not seem to correspond to any relict channels and may merely be the results of surveying errors. Stereo aerial photographs from the 1951 and 1957, however, show localized flood deposits (sand) on some areas mapped as Qabc3. Thus, major floods still impacted distal alluvial surfaces in historic times. Some small alluvial fans lie atop Qabc3. Aerial photographs indicate that these fans received new sediment at least as recently as 1951.

Qpo - Peoria Loess (thin) atop shallow Ogallala Group (late Pleistocene)

Qpo - Peoria Loess (thin) atop shallow Ogallala Group (Late Pleistocene; Wisconsinan)

Light brownish gray, brown, pale brown, and light yellowish brown clayey silt and medium to coarse silt or sandy silt with a sandy substrate.

Peoria Loess in soil profiles in areas mapped as Qpo may be partially or completely amalgamated into the underlying, unconsolidated sands of the Valentine Formation of the Ogallala Group).

Qp - Peoria Loess (late Pleistocene)

Qp - Peoria Loess (Late Pleistocene; Wisconsinan)

Light brownish gray, brown, pale brown, and light yellowish brown clayey silt and medium to coarse silt; laminated to massive.

The eolian silts of the Peoria Loess are widespread atop sands and gravels in the uplands south of the Niobrara River in the southwestern part of the mapped area of Nebraska. Elsewhere in the mapped part of Nebraska, the Peoria Loess is either absent or it is distributed sparsely and very discontinuously in uplands. Very thin and sandy loess appears atop, and partially amalgamated into, some of the high, flat summits in these upland areas, making it more difficult to distinguish the Peoria Loess as a discrete stratigraphic unit. In South Dakota, Qp is mapped on certain flat upland surfaces atop glacial till, on small stream terraces, and, in the western part of the mapped area, on hill summits atop the Pierre Shale.

Qante - Eolian sands atop Niobrara River high terrace (late Pleistocene to Holocene)

Yellowish brown, fine sand.

This mapping unit encompasses dunes developed from wind-reworked high terrace sands ([Qant](#)). Small eolian dunes characterize the surfaces of areas mapped as Qante.

Qant - High alluvial terrace sediments of the Niobrara River (late Pleistocene to Holocene)

Yellowish brown, fine to medium sand.

High terrace deposits along the Niobrara River are mapped as Qant. This mapping unit may, in fact, encompass multiple Pleistocene terraces. Almost all of these terrace deposits lie on the south side of the Niobrara River, and only a few very small remnants are mapped on the north side of the river. The width of high terrace deposits on the south side of the river ranges from more than 6 km at the western end of the mapped area, to approximately 1 km where they terminate at a point approximately 2 km south-southwest of the town of Niobrara, Nebraska.

Qtw1 - Till, stagnation moraine (late Pleistocene)

Qtw1 - Till, stagnation moraine (Late Pleistocene; Wisconsinan)

Diamicton consisting of silty clay to sand with pebbles, cobbles, and boulders; minor amounts of alluvium and colluvium are included.

Mapping unit Qtw1 is restricted to the South Dakota side of the Missouri River. Unlike adjacent northeastern Nebraska, eastern South Dakota was covered by the James Lobe of the Laurentide Ice Sheet well past the time of the Last Glacial Maximum, and Wisconsinan glacial sediments are widespread. Mapping unit Qtw1 in the present map corresponds to a unit described as stagnation moraine by Martin et al. (2004), and the present map follows the interpretation those authors. Minor amounts of other kinds of sediments are present in Qtw1, but they cannot be effectively distinguished at the scale of mapping.

Qtw2 - Till, ground moraine (late Pleistocene)

Qtw2 - Till, ground moraine (Late Pleistocene; Wisconsinan)

Diamicton consisting of silty clay to sand with pebbles, cobbles, and boulders; minor amounts of alluvium and colluvium are included.

Mapping unit Qtw2 is restricted to the South Dakota side of the Missouri River. Unlike adjacent northeastern Nebraska, eastern South Dakota was covered by the James Lobe of the Laurentide Ice Sheet well past the time of the Last Glacial Maximum, and Wisconsinan glacial sediments are widespread. Mapping unit Qtw2 in the present map corresponds to a unit described as ground moraine by Martin et al. (2004), and the present map follows the interpretation those authors. Minor amounts of other kinds of sediments are present in Qtw2, but they cannot be effectively distinguished at the scale of mapping.

Qosg1 - Younger coarse alluvium, interpreted as glacial outwash (late Pleistocene)

White, gray, and grayish brown, horizontally stratified and trough cross-stratified, well-sorted and fine to poorly-sorted very coarse pebbly sand; matrix- and clast-supported pebble to boulder gravels, with common clasts of crystalline rock; rare beds of ripple cross-laminated fine to medium sand; includes strata of pale brown to brown silt overlying the aforementioned sand and gravel interval and rare lenses of brown silt within the that interval.

Cobbly to bouldery coarse alluvium containing clasts of granite, gneiss, greenstone, schist, limestone, Niobrara Formation chalk, Pierre Shale ironstone, and Ogallala Group opaline sandstones, appears in terrace remnants in a few places along the Nebraska-side valley wall of the Missouri River. Because of its coarse texture and clast composition, mapping unit Qosg1 is interpreted as glacial outwash even though it is spatially unassociated with glacial till. Places where these sediments have been mapped are: (1) in an upland position approximately 2 km north-northeast of Verdel, Nebraska; (2) approximately 6 km northwest of Verdel, Nebraska in a pit atop a conspicuous terrace remnant; and (3) much farther upstream, in pits atop terrace remnants closer to river level, approximately 17 km northwest of Monowi, Nebraska.

It is hypothesized that a more continuous sheet of outwash extended along the Nebraska side of the trench of the Missouri River Valley prior to the river achieving its present state of incision, and that only a few remnants of that sheet remain.

Mapping unit Qosg1 contains clasts of crystalline rock, apparently derived from the Canadian Shield, that are well-rounded and a few of them exhibit flat-faceted surfaces similar to those seen on many glacial erratics in the glaciated part of the U.S. Midcontinent. Qosg1 contains a large component of material derived either directly from outwash streams draining the Laurentide ice sheet immediately to the north in present-day South Dakota, or from the erosion of glacial deposits and the transport of that eroded sediment by the Missouri River.

Qosg2 - Older coarse alluvium, interpreted as glacial outwash (late Pleistocene)

Qosg2 - Coarse alluvium, interpreted as glacial outwash (Late Pleistocene; Wisconsinan)

Light yellowish brown, light yellowish gray, and grayish brown fine sand to coarse gravelly sand.

All areas mapped as Qosg2 are in South Dakota and they are closely associated with Wisconsinan tills (mapping units [Qtw1](#) and [Qtw2](#)). By virtue of this close association, these sand and gravel deposits are interpreted as glacial outwash.

Qapct - High alluvial terrace sands of Ponca Creek (late Pleistocene)

Gray, light brownish gray, very pale brown, and brown fine to coarse sand, locally containing a few pebbles of crystalline and sedimentary rocks.

Old terraces of Ponca Creek are perched high on the divide between Ponca Creek and the Niobrara River. Their elevations are lower than the crest of that divide, allowing them to be distinguished from high terrace deposits of the latter river.

Qath - High alluvial terrace sand and gravel (late Pleistocene)

Yellowish brown fine to coarse sand and pinkish, lithic, granule to pebble gravel.

Diffendal et al. (2008) recognized this mapping unit as a Quaternary fluvial unit distinct in age and characteristics from both younger terrace alluvium and the older Broadwater Formation. Mapping unit Qath may encompass multiple terrace levels, although the consistent differentiation of such levels is impossible. Deposits mapped as Qath are, overall, coarser than those mapped as [Qant](#) and they contain more pebbles of igneous and metamorphic rocks, particularly granite and/or granite gneiss. Qath is mostly mantled by Wisconsinan loess and they have been deeply dissected by small streams. There is a relatively sharp break in topography between the flatter slopes mapped as Qath and the higher, more dissected upland mapped as [Nb](#).

Qtpi - Pre-Illinoian glacial till (Pleistocene)

Diamicton consisting of clay, silty clay, or sandy clay with pebbles, cobbles, and boulders.

Mapping unit Qtpi is restricted to the Nebraska side of the Missouri River. There were several advances of the Laurentide Ice Sheet into eastern Nebraska in pre-Illinoian times and, specifically, prior to ca. 640ka. Although some geologists have proposed that Wisconsinan tills are present in northeastern-most Nebraska, there is insufficient evidence to refute the assignment of pre-Illinoian ages to any tills in northeastern Nebraska or in any other part of the state.

Nb - Broadwater Formation (Pliocene to early Pleistocene?)

Pinkish, lithic, granule to pebble gravel and very coarse sand.

Diffendal et al. (2008) recognized the Broadwater Formation in the upland areas south of the Niobrara River in a part of the present mapped area. The area mapped herein is nearly the farthest-eastward extent of the Broadwater Formation, which is dominated by fluvial sands and gravels derived from the Rocky Mountains. The Broadwater Formation is present in but a small portion of the mapped area at elevations of 1750 ft (533 m) above sea level. Upland areas mapped as Nb are much more heavily dissected than the mapped terrace deposits of the Niobrara River ([Qant](#) and [Qath](#)). The Broadwater Formation can be distinguished from terrace deposits of the Niobrara River by its comparative coarseness. The maximum thickness of the formation in the mapped area is approximately 100 ft (30 m). Age control on the Broadwater Formation is imperfect, but it is thought to be Pliocene in age, although some of it may be Pleistocene.

Nofr - Fort Randall Formation of the Ogallala Group (middle Miocene)

Nofr - Fort Randall Formation of the Ogallala Group (Neogene, middle Miocene)

Massive light yellowish brown to pale yellow weakly-consolidated siltstones with nodules of authigenic carbonate. Includes subordinate light brown fine to coarse sands and, possibly, local lenses or beds of opaline sandstone.

Massive light yellowish brown siltstones with abundant nodules of gray, light gray, and white authigenic carbonate appearing below the dominantly unconsolidated sands of the unit identified as the Valentine Formation in this map are provisionally assigned to the Fort Randall Formation of the Ogallala Group. The present state of knowledge suggests that the siltstones mapped herein as m. There are, however, siltstones in the basal part of the Valentine Formation in the area surrounding Valentine, Nebraska, some 200 km or more west of the depicted in the present map. Those siltstones are assigned to the Cornell Dam Member of the Valentine Formation (Skinner and Johnson, 1984).

Additional work will be required to ensure a convincing distinction of the unit mapped here as the Fort Randall Formation from the putatively younger strata of the Cornell Dam Member.

Authigenic carbonate nodules in mapping unit Nofr are distinctive. They range in shape from roughly spherical to cylindroidal or disc-shaped and they may have smooth or ragged margins. Some nodules exceed 30 cm in diameter. Smaller and blunt-ended cylindroidal nodules appear to be the cemented fills of invertebrate burrows. Some nodules are geodic and have linings of drusy calcite, and others appear to have spherulitic cortical zones. Dark gray to black manganese oxide staining is common in the nodules.

Nov - Valentine Formation of the Ogallala Group (middle Miocene)

Nov - Valentine Formation of the Ogallala Group (Neogene; middle to late Miocene)

Dominantly well-sorted, unconsolidated, light brown, brown, and yellowish brown, very fine to fine sands, in some places containing a few granules and pebbles. Such sands may also be weakly cemented by carbonate in places, thus appearing as friable, calcareous sandstones. Locally contains beds or lenses of indurated, greenish gray (weathering to white), opaline sandstones; these indurated strata typically appear near the base of the unit.

The Valentine Formation is present chiefly in the western part of the mapped area in Nebraska and it crops out in a few places in the South Dakota portion as well. It consists chiefly of unconsolidated fluvial sands. Greenish gray opaline sandstones or pebbly sandstones (so-called "green quartzites") of the Ogallala Group have been noted at different stratigraphic positions in the Ogallala Formation/Group in Nebraska, South Dakota, and Kansas (Swineford and Frye, 1946; Swineford and Franks, 1959; Skinner and Taylor, 1967). Such erosion-resistant sandstone crops out atop the hill once known by locals as "Stony Butte" south-southwest of the town of Verdel, Nebraska (42° 46' 49.71" N, 98° 12' 29.35" W). There is a second hill (42° 39' 44.18" N, 98° 12' 34.19" W) capped by resistant, cemented strata of the Valentine Formation approximately 16 km northwest of Verdigré, Nebraska. This feature is officially named Stony Butte by the U. S. Geological Survey.

Kp - Pierre Shale (Upper Cretaceous)

Kp - Pierre Shale (Upper Cretaceous, Campanian-Maastrichtian)

Gray to dark gray (weathering light gray, olive gray, olive brown, grayish brown, pale brown, and pale yellow) silt shale to clay shale, with rare, very thin to thin beds of siltstone, very fine sandstone, and bentonite, as well as some beds of chalky limestone. In many places, this mapping unit may also include thin (< 1 m) colluvium partially or completely derived from the Pierre Shale.

In Nebraska, the Pierre Shale is mapped over large areas between the Niobrara and Missouri rivers west of the town of Niobrara, Nebraska. It is mapped continuously, or nearly so, on valley-side slopes along the north bank of the Niobrara River and in heavily dissected land north of Ponca Creek. It is also mapped over large areas along Verdigré, Bazile, and Lost creeks, as well as the south bank of the Missouri River east and northeast of the town of Niobrara. In South Dakota, the Pierre Shale is mapped nearly continuously along the Missouri River upstream of the town of Springfield to the shores of Lake Francis Case. It is also mapped along Sevenmile, Choteau, Slaughter, and Spring creeks, and other low-order drainages that empty into the Missouri River. At least 91 m (300 ft) of the Pierre Shale are exposed within the mapped area.

Knsh - Smoky Hill Chalk Member of the Niobrara Formation (Upper Cretaceous)

Light gray to dark gray shaly chalk, weathering prominently white or brownish yellow; also, multiple, thin bentonites. In many places, this mapping unit may also include thin (< 1 m) colluvium partially derived from the Niobrara Formation.

The Niobrara Formation underlies the Pierre Shale in the enclosing region, but it crops out, or has a very shallow subcrop, only along the lower slopes of the valley walls of the Missouri River in both Nebraska and South Dakota, along Ponca Creek and the Niobrara River in Nebraska, and along the downstream reaches of Choteau, Emanuel, Coffee, and Spring creeks in South Dakota, as well as many low-order drainages there. In much of its mapped area, the Niobrara Formation is obscured by colluvium and in some places along valley walls it is also densely overgrown by trees.

Casual observations of poor exposures may lead to some confusion between the strata of the Smoky Hill Chalk Member of the Niobrara Formation and those of the overlying basal Pierre Shale, but the Niobrara Formation is perceptibly lower in density, firmer, and significantly more calcareous than is the Pierre Shale. In good exposures it is impossible to mistake the two units. The elevation of the contact between the Niobrara Formation and the overlying Pierre Shale is approximately 390-427 m (1280-1300 ft) above mean sea level. The Smoky Hill Chalk shows weak conchoidal fracture, splits into slabs or splinters (rather than fissile chips like the lower part of the Pierre Shale) and it can be further distinguished by its tendency to weather brownish yellow, or even slightly reddish, at the land surface. Fossil oysters (*Ostrea*) and fish scales can be found in the Smoky Hill Chalk. Crystals of secondary selenite gypsum commonly appear on bedding and fracture planes in weathered strata of the Smoky Hill Chalk.

Digital Geologic-GIS Map of the 59-Mile Reach of Missouri National Recreational River and Vicinity

59-Mile Reach Map Unit List

The geologic units present in the 59-Mile Reach digital geologic-GIS data produced for Missouri National Recreational River and Vicinity, South Dakota, Nebraska and Iowa (MNRR) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Hsb - Modern emergent sand bar). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (MRFNUNIT) table included with the GRI digital geologic-GIS data. Some source unit symbols, names and/or ages may have been changed in this document and in the GRI digital geologic-GIS data. This was done if a unit was considered to be the same unit as one or more units on other source maps used for this project, and these unit symbols, names and/or ages differed. In this case a single unit symbol and name, and the unit's now recognized age, was adopted. Unit symbols, names and/or ages in unit descriptions, correlation figures or other source map figures were not edited. If a unit symbol, name or age was changed by the GRI the unit's source map symbol, name and/or age appears with the unit's source map description.

Cenozoic Era

Quaternary Period

[Hsb](#) - Modern emergent sand bar
[Hvb](#) - Modern vegetated sand bar
[Hep](#) - Extractive pits
[Hef](#) - Engineered fill
[Hbsa](#) - Backswamp axial Yazoo alluvium and marsh deposits
[Hj](#) - Alluvium of James River
[Hs](#) - Alluvium of Big Sioux River
[Hal](#) - Tributary alluvium, including alluvial fans
[Hds](#) - Dune sand
[Qal](#) - Tributary alluvium
[Qtr](#) - Tufa, travertine and hosting clastic matrix
[Qoa](#) - Outwash and alluvium
[Qls](#) - Landslide deposits and colluvium
[Hpbc](#) - Point bar and paleochannel sand
[Hlcs](#) - Levee and crevasse splay silt and very fine sand
[Hcf](#) - Abandoned channel fill
[Hmc](#) - Minor channel and chute sediment
[Hu](#) - Fluvial sediment of Missouri River, undivided
[Hbs](#) - Backswamp mud
[Qvf](#) - Valley fill
[Q/Ku](#) - Discontinuous thin undivided Quaternary sediments overlying Cretaceous rocks
[Qes](#) - Eolian sand
[Qu](#) - Undivided surficial deposits of uplands
[Qtu](#) - Terrace alluvium
[Qt](#) - Alluvial and/or outwash terrace
[Qg](#) - Glacial gravel, including outwash
[Qwgs](#) - Glaciofluvial deposits along valley margin slope
[Qwgp](#) - Glaciofluvial deposits, pitted to flat morphology
[Qwgr](#) - Ridge-forming glaciofluvial deposits
[Qwtg](#) - Till of ground moraine
[Qwth](#) - Till of hummocky moraine
[Qwtb](#) - Till of bedrock cored moraine or end moraine
[Qlu](#) - Peoria loess over older Quaternary units
[Ql1](#) - Lower sandy loess

[Qot](#) - Older glacial till and associated sediment

[Qo](#) - Older glacial outwash and associated sediment

Neogene Period

[No](#) - Ogallala Group

Mesozoic Era

Cretaceous Period

[Kp](#) - Pierre Shale

[Kn](#) - Niobrara Formation

[Knc](#) - Niobrara Formation and Carlile Shale, undivided

[Kc](#) - Carlile Shale

[Kfb](#) - Fort Benton Group

[Kgg](#) - Greenhorn Limestone and Graneros Shale, undivided

[Kgd](#) - Greenhorn, Graneros, and Dakota formations, undivided

[Kd](#) - Dakota Formation

59-Mile Reach Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. All unit descriptions taken from source map: [59-Mile Reach of Missouri National Recreational River](#).

Hsb - Modern emergent sand bar (Holocene)

sb - Modern emergent sand bar (modern - 2004)

Riverine bar dominated by exposed and sparsely vegetated sediment, largely fine- to medium-sand and lesser areas of mud, occupies more than half of the map unit area, interspersed with more densely vegetated areas too small to map separately; includes both islands and areas of accretion ground (attached to mainland) subject to submergence at high river stage; extent based on 2004 NAIP orthophotography. Because these features become submerged and part of the modern channel during high flow events, these ephemeral features change position and extent, especially during high magnitude events. Thickness unknown, unit grades downward into modern and older channel sand of a few meters thickness.

Hvb - Modern vegetated sand bar (Holocene)

vb - Modern vegetated sand bar (modern - 2004)

Riverine bar in which vegetated areas occupy more than half of the area, and are developed in fine- to medium- sand, silt and mud; interspersed with areas of exposed sediment too small to map separately; includes both islands and areas of accretion ground (attached to mainland) subject to submergence at high river stage; extent based on 2004 NAIP orthophotography. Because these features become submerged and part of the modern channel during high flow events, these ephemeral features change position and extent, especially during high magnitude events. Thickness unknown, unit grades downward into modern channel sand of a few meters thickness.

Hep - Extractive pits (Holocene)

ep - Extractive pits (historic)

Areas of borrow pits to extract sand and gravel, largely from units [Qo](#) and [Qvf](#). Unit is mapped only within Nebraska uplands area per quadrangle mapping of Dillon and others (2008, 2010, 2011, 2012, 2013). Where pits have been superimposed on natural contacts, the former natural extent of adjoining map units is obscured. Not all borrow pits are readily recognized or mapped.

Hef - Engineered fill (Holocene)

ef - Engineered fill (Historic)

Engineered material includes the range of earthfill materials, concrete and angular bouldery riprap which form the construction materials of the Gavins Point Dam area, as well as prominent fill for the most recent highway engineering such as the south approach to the new US 81 bridge at Yankton; only mapped where the material dominates the landscape and covers or has altered the distribution of riverine materials; thickness from 1 m to 50 m.

Hbsa - Backswamp axial Yazoo alluvium and marsh deposits (Holocene)

Organic rich mud deposited in sluggish intermittently marshy drainage environments that overflow southeastward parallel to northeast upland margin between distal portions of backswamp deposits and distal toes of alluvial fans from the uplands; thickness from 1 – 3 m.

Hj - Alluvium of James River (Holocene)

Clay- and silt-rich alluvial mud; in the James River valley north of Highway 50, unit is dominated at the surface by dark, expansive overbank mud forming vertisol-like soils; upon drying forms surface polygons over columns separated by open cracks up to 1 m deep; includes only the channel portion of the highly variable surficial extent of the modern James River, which commonly inundates its floodplain and valley floor for up to several weeks each year. South of Highway 50, this unit also marks abandoned channel courses of the James River that have been partly constrained within abandoned paleochannels of the Missouri River (Moreno, 2010). Floodplain sedimentation by the Missouri River since abandonment of these James River paleochannels has partly infilled these paleochannels with Missouri River sediments, but the distinctive amplitude and scale of the meandering pattern of the James River remains; thickness from 1 – 4 m.

Hs - Alluvium of Big Sioux River (Holocene)

Gravelly sand, silt and mud, dominated at the surface by dark, expansive overbank mud forming vertisol-like soils; includes modern channel sediment, point bar sand, overbank sediment and abandoned channel fill sediment of the modern and recent Big Sioux River, which commonly inundates its floodplain and valley floor for up to several weeks each year. Upstream of the Missouri River Valley, this unit occupies the central active meander belt and floodplain of the Big Sioux River Valley; the active meander belt and channel of the Big Sioux continues along the eastern edge of the Missouri River Valley as a yazoo type of drainage system for its lowest 15 miles above its mouth into the Missouri; thickness from 1 – 8 m.

Hal - Tributary alluvium, including alluvial fans (Holocene)

Alluvial mud, gravel, sand, silt and clay of tributary valleys derived from uplands that flank the Missouri River valley; where these drainages enter the Missouri Valley, the larger drainages have built fans at the tributary valley mouth, which are more extensive where active river channel migration has not erosively removed the fans; in some valleys unit grades downward into late glacial alluvium or possibly outwash; thickness from 1 – 10 m.

Hds - Dune sand (Holocene)

Well-sorted fine- to very fine- eolian sand; forms hummocky irregular ground of incipient dunes which have been reworked by wind from sandy fluvial deposits of abandoned point bars and exposed riverbanks; generally less than 10 m thick.

Qal - Tributary alluvium (Holocene and late Pleistocene)

Alluvial mud, gravel, sand, silt and clay in tributary valleys developed within uplands that flank the Missouri River valley; as much as 5 m thick; in some valleys unit probably grades downward into late Pleistocene alluvium or possibly outwash; thickness from 1 – 10m.

Qtr - Tufa, travertine and hosting clastic matrix (Holocene and late Pleistocene)

Calcareous tufa and travertine that has precipitated at and very near the surface from water that has discharged from groundwater. The calcitic precipitates range from relatively pure sparry travertine to

cements of various morphology around and within pore space of the preexisting clastic surface sediment and soils, including varying portions of gravel, sand, silt, and clay; thickness generally less than 1 m, but may locally exceed 1 m.

Qoa - Outwash and alluvium (Holocene and late Pleistocene)

Expansive dark humic alluvial mud overbank deposits of the James, Vermillion, and Big Sioux Rivers that overlie and grade downward into coarser, generally well-sorted sand and gravel of late Pleistocene age. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, and friable clasts of Cretaceous shale and chalk; gravel and sand include common and locally very prominent secondary mineralization of oxides of iron and manganese. This coarse alluvium potentially includes proglacial outwash and flood deposits (particularly along the Big Sioux River), and subglacially deposited gravel and sand (particularly in the valley fills of the James and Vermillion Rivers) ; thickness from 1 – 20 m.

Qls - Landslide deposits and colluvium (Holocene and late Pleistocene)

Slump blocks and other colluvial slope mantle derived from Cretaceous shales, marls, and overlying Quaternary deposits in landslide-prone steep slopes marginal to the Missouri River valley; thickness poorly known but slide blocks are locally at least 5 m deep.

Hpbc - Point bar and paleochannel sand (Holocene)

Fine- to medium-grained, well-sorted sand that was deposited in higher energy settings of former active channels and point bars; thickness, a defining characteristic, is greater than 2 m, commonly 4 m or more. Includes occasional fine gravel (pebble to granule) clasts generally composed of low-density shale concretions, and less common igneous and metamorphic clasts reworked from glacial deposits. Includes occasional transported bones: vertebra, scapula and ribs of bison are most commonly found. The sand is capped by mud (clay- and silty-clay-rich) overbank deposits that are less than 2 m thick; relict surface morphology, if not too muted by overbank sediments, consists of curving broad ridges and swales that are subparallel to a paleochannel scarp and/or an abandoned channel fill and swale that adjoin the outer margin of point bar deposits. In some cases, a relatively younger unit Rpbpc polygon is juxtaposed by such a fluvial scarp against an older unit Rpbpc polygon.

Hlcs - Levee and crevasse splay silt and very fine sand (Holocene)

Levee and crevasse splay silt and very fine sand (Holocene)— Constructional low ridge of levee morphology; composed of interbedded silt loam and very fine sand of laterally varying proportions, formed at margin of former river channel by cumulative overbank flood events of high suspended sediment load, typically on outside bend of fluvial scarp. Highest part of ridge adjoins the fluvial scarp and slopes gently away from scarp. Locally includes ridge and swale forms of crevasse splays with axes at high angles to paleoscarp that bounds the proximal side of the levee. Levee and splay deposits are mappable because they bury and obscure the surface morphology of older features that they lap upon; they form local high ground effective in controlling surface and tributary drainage patterns within the river valley; thickness from 1 – 4 m.

Hcf - Abandoned channel fill (Holocene)

Interbedded mud, fine sand, silt, clay, and various loam textures deposited in cumulative fills that are greater than about 4 m in thickness but with individual textural beds generally no thicker than about 1 m; deposited in the accommodation space of abandoned channels on the floodplain including oxbow lake environments, especially during episodic river flood events and overbank sedimentation; surface morphology consists of broad curving swales in the floodplain bounded by steeper paleochannel scarps along the outer margin of the swale; thickness from 4 – 10 m.

Hmc - Minor channel and chute sediment (Holocene)

Fine sand, with interbedded mud, silt, clay, and various loam textures; deposited in former minor channels and chutes; deposits include a greater portion of sand than in unit Rcf; surface morphology consists of linear swales less than 200 m in width, commonly anastomosing; thickness from 1 – 3 m.

Hu - Fluvial sediment of Missouri River, undivided (Holocene)

Silty loam overbank deposits over undivided alluvial facies of the Missouri River; forms a low terrace; symbol used in cross section (fig. 3) for all recent fluvial facies, undivided; thickness from 1 – 5 m.

Hbs - Backswamp mud (Holocene)

Clay, silty clay, silt and fine-grained mud in massive to poorly bedded deposits generally at least 6 m thick and up to 12 m thick which underlie smooth flat floodplain that lacks paleochannel and associated surface morphology; generally occurs in the north part of the Missouri River valley north of the mosaic of units [Hlcs](#) (into which [Hbs](#) grades), [Hpbc](#), and [Hcf](#), and south of unit Hbsa and alluvial fans of unit [Hal](#) with which [Hbs](#) interfingers; thickness up to 10 m.

Qvf - Valley fill (Quaternary)

Discontinuous late Quaternary alluvial silt, sand, and gravel (Dillon, 2004; Dillon and others 2008), and underlying pre-Illinoian sand, gravel, diamicton-till, and ash beds. This unit includes undivided units of Dillon and others (2008-2013), including sandy and silty tributary alluvium, valley floor alluvium, alluvial fans, slope wash, footslope colluvium, low and high terrace alluvium (including Roberts Creek, Honey Creek, and Gunder members of the informal DeForest formation, Dillon and others, 2013). The unit locally includes patchy capping eolian sand and associated erosional features attributed to late Pleistocene episodes of eolian deflation (Hanson and others, 2009; Dillon and others, 2009). Thickness ranges from about 40 m to discontinuous and thin (< 4 m thick) between small Cretaceous bedrock exposures. Near Wynot, a buried humic horizon locally occurs beneath 3 meters of less humic silt that underlies the surface. Beneath this buried humic silt horizon, sand, gravel and silt beds show marked soft sediment deformation with disharmonic folds.

Q/Ku - Discontinuous thin undivided Quaternary sediments overlying Cretaceous rocks (Holocene and Pleistocene)

Undivided Quaternary deposits as described in unit [Qu](#) that form discontinuous cover over Upper Cretaceous Niobrara Formation as described in unit [Kn](#). In some cases near the local mapped contacts the subcropping units include Carlile Shale ([Kc](#)), and near the upper limit of [Kn](#), lowermost

Pierre Shale ([Kp](#)). Includes common local exposures of [Kn](#); discontinuous Quaternary sediment is generally less than 3 m thick.

Qes - Eolian sand (early Holocene and late Pleistocene)

Fine and very fine eolian sand. Eolian sand; occurs as patchy, discontinuous deposits near broad southeast trending valleys in which loess cover is anomalously thin to absent (Hanson and others, 2009), perhaps due to erosion by very strong winds. Eolian sediments are derived from nearby exposures of fine sandy outwash and/or lower fine sand rich portions of loess unit [Qlu](#). The sand occurs in a variety of positions on the landscape and mantles a variety of mapping units; thickness from 1m to at least 7 m known from boreholes.

Qu - Undivided surficial deposits of uplands (Quaternary)

Older dissected deposits that underlie upland areas and ridges between anastomosing valley network with marked northwest to southeast orientation. Partially mantled by eolian deposits; locally includes eolian sand and associated erosional features attributed to late Pleistocene episodes of eolian deflation (Hanson and others, 2009; Dillon and others, 2009). Most but not all areas have a patchy and discontinuous tan loess (silt) cover ranging from a feather edge up to a few meters thick. Loess is underlain by up to 10 m of intercalated but poorly exposed sand, gravel, silt, diamicton including till, and ash beds (Izett and Wilcox, 1982); which are underlain by Cretaceous sedimentary bedrock units described below. Map unit includes very sparse, occasional outcrops of Cretaceous bedrock; thickness of at least 25 m known from boreholes.

Qtu - Terrace alluvium (Holocene)

Silty loam overbank deposits over sand, silt, and gravel of early postglacial terrace alluvium of the Missouri River in the southern part of the city of Yankton (where it overlies unit [Qg](#)); thickness from 1 – 5 m.

Qt - Alluvial and/or outwash terrace (Holocene and late Pleistocene)

Clay, silt, mud, sand and gravel ranging from interbedded to normally graded; surface morphology consist of single terrace to multiple inset terraces that adjoin or include alluvium of modern creeks and tributaries; thickness from 1 – 5 m.

Qg - Glacial gravel, including outwash (late Pleistocene)

Well-rounded cobble-rich gravel; clasts are predominantly crystalline granitic and metamorphic rocks derived from glacial erosion of the Canadian Shield. This deposit is only known to occur at the surface in this map area along the south riverbank just east of Yankton, where it coincides with a riffle in the Missouri River at low stage and discharge. The coarse cobbly size of this unit contrasts markedly with the much finer texture of all surficial postglacial Missouri River alluvial units, including [Rpbc](#). Unknown local thickness; however, this exposure is probably contiguous with glacial sand and gravel that underlies postglacial Missouri River alluvium, and its maximum thickness in the river valley is about 35 m beneath this outcrop. During the construction of the new US 81 bridge, glacial gravel of similar size range and lithology was exposed by excavations under the north bridge abutment in Yankton under about 2 m of sand of map unit [Qtu](#) ; at this site cobble gravel was intercalated with diamicton, sand, and pebble-rich gravel.

Qwgs - Glaciofluvial deposits along valley margin slope (late Pleistocene)

Sand and gravel of glaciofluvial origin in valley-margin slope position; relatively well sorted. Poorly to well stratified; bedding based on grain size variations ranges from massive to well-bedded, commonly interbedded and intergradational with poorly sorted sediments such as diamictons; includes outwash, kame gravel, and subglacial deposits. Textures vary gradually to abruptly, laterally and vertically. Locally highly deformed by soft sediment deformation, in part related to ice meltout. Locally map unit is dominantly boulder or cobble gravel; in some places pebbly fine sand. Clasts are subrounded to well rounded. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, friable clasts of Cretaceous shale and chalk; locally includes blocks and clasts of redeposited till. Variably cemented: gravel and sand include common and locally very marked secondary stains and pervasive cement of oxides of iron and manganese, calcium carbonate, and locally gypsum. Occurs on irregular slopes of valley margins. Thickness up to 70 m known from boreholes.

Qwgp - Glaciofluvial deposits, pitted to flat morphology (late Pleistocene)

Sand and gravel of glaciofluvial origin with pitted to flat morphology; relatively well sorted. Poorly to well stratified; bedding based on grain size variations ranges from massive to well-bedded, commonly interbedded and intergradational with poorly sorted sediments such as diamictons; includes outwash, kame gravel, and subglacial deposits. Textures vary gradually to abruptly, laterally and vertically. Locally highly deformed by soft sediment deformation, in part related to ice meltout. Locally map unit is dominantly boulder or cobble gravel; in some places pebbly fine sand. Clasts are subrounded to well rounded. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, friable clasts of Cretaceous shale and chalk; locally includes blocks and clasts of redeposited till. Variably cemented: gravel and sand include common and locally very marked secondary stains and pervasive cement of oxides of iron and manganese, calcium carbonate, and locally gypsum. Surface morphology includes irregular closed depressions of up to 500m in diameter. Thickness up to 70 m known from boreholes.

Qwgr - Ridge-forming glaciofluvial deposits (late Pleistocene)

Sand and gravel of glaciofluvial origin that underlie ridges; relatively well sorted. Poorly to well stratified; bedding based on grain size variations ranges from massive to well-bedded, commonly interbedded and intergradational with poorly sorted sediments such as diamictons; includes outwash, kame gravel, and subglacial deposits. Textures vary gradually to abruptly, laterally and vertically. Locally highly deformed by soft sediment deformation, in part related to ice meltout. Locally map unit is dominantly boulder or cobble gravel; in some places pebbly fine sand. Clasts are subrounded to well rounded. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, friable clasts of Cretaceous shale and chalk; locally includes blocks and clasts of redeposited till. Variably cemented: gravel and sand include common and locally very marked secondary stains and pervasive cement of oxides of iron and manganese, calcium carbonate, and locally gypsum. Forms ridges that are aligned along NNW-SSE trends. Thickness up to 70 m known from boreholes.

Qwtg - Till of ground moraine (late Pleistocene)

Glacially deposited diamicton - till of ground moraine - consisting of heterogeneous mixture of boulders, gravel, sand, silt and clay; matrix is predominantly silty clay loam; includes lenses and stringers of better sorted sand and gravel that range in thickness from a few cm to several meters and in lateral extent from 1 cm to 10 m or more. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, and more friable clasts of Cretaceous shale and chalk. Upper oxidized and weathered zone is typically 8-12 m thick, and up to 15 m thick; variable

depth of oxidation may be related in part to heterogeneity of fractures. Flat to gently undulating surface morphology; thickness of at least 60 m known from boreholes.

Qwth - Till of hummocky moraine (late Pleistocene)

Glacially deposited diamicton - till of hummocky moraine - consisting of heterogeneous mixture of boulders, gravel, sand, silt and clay; matrix is predominantly silty clay loam; includes lenses and stringers of better sorted sand and gravel that range in thickness from a few cm to several meters and in lateral extent from 1 cm to 10 m or more. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, and more friable clasts of Cretaceous shale and chalk. Upper oxidized and weathered zone is typically 8-12 m thick, and up to 15 m thick; variable depth of oxidation may be related in part to heterogeneity of fractures. Hummocky and highly undulating surface morphology, with numerous closed depressions, sloughs and lakes; locally has irregular low (< 2 m high) subparallel ridges; thickness of at least 60 m known from boreholes.

Qwtb - Till of bedrock cored moraine or end moraine (late Pleistocene)

Glacially deposited diamicton - till of bedrock cored moraine or end moraine - consisting of heterogeneous mixture of boulders, gravel, sand, silt and clay; matrix is predominantly silty clay loam; includes lenses and stringers of better sorted sand and gravel that range in thickness from a few cm to several meters and in lateral extent from 1 cm to 10 m or more. The lithology of gravel clasts include Canadian Shield-derived crystalline granitic and metamorphic rocks, and more friable clasts of Cretaceous shale and chalk. Upper oxidized and weathered zone is typically 8-12 m thick, and up to 15 m thick; variable depth of oxidation may be related in part to heterogeneity of fractures. Relatively high relief, can be broadly ridge-like. Borehole records show that areas of higher ground broadly coincide with areas of relatively high bedrock topography, thus supporting a bedrock-cored moraine interpretation; thickness of at least 25 m known from boreholes.

Qlu - Peoria loess over older Quaternary units (late Pleistocene)

Tannish brown loess, Peoria Loess is typically massive to laminated silt and very fine sandy silt. Loess, a windblown silt, forms a discontinuous (on north and west parts of Nebraska uplands) to nearly continuous cover (on south and east parts of Nebraska uplands) on upland areas and ridges with marked northwest to southeast orientation. Loess is mostly underlain by up to 10 m of intercalated but poorly exposed sand, gravel, silt, diamicton, and occasional ash beds (Izett and Wilcox, 1982); which are underlain by Cretaceous sedimentary bedrock units described below; locally, especially near upland breaks adjoining margin of Missouri River Valley, loess directly overlies Cretaceous sedimentary bedrock. The upper portions are oxidized brown to light gray. A thick soil has developed in the upper portions of the deposit. The lower portions range from massive silt to thin bedded silt and fine sand. Peoria Loess in this area is locally subdivided by Dillon and others (2008-2013) into two mapping units: the main units described herein and a lower sandy loess ([Ql1](#)) Local main loess thickness of up to 28 m known from boreholes.

Ql1 - Lower sandy loess (late Pleistocene)

Fine sandy silt overlying fine to medium sand. Ql1 includes eolian sand deposits which cannot be meaningfully separated at this scale. The sand is mostly derived from glacial outwash, although valley bottoms, terraces, and till may be locally important sources; thickness of up to 2.5 m.

Qot - Older glacial till and associated sediment (middle and early Pleistocene)

Gray to dark-gray matrix-supported diamicton. Weathers to light brown and orange-yellow, with secondary carbonate (light-toned) and manganese (black) and iron (yellow) oxide coatings that are found along fractures. Sand and gravel units that are up to 1 m in thickness are commonly found within this unit. Till commonly overlies sand and gravel and silt deposits. The unit locally includes patchy and discontinuous eolian sand and loess (silt) cover ranging from a feather edge up to a few meters thick. Unit thickness varies, but can be up to 35 m.

Qo - Older glacial outwash and associated sediment (middle and early Pleistocene)

Poorly- to well-sorted sand and cobbly gravel. Clast sizes range from sand to cobbles, with few boulders. Scattered boulders commonly occur on the surface, presumably remnants due to removal of the finer sediments through eolian and/or fluvial erosion. Gravel and larger clasts include a variety of igneous and metamorphic types including quartzite, granite, granodiorite, and distinctive pinkish, resistant Sioux Quartzite. Locally-derived sedimentary rocks are also present, including greenish Ogallala sandstone, along with resistant limestones and dolostones from a variety of Phanerozoic bedrock sources to the north. Sediment from this unit has been utilized in numerous gravel pits in the region. Till occurs as clasts within the sand and gravel and as intercalated beds. Unit thickness up to 30 m.

No - Ogallala Group (Miocene)

Siltstone, sandstone, and conglomerate; predominantly fluvial; sandstone is locally strongly cemented by silica – this is a resistant lithology which commonly occurs as reworked clasts in glacial till. This stratigraphically highest and youngest unit of pre-Quaternary bedrock is not exposed in the map area but occurs only in a part of the subsurface of Nebraska in the map area. Thickness ranges from 0 - 30 m.

Kp - Pierre Shale (Upper Cretaceous)

Dark-gray to black fissile shale and light tan to pale orange calcareous marl; includes interbeds of bentonite that represent ashfall deposits into the marine seaway; fossiliferous; contains thin seams of gypsum; slumps commonly occur within this unit; thickness ranges from 0-65m (Burchett and others, 1988).

Kn - Niobrara Formation (Upper Cretaceous)

Light to dark-gray interbedded chalk, limestone, and calcareous shale; weathers to white, pale yellow and orange; contains many fossil clams, oysters, shell fragments, and foraminifera; includes gypsum veinlets in boxwork and on bedding planes; lower 30 m is medium-gray calcareous shale; thickness ranges from 0-100m (Burchett and others, 1988).

Knc - Niobrara Formation and Carlile Shale, undivided (Upper Cretaceous)

See descriptions for [Kn](#) and [Kc](#). These marine sedimentary bedrock units are locally overlain by Quaternary loess in outcrops interspersed between landslides in bluffs along the river just east of the mouth of Bow Creek.

Kc - Carlile Shale (Upper Cretaceous)

Dark gray to medium gray shale, with minor limestone and sandstone; locally includes euhedral selenite (gypsum) crystals, septarian nodules, and pyrite nodules; thickness 0-60m (known to be removed by erosion beneath much of river valley in this map area) (Burchett and others, 1988; Witzke and others, 1997).

Kfb - Fort Benton Group (Upper Cretaceous)

Includes Carlile Shale, Greenhorn Limestone, and Graneros Shale; only shown as a map unit within Iowa on pre-Quaternary geologic map of bedrock subcrop (Witzke and Ludvigson, 1987; Witzke and others, 1997).

Kgg - Greenhorn Limestone and Graneros Shale, undivided (Upper Cretaceous)

Greenhorn Limestone and Graneros Shale Greenhorn is medium to light-gray limestone and chalk, interbedded with argillaceous limestone, marl, and calcareous shale; contains Inoceramid bivalves, fish debris and abundant coccoliths and foraminifera (Turonian); about 8 m thick (Burchett and others, 1988). Underling "Graneros" Shale (which is probably not biostratigraphically equivalent to the type Graneros in Colorado) is dark gray, partly calcareous shale; includes interbeds of siltstone, sandstone and carbonaceous shale, and thin bentonite layers in upper part; about 12-17 m thick (Burchett and others, 1988; Witzke and Ludvigson, 1987; Witzke and others, 1997).

Kgd - Greenhorn, Graneros, and Dakota formations, undivided (Cretaceous)

Greenhorn Limestone, Graneros Shale, and Dakota formation, undivided.

Kd - Dakota Formation (Cretaceous)

Sandstone and shale (Burchett and others, 1988; Witzke and others, 1997; McCormack and Hammond, 2004; Joeckel and others, 2005); varicolored, including light- to brownish gray, yellow and reddish-brown. [Kd](#) includes two members in this area near Sioux City, which is the original type area of the Dakota. Upper The upper mudstone-dominated Woodbury Member is dominated by/includes noncalcareous mudstone and minor fine sandstone; facies interpreted as deposited in the lower coastal plain along the margin of the encroaching Western Interior Seaway. (Witzke and Ludvigson, 1987; Witzke and others, 1997) Lower. The lower sandstone-dominated Nishnabotna Member (not exposed in the map area but known from boreholes and from exposures to the south) includes sandstone that is fine- to coarse-grained, micaceous, crossbedded and lenticular, and interbedded with mudstone; overlying a middle part dominated by carbonaceous shale; and a lower part includes sandstone similar to that in upper part; sandstone facies are interpreted to have been deposited in nonmarine braided fluvial and shallow marine environments; [Kd](#) in this area is about 120 m thick.

Ancillary Source Map Information

The following sections present ancillary source map information associated with sources used for this project.

39-Mile Reach of Missouri National Recreational River

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Prominent text associated with this source:

Map Production Note

This map was produced using multiple sources of data and it is intended to be reliable at the scale of 1:24,000. Only a small fraction of the present mapped area had already been mapped at that scale, and two pre-existing maps in Nebraska were moderately revised in the course of the production of the present map. All spatial data employed in the production of the present map were compiled and modified in ArcMapTM GIS. LiDAR data (Nebraska) and conventional DEMs were employed topographic bases, in addition to DRGs of U.S. Geological Survey 7.5-minute topographic quadrangles. Photography imagery used in the production of this map included base map aerial imagery available in ArcMapTM GIS and selected, scanned, analog aerial stereophotographs, dating from particular years between 1938 and ca. 1970, which are archived in the files of the Conservation and Survey Division, School of Natural Resources at the University of Nebraska-Lincoln. An initial classification of surficial geology was made using digital soil survey data (Soil Survey Geographic Database or SSURGO) from the Natural Resources Conservation Service and existing geologic maps and reports. SSURGO data were reclassified by parent material in an iterative process that reduced parent-material classification to rational units of bedrock and unconsolidated materials present at the land surface, whether those units have official stratigraphic names or not. Existing, large-scale, digital bedrock and surficial geological maps from both the Conservation and Survey Division (Nebraska Geological Survey) and the South Dakota Geological Survey were used to evaluate digital SSURGO data and the spatial distributions of mapping units. Two phases of field reconnaissance were employed in the course of the mapping project, the first after the initial classification of surficial geology and the production of a working digital map, and the second much later in the project as a means of refining map interpretations. Landslides depicted in this map were identified from LiDAR imagery and aerial photography in Nebraska and from aerial photography alone in South Dakota.

Text from source map: [39-Mile Reach of Missouri National Recreational River](#)

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References from source map: [39-Mile Reach of Missouri National Recreational River](#)

Suggested Ordering of Map Units by Approximate Age

From oldest at top to youngest at the bottom (see note after list):

Knsh Smoky Hill Chalk Member of the Niobrara Formation
 Kp Pierre Shale
 Nb Broadwater Formation
 Nov Valentine Formation of the Ogallala Group
 Nofr Fort Randall Formation of the Ogallala Group
 Qtpi Pre-Illinoian glacial till
 Qath High alluvial terrace sand and gravel
 Qapct High alluvial terrace sands of Ponca Creek
 Qosg1 Coarse alluvium, interpreted as glacial outwash
 Qosg2 Coarse alluvium, interpreted as glacial outwash
 Qtw1 Till, stagnation moraine
 Qtw2 Till, ground moraine
 Qant High alluvial terrace sediments of the Niobrara River (late Pleistocene to Holocene)
 Qante Eolian sands atop Niobrara River high terrace
 Qp Peoria Loess
 Qpo Peoria Loess (thin) atop shallow Ogallala Group
 Qabc3, Qabc2, and Qabc1 Bazile Creek alluvium
 Qalc1, Qalc2, Qalc3, and Qalc4 Lost Creek alluvium
 Qam4, Qam3, Qam2, and Qam1 Missouri River alluvium
 Qan5, Qan4, Qan3, Qan2, and Qan1 Niobrara River alluvium
 Qansr Sand ridges atop alluvium of Niobrara River (Holocene)
 Qapc1, Qapc2, Qapc3, Qapc4, and Qapc5 Ponca Creek alluvium
 Qavc3, Qavc2, and Qavc1 Verdigre Creek alluvium
 Qalt Alluvial terrace deposits of small streams
 Qal Alluvium of small streams
 Qanfc Flood-channel deposits of Niobrara River
 Qc Colluvium
 Qf Alluvial fan sediments
 Qantd Niobrara River tributary delta, subaerial part
 F Fill
 P Pit
 W Water

Note: multiple alluvial units have similar ages and, therefore, an exact grouping by age is impractical if their context relative to each other is to be conserved. Such units are grouped alphabetically, by relative age within a group corresponding to a single drainage, and then* *Text incomplete on source map.

Text from source map: [39-Mile Reach of Missouri National Recreational River](#)

59-Mile Reach of Missouri National Recreational River

The formal citation for this source.

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Prominent text associated with this source:

Data Dictionary

The following information was provided by the source map author to better explain fields in the source digital data. Information from the source fields was compiled into the Notes field of feature classes in the geodatabase of the GRI digital geologic-GIS product (mrfrn_geology.gdb).

Geologic Sample Localities

lithology - predominant grain size and texture of sample, assessed in field

U ppm - Uranium content of sample environment in parts per million

Th ppm - Thorium content of sample environment in parts per million

K2O% - Potassium oxide content of sample environment in percent

location confidence - Horizontal distance representing feature locational certainty, as a halo in meters surrounding the point location

H2O% - moisture content of sample environment in percent

dose rate - dose rate for sample determined from content of U, Th, K2O, and moisture, and cosmic ray flux

equivalent dose - equivalent dose (ED) in Grays of radiation energy determined from luminescence measurements and ED curve reconstruction

aliquots - number of aliquots used for determination of equivalent dose

cosmic rate - cosmic radiation flux calculated from location and depth

material sampled - description of material that was sampled

depth - depth from surface in meters at which sample was collected

stratigraphic texture - stratigraphic notes about map unit that was sampled

material analyzed - description of material that was micro-sampled and analyzed

Geologic Line Features, Geologic Contacts and Geologic Units

age relationship to the early 1890s Missouri River - provides the relative age relation of features to the position of the Missouri River in the early 1890s as shown by georeferenced raster data for the Missouri River Commission (MRC) surveys, with riverbank positions vectorized as line features in the Geologic Lines feature class. For example, contacts and map unit polygons with MRC relation = 'later'

designate features that are interpreted from discordant (cross-cutting) relations to the 1890s MRC-surveyed Missouri River position to have formed more recently than ca. 1894.

Text from source map: [59-Mile Reach of Missouri National Recreational River](#)

GRI Digital Data Credits

This document was developed and completed by James Winter (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Ron Karpilo (Colorado State University).

The information in this document was compiled from GRI source maps, and is intended to accompany the digital geologic-GIS maps and other digital data for Missouri National Recreational River and Vicinity, South Dakota, Nebraska and Iowa (MNRR) developed by James Winter (Colorado State University) (see the [GRI Digital Maps and Source Map Citations](#) section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps).

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GRI program coordination and scoping provided by Bruce Heise, Jason Kenworthy and Tim Connors (NPS GRD, Lakewood, Colorado).