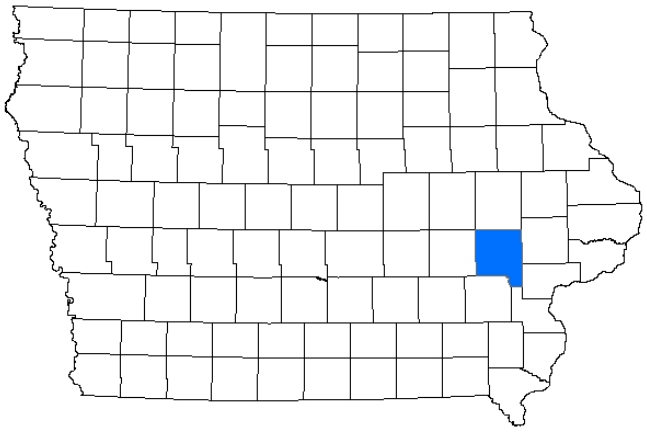
A Summary of the Geology of Johnson County, Iowa and Lake MacBride State Park



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Abstract:

Iowa's geology consists dominantly of limestone and dolomite. Both are sedimentary rocks, formed via chemical processes and can be generally associated with warm, shallow seas. Iowa's bedrock is a good indicator of the past ecological settings that occurred in Iowa thousands to millions of years ago. Iowa has many different bedrocks, landform regions, and ecological diversity that creates the beautiful state that is here today. Within this state there are over 70 state parks that anyone can visit to learn more about the state's nature, history, and ecology. This paper focuses specifically on Johnson County and Lake MacBride State Park that is located along its northern edge.

The main bedrock of the county and state park is Devonian aged limestone. Within this limestone there are many marine fossils that help hint at what past environments were like in the county and state park's history. Lake MacBride State Parks lies on predominantly on the Southern Iowa Drift Plain landform region, this region is characterized by gently rolling hills, loess, and other influences of past glacial events. The PreIllinoian, Illinoian, and Wisconsinan Glacial stages shaped many of Iowa's landscapes and have heavily influenced the landscapes of Johnson County.

Introduction:

Iowa's geology is diverse and creates unique history that is told in the rock record. Iowa's geologic record goes all the way back to the Precambrian, found in northwest Iowa, that began approximately 3 billion years ago (Ga), and ends with deposits from the most recent Quaternary period, including glacial till and loess deposits. The bedrock, landscapes, and fossil records piece together the history of this state.

This project will be focusing on the geology of Johnson County, Iowa and Lake MacBride State Park located within the county. This review will discuss both the human and geologic history of the county, geography, important topographic features, bedrock geology, and applied geology of the county and how it influences the recreational areas. Lake MacBride is a highly visited area, which allows people to discover more about what is offered within this county. The geology of an area heavily influences what the topography and landscape. By preserving areas, such as state parks, scientists, historians or anyone interested is able to learn about an area and how geological processes, natural processes, nature and ecology, and so many other factors influenced the way it formed. This review serves to be used as a guide to the county, to supplement learning the county's geology and topography and to acquire more knowledge about Lake MacBride State Park and its importance.

Geologic History of Iowa

Precambrian:

Although there is no Precambrian aged rock in Johnson County, Precambrian bedrock is found in the very northwestern Iowa (Figure 1). Precambrian age rocks occur over a large area of North America and create a feature known as the Precambrian basement complex, which is a foundation to many of the deposited Paleozoic rocks of the Midwest. Iowa's Precambrian rock record includes rock from the Archean, Early Proterozoic, and Middle Proterozoic ages. Iowa's oldest bedrock is the Otter Creek Layered Mafic Complex, which dates back approximately 2.9 billion years ago, however the Sioux Quartzite is Iowa's oldest exposed bedrock (Anderson, 1998).

Part of Iowa's Precambrian includes the Midcontinent Rift System (MRS), where 1.1 Ga the continental crust nearly tore North America apart. The MRS runs from the southwest corner of Iowa, up through the north-central boarder. Although the Precambrian rock is buried under Phanerozoic rocks, their presence is indicated by sensitive gravity measurements. Due to the dense basalts and red clastic rocks found in the Precambrian rocks, it has become one of the most pronounced gravity anomalies in North America. Another prominent feature of the Midcontinent Rift System found in Iowa is the enormous block of basalt, known as the Iowa Horst that follows the axis of the rift across the entire state (Anderson, 1998).

Other significant features and projects in Iowa regarding the Precambrian rock record include the Quimby Drill Hole; a drill hole that was made for scientific information rather than economic wealth, and the Matlock cores that were drilled in search of iron ore (Anderson, 1998). Although Iowa's exposed Precambrian record is limited, data from cores and Precambrian rock from surrounding states show there is a lot of Precambrian history in the state of Iowa.

Cambrian:

The Cambrian starts around 485 Ma and ends near 541 Ma. This is the age known for the "explosion of life" and the dramatic increase in atmospheric oxygen. Similar to the Precambrian aged rock, rock dating back to the Cambrian is limited in Iowa and is only found in the very Northeast corner of the state (Figure 1), and consequently cannot be found in Johnson County. Iowa's Cambrian rock record is made up of mostly Quartzose and feldspathic sandstones. Major formations of the Cambrian rock include the Jordan, St Lawrence, Lone Rock, Wonewoc, Eau Claire, and Mt. Simon formations (Anderson, 1998).

The Jordan sandstone is particularly well known due to the maturity and exceptional shape and roundness of the grains. Mature quartz sandstones are indicative of many transgressive-regressive sequences that occurred during the Cambrian, the Mt. Simon, Wonewoc, and Jordan formations exemplify these transitions. While the St. Lawrence, Lone Rock, and Eau Claire formations were likely deposited on deeper marine shelves. The Cambrian rock record, known for the abundance of life, is seen in the Cambrian bedrock in Iowa. Although conditions were not ideal for fossilization there is still a great variety and diversity of fossils found in Iowa. Fossils found include, but are not limited to, trilobites, inarticulate brachiopods, echinoderms, algae, etc. (Anderson, 1998).

Ordovician

The Ordovician began 443 Ma and ended 485 Ma. This time period was dominated by warm shallow seas, which can be seen in the Ordovician rock record in northeastern Iowa (Figure 1). The marine setting of the Late Cambrian carried over to the Ordovician, and created very similar depositional features in the rock record. However, in the Early Ordovician the seas regressed and exposed the Upper Cambrian and Lower Ordovician depositions to weathering and eroded them away, causing an unconformity in the Iowa rock record. Rocks from the Middle Ordovician were deposited in place of these layers. During the Middle Ordovician, seas began to transgress and seas covered the state of Iowa once again (Anderson, 1998).

Major formations from this time period are the Maquoketa, Galena, Platteville, St. Peter, and Prarie du Chein formations. The dominating rocks of this period are carbonate rocks, such as limestone and dolomite. Stromatolites are commonly found in the Lower Ordovician record, specifically in the Pariarie du Chien Group, which indicates that it was deposited during a time of shallow seas. Other indications of shallow seas include oolites found in the Early Ordovician

record. Besides carbonates, there are also deposits of sandstones found in the Middle and Late Ordovician record. The most well-known and characteristic sandstone of the Middle Ordovician is the super-mature, very pure quartz sandstone known as the St. Peter Formation. The sandstone deposited in the Middle and Upper Ordovician indicates a period of many transgression-regression cycles (Anderson, 1998).

Silurian:

The Silurian spans from 419 Ma to 443 Ma, and is the oldest rock found in Johnson County. Silurian bedrock can be found in eastern Iowa (Figure 1). The Silurian rock make up the foundation of many state parks in eastern Iowa, and contribute to the landscape of these parks. In Iowa the Silurian rock consists dominantly of dolomites, and is well known for its resistance to erosion. Generally dolomite does not preserve fossils in great detail in comparison to their calcium carbonate precursors. However, fragments of brachiopod shells, pieces of echinoderms, spicules of sponges, skeletal components of corals, bryozoans, and other fossils can be found. Iowa's Silurian formations also contain chert, which occurs as nodules and as thin layers in the dolomite beds, and carbonate mounds, which contain a high amount of crinoid fossils (Anderson 1998).

Formations found in Iowa's Silurian strata include the Gower, Scotch Grove, Hopkinton, Blanding, Tete des Morts, and Mosalem. Fossil communities found in the Lower Silurian strata have indicated relative changes in water depths, which have been applied to sea level change and were found to be global in nature. The Lower Silurian strata include the Mosalem, Tete Des Morts, Blanding, Hopkinton, and the lower Scotch Grove formations. The Upper Silurian consists of the middle Scotch Grove formation through the Gower formation. Depositional

environments of the six formations range from restricted marine settings to open marine shelves (Anderson, 1998).

Devonian

The Devonian time period ranges from 358 Ma to 419 Ma, and the bedrock stretches north to south across eastern Iowa (Figure 1). However, there is a large unconformity between the Silurian and Devonian bedrock in Iowa, due to exposure to erosion and weathering part of the Late Silurian and all of the Early Devonian is missing, which consisted of 30 million years of the rock record (Anderson, 1998).

During the Middle and Late Devonian, seas advanced and retreated several times over the Iowa landscape, forming a shallow marine record. The Middle Devonian is comprised mostly of limestones and dolomites, with the occasional outcrop of shales and evaporites. The rock formed during this time is indicative of a shallow marine setting that represents subtidal, intertidal, and supratidal settings. This is the time when the deposition of carbonates, shales, and evaporites that make up the Wapsipinicon Group were formed, which is the oldest Group in Iowa's Devonian record. The deposits in the Wapsipinicon Group indicate that it was primarily a shallow, restricted marine setting, and the lack of fossils found in the Wapsipinicon indicate that it was not a highly productive habitat for marine life (Anderson, 1998).

The Wapsipinicon and the Cedar Valley Groups play a large role in the bedrock of Lake Macbride State Park (Anderson and Fields, 2006). Unlike the restricted marine setting of the Wapsipinicon, the Cedar Valley Group was deposited during normal marine settings, when seas began to transgress back across Iowa. The first formation of the Cedar Valley Group, is the Little Cedar Formation which is made up of various limestones and dolomites. The Cedar Valley

Group contains a diverse assemblage of fossils that includes brachiopods, colonial and solitary corals, chinoderms stromatoporoids, and bryozoans (Anderson, 1998). Within the Cedar Valley Group also lies the Coralville formation, which makes up high quality rock that is mined in Johnson County (Anderson and Fields, 2006).

Mississippian

The Mississippian time period begins around 358 Ma and ends approximately 323 Ma, and is the lower part of the Carboniferous. During this period is when the last widespread carbonate seas invaded Iowa and large abundancies of marine fauna fossils are found. Mississippian bedrock runs from northcentral Iowa to the southeastern edge (Figure 1). There are ten rock formations found in the Mississippian record of southeastern Iowa and include the Pella, St. Louis, Salem, Warsaw, Keokuk, Burlington, Wassonville, Starrs Cave, Prospect Hill, and McCraney formations. Limestone was the predominate rock deposited during the Mississippian, however there are also records of dolomite and chert. There is evidence of ten transgression-regression (T-R) cycles that are indicated by the abundance of siliciclastic sediments found in the record (Anderson, 1998).

Many geodes found in Iowa are from the Mississippian, generally associated with the lower Warsaw Formation. Geodes are a large collector item in the geology world. This time period is also the last abundance of marine fauna, specifically it was dominated by crinoids and other marine invertebrate. Other invertebrate include echinoderms (i.e. crinoids and blastoids), brachiopods and lacy bryozoans, as well as other fossils like corals arthropods, fish remains conodonts, etc. There is also record of amphibians, the earliest known tetrapods, however the Iowan amphibians are younger than some amphibians found from the Upper Devonian in East Greenland and Australia (Anderson, 1998).

Pennsylvanian

The Pennsylvanian time period begins 298 Ma and goes till about 322 Ma, and makes up the Late Carboniferous. The Pennsylvanian bedrock spans across southern Iowa and up into central Iowa (Figure 1). After the Mississippian, carbonate seas retreated from Iowa, revealing the Upper Mississippian bedrock to weathering and erosion, creating another unconformity between the Mississippian and Pennsylvanian bedrock in Iowa. Although the Mississippian was the last period of carbonate seas, the Pennsylvanian continued to alternate between marine and nonmarine environments. The rock record shows the Lower and Middle Pennsylvanian strata being dominantly nonmarine environments, while the Upper Pennsylvanian showed more marine dominated conditions. Pennsylvanian life in Iowa included nonmarine fauna such as lycopods (e.g. Lepidodendron), sphenopsids, ferns/seedferns, and cordaitean trees, as well as marine life like fusulinids, brachiopods, and calcareous algae (Anderson, 1998).

Jurassic

The Jurassic period is part of the Mesozoic Era and begins approximately 146 Ma and ends 208 Ma and makes up a very small portion of Iowa's bedrock (Figure 1). The Jurassic period is very limited in Iowa's rock record and include unnamed basal units, the Fort Dodge Gypsum and clastic strata known as Soldier Creek beds. The Fort Dodge Formation can be found in Webster County, Iowa where the Fort Dodge Gypsum beds can be found. There are no visible fossils found in the Fort Dodge Gypsum. However, the Soldier Creek beds found in the Fort Dodge Formation consist of red, buff, and green shales and red sandstones and siltstones. The red coloration of these sedimentary rocks could be indicative of a highly oxidized environment, indicating it was possibly a nonmarine environment. However, the Upper part of the Fort Dodge Formation can be interpreted as a fluvial or deltaic environment (Anderson, 1998).

Cretaceous

The Cretaceous period is also part of the Mesozoic Era and begins 65 Ma and ends 146 Ma and is made up of the Dakota Formation, Graneros Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, and Pierre Shale. The Cretaceous bedrock of Iowa can be found in the west and northwest corner of Iowa (Figure 1). Multiple environments of deposition are recorded in Iowa's Cretaceous bedrock. The Dakota Formation contains sandstone, mudstone, shale siltstone conglomerate, and lignite which indicate these bedrocks were laid down adjacent to the advancing Cretaceous sea. As the Dakota strata progress there is a shift to fluvial conditions, and then to coastal and nearshore marine conditions found in the Upper Dakota Formation. Some fossil evidence can be found in the Cretaceous shales such as fish scales, fecal pellets, coccoliths, planktonic foraminifera, even bivalves and ammonoids, although the latter two are more rare (Anderson, 1998).

Quaternary

The Quaternary spans from present day to approximately 1.65 million years ago, deposits from the Quaternary help to describe and define Iowa's landscapes. These deposits consist of tills loess, paleosols, glacial fluvial sediments and glacial drift. During the Pleistocene Epoch Iowa underwent three periods of glaciation, The Pre-Illinoian, the Illinoian, and the Wisconsinan glacial periods, which help contributed to the shape of the landform regions of Iowa (Figure 1). The Pre-Illinoian sequence found in western Iowa consists of more than seven separate till sheets, and describes all glacial and interglacial deposits before the Illinoian Glacial stage. The Pre-Illinoian Glacial and Interglacial stages are comprised of two stratigraphic formations, the Wolf Creek Formation and the Alburnett Formation, separated by layers of volcanic ash. The

Iowan Surface, one of Iowa's seven landform regions (Figure 8), developed on Pre-Illinoian drift, however that was overlain by Late Wisconsinan glacial deposits (Anderson, 1998).

Between the Pre-Illinoian and the Illinoian glacial stages is the Yarmouthian Interglacal stage which consists of Yarmouth paleosol and alluvium and lasted approximately 200,000 years. During this time is when the major stream systems of southern Iowa developed. The Yarmouthian Interglacial period was followed by the Illinoian Glacial stage. Illinoian drift can be found in the southeastern corner of Iowa and is made up of the Kellerville Till Member of the Glasford Formation. The Illinoian drift found in Iowa contains fossils that date back to the Pennsylvanian, however the Illinoian drift only began approximately 300,000 years ago, meaning they were likely derived from Pennsylvanian bedrock in eastern Illinois. During the time of the Illinoian Glacial period the Loveland Loess (approximately 140,000 to 160,000 years old) was deposited in the western part of Iowa (Anderson, 1998)

Between the Illinoian and Wisconsinan Glacial stages was the Sangamonian Interglacial stage. Paoleosol evidence of this stage is found in the Loveland Loess. After the Sangamonian Interglacial stage, the Wisconsinan Glacial stage began approximately 55,000 years ago. This stage includes drift deposits of the Sheldon Creek and Dows formations and eolian deposts of the Pisgah and Peoria formations. The Wisconsinan ice entered Iowa from the northwest, similar to the Pre-Illinoian advances. During the Late Wisconsinan Glacial stage, between 16,500 and 21,000 years ago, the Iowan Surface landform region formed. Wisconsinan Loess was deposited during and after the deposition of the earlier Sheldon Creek drift, and consists of Pisgah Loess and Peoria Loess, which are separated by Farmdale Geosol. The Wisconsinan Glacial drift also makes up the Des Moines Lobe landform region, which is made up of the Dows Formation. The

Dows formation is the last interval of glaciation in Iowa, about 15,000 years ago (Anderson, 1998).

Johnson County, Iowa

History

Johnson County was settled by Philip Clarke and Eli Meyers in the year 1836 (Irish, 1868) and was named after Colonel Richard M. Johnson, a political celebrity in the 1800's. Clarke and Meyers wanted to go west, from Indiana, to "grow up with the country." After they settled and claimed their land, neighbors soon followed. In Johnson County three Native American villages belonging to the Sac and Fox tribes were established when the first settlers came to Johnson County, the largest tribe located south of Iowa City. By 1839 Iowa City was established as the Capitol. In 1846 Iowa became an official state in the United States, the following year in 1847 the University of Iowa was established as the State University. Then ten years preceding the establishment of the University of Iowa the state capitol was moved to Des Moines (Unknown, 1883).

Geography

Johnson County is located in the upper portion of Southeast Iowa (Figure 2) and is one of the most populated counties in Iowa (Figure 3). Iowa City is located within Johnson County and is one of Iowa's more highly populated cities. With a population of approximately 73,500, Iowa City is Iowa's 5th ranked city by population (Iowa Demographics, 2016). Iowa City is also home to Iowa's largest University, The University of Iowa. The University of Iowa, largely known for its medical and creative writing programs, pulls in a student body of approximately 30,000

undergraduates and graduate students (U of I, 2016) Aside from Iowa City, Johnson County is also home to many small to mid-sized towns as well, including Coralville, Hills, Lone Tree, North Liberty, Oxford, Shueyville, Solon, Swisher, Tiffin, University Heights, and West Branch (Figure 4) (Iowa League of Cities, 2016).

Johnson County's land use is fairly diverse. In the southeastern corner there is a lot of agricultural use, where in the north the landscape is dominated by more deciduous areas, and the west grasslands are abundant (Figure 5). However, Johnson County has many recreational areas which help promote economic growth within the county, including Lake MacBride State Park. The Iowa River is one of Iowa's major streams and runs through Johnson County's interior (Figure 6). Stretching from the Coralville Lake to River Junction, the lake is 29.00 miles in length. Some popular fish species that thrive here include Catfish, Crappies, Bass, Walleye, Bluegill, Pike, and more. Lake MacBride and the Coralville Reservoir are two popular bodies of water that are also found in Johnson County, both equipped with hiking trails, picnic areas, boat docks, and other recreational areas for visitors (Iowa DNR, 2016).

Geology of Johnson County

Silurian

Silurian bedrock can be found in the northeastern corner of Johnson County, and consists mostly of bedrock from the Gower Formation (Figure 7). The Gower Formation shows a deposition of bedrock that is indicative of a restricted marine environment with hypersaline bottom water. Carbonate mounds formed on the seafloor and projected the hypersaline environment to a normal saline marine ecosystem. Evidence from this include fossil remains of crinoids, brachiopods, and corals that are found within the carbonate mounds. The Gower

Formation has three members, the Anamosa Member, which was deposited when the environment was hypersaline, and the Brady and Le Claire members which contain carbonate mound facies and projected the hypersaline waters to normal salinity. Due to the hypersaline conditions the Anamosa Member does not contain fossil but instead is a uniformly flat-lying laminated dolomite. The uniform bedding in the Anamosa facies make it economically valuable and make it an ideal building stone (Anderson, 1998).

Devonian

Devonian bedrock covers majority of Johnson County (figure 7). The oldest section of Iowa's Devonian record is the Wapsipinicon Group, which includes the Bertram-Otis and Pinicon Ridge formations (Marshall and Fields, 2010), and is part of the Middle Devonian record. The Wapsipinicon Group has deposits of carbonates, shales, and evaporites, which suggests that this group was formed primarily in a shallow, restricted sea. The evaporites found indicate that the seas were brackish. There are also few fossils found in the Wapsipinicon Group, suggesting that the seas were uninhabitable for marine life (Anderson, 1998). Within the Wapsipinicon Group is the Pinicon Ridge Formation, which includes some high quality aggregate limestone beds (Marshall and Fields, 2010). The Pinicon Ridge Formation can be described as variably shaley and laminated, or brecciated (Anderson, 1998). The Pinicon Ridge formation is subdivided into Kenwood, Spring Grove, and Davenport members. Most of Iowa's high-quality aggregate can be found in the Davenport member, causing it to be a good aggregate resource (aforementioned in Natural Resources of Johnson County section).

Following the Wapsipinicon Group is the Cedar Valley Group, which was formed by the advancement of seas. Through this transgression, many fossils were deposited and formed fossiliferous carbonate sediments, to make up the Little Cedar Formation (Anderson, 1998). In

Johnson County there are three formations found in the Cedar Valley Group, Little Cedar, Coralville, and Lithograph City, this excludes the Shell Rock Formation that can be found in other areas of Iowa. As mentioned previously, this is a period of highly fossiliferous deposits. The Little Cedar Formation is made up of fossiliferous limestone intervals which indicate this as a transgressive-regressive cycle (Marshall and Fields, 2010). Diverse marine organism deposits are found in the Little Cedar Formation, such as brachiopods, colonial and solitary corals, chinoderms, stromatoporoids, and bryozoans which were all dominant in the Cedar Valley seas. This diverse representation reflect a warm, shallow sea with normal marine circulation (Anderson, 1998).

Overlying the Little Cedar Formation is the Coralville formation, where there is evidence of progressively shallowing waters and an environmental sequence ranging from shallow subtidal, through intertidal, to supratidal conditions, and less fossiliferous bed deposits. The Coralville Formation is the end of the Middle Devonian and the overlying Lithograph City Formation begins the Upper Devonian (Anderson, 1998).

The Lithograph City Formation overlies the Coralville deposit, however it is not as abundant as the Coralville formation. Between the two there is evidence of erosion that followed the Coralville deposition (Marshall and Fields, 2010). The Lithograph City Formation records transgression-regression cycles of the Devonian sea, but in general show charateristics of shallowing upward patterns. It is common to find biostromes that are made of stromatoporoids in the formation. Lithograph City is mostly represented by channel-filling limestones in Johnson County. This formation is best seen in the area of the Old State Quarry and Mehaffey Bridge near the Coralville Lake, as well as some small exposures in the Dingleberry-Ernst Quarry (Marshall and Fields, 2010).

Mississippian

Mississippian bedrock can be found in a very small outcrop in the southwest corner of Johnson County (Figure 7). This outcrop is of the Kinderhookian Group, which makes up the Lower Mississippian rock record (Anderson, 1998).

Pennsylvanian

There are several outcrops of Pennsylvanian bedrock that can be found in Johnson County (Figure 7). All of these outcrops are from the Lower Cherokee Group, which is composed of alternating shale, sandstone, and limestone and major coal resources of Iowa are associated with the Lower Cherokee Group (Anderson, 1998) however, coal mining is not an economic resource of Johnson County itself.

Fossils

Major Fossil groups that can be found in Johnson County include Corals, Stromatoporoids, Brachiopods, Bryozoans, Crinoids, and Other fossils. Corals are one of the most abundant and obvious corals that can be found in Johnson County. There are many genus and species of these corals that can be found around Johnson County. The two major groups of corals are Rugosa and Tabulata. Rugosa corals can be broken down into two forms, colonial rugose corals and solitary rugose corals (Clark, 2015).

An example of a colonial rugose coral that can be found in Johnson County is *Hexagonaria* and can found in the Rapid Member of the Little Cedar Formation, and other groups in the Johnson County rock record (Clark, 2015). As mentioned previously, the Little Cedar Formation dates back to the Devonian (Anderson, 1998). *Asterobillingsa*, is another colonial coral found in Johnson County, and are slightly larger than *Hexagonaria*. Solitary corals

that can be found are more difficult to determine genus or species names, however they can be classified as horn corals or cup corals. There are many solitary rugose corals found in Johnson County (Clark, 2015).

Tabulate corals are only found in colonial forms. Tabulate corals known as *Favosites* can be found in outcrops around Johnson County. *Favosites*, or more commonly known as the "honeycomb coral", is found in the Rapid Member of the Cou Falls Formation. Other tabulate corals that are present include auloporid and pachyporid forms (Clark, 2015).

Stromatoporoids are an extinct group that are related to sponges, however do not possess spicules such as sponges do, and have been identified in the Cedar Valley Group. A correlation between the environment and the form of stromatoporoid that is found was observed by Danielle Shapo-Jannusch. Jannusch found that in environments with less current movement digitate forms appear more often than massive hemispherical forms (Clark, 2015).

Brachiopods are another common fossil group found in Johnson County, and are the most diverse and abundant fossils found in the rock record. Brachiopods are similar to bivalve mollusks, but are instead identified by the line of symmetry between their two shells. They can be divided into two groups, articulate and inarticulate, which are identified by the presence or absence of structures that help hold the shells together. Inarticulate brachiopods do not have teeth and sockets, but instead use muscles to hold them together. Inarticulate brachiopods are rare to find in Johnson County bedrock. However, the highly diverse articulate brachiopods can be found in various groups and formations in the Johnson County bedrock. The groups and formations include, but are not limited to, the Cedar Valley Group, Little Cedar Formation, and Coralville Formation (Clark, 2015).

Bryozoans are small colonial organisms that can be found in the rock record of Johnson County. An example would be the fenestellids, or lacy bryozoans, which can typically be found in the Little Cedar Formation. Another bryozoan found in the Rapid Member as well are trepostomes, or stony bryozoans, which can be up to 10 cm in size (Clark, 2015).

Crinoids are another major group of fossils found in the Johnson County rock record. Crinoids are easily disarticulated after death due to their fragile nature. However, their debris is commonly found in the rock record and can be identified by the "cherrios" shape of their stems. Other Fossils that are found in Johnson County include trilobites, molluscs, fish fossils, graptolites, and more (Clark, 2015).

Landform Regions

Landform regions are large areas, or regions, of land that have specific physical characteristics in the landscape, such as plains, plateaus, alluviums, and more. Each of these features are characterized due to geological processes and characteristics such as erosion, streams, glacial activity, bedrock, and more. (Prior, 1991)

There are seven landform regions in the state of Iowa (Figure 8), three of which can be found in Johnson County. These are the Iowan Surface, Southern Iowa Drift Plain, and the Mississippi Alluvial Plain. Southern Iowa Drift Plain make up most of Johnson County, but the Mississippi Alluvial Plain takes up the Southeast corner of the county and the Iowan Surface can be found in the north (Figure 9).

The Iowan Surface is characterized by gently rolling terrain, and illustrates periglacial activity that is associated with the Wisconsin glacial maximum, between 16,500 years ago to

21,000 years ago (Anderson and Fields, 2006). Topographically the Iowan Surface region displays characteristics of low relief, with long slopes and poorly defined drainage divides. The paha found around the Iowan Surface are considered either till from the Wisconsinan glacial advance or topographic high points that were passed by thin Wisconsinan ice. Features such as the paha and glacial boulders found around this landform are indicative of past glacial activity. The Iowan Surface was the last period of intense glacial cold, and had a large affect in northern Iowa's landscapes. Glacial activity greatly weathered the terrain and formed the characteristic rolling hills of the Iowan Surface that is seen today (Iowa DNR, 2000). The western portion of Lake MacBride State Park stretches into part of the Iowan Surface in the northern part of Johnson County (Figure 10).

The Southern Iowa Drift Plain is Iowa's largest landform region and stretches across nearly all of southern Iowa and covers most of central Iowa (Figure 8). The Southern Iowa Drift Plain is characterized by the glacial deposits left behind from ice sheets that stretched across the region (Iowa DNR, 2000). The region is mainly underlain by the Pre-Illinoian glacial drift, and is mantled with various amounts of Wisconsinan loess (Anderson, 1998). The Southern Iowa Drift Plain was glaciated several times between 2.2 Ga and 500,000 years ago (Anderson and Fields, 2006), these glacial deposits left after were eroded by streams, rills, creeks and rivers that created a landscape of intense rolling hills and valleys. Loess is abundant in the uplands and upper hill slopes of the region (Iowa DNR, 2000). Topographically the Southern Iowa Drift Plain characteristically displays noticeable relief and has a well-established drainage system (Anderson, 1998). Majority of Lake MacBride State Park lies within the Southern Iowa Drift Plain (Figure 10), and covers majority of the park's landscape.

The Mississippi Alluvial Plain is generally grouped with the Missouri Alluvial plain found on the western border of Iowa (Figure 8). These Alluvial Plains are characterized by the sediment deposited by the adjoining rivers. Features include oxbow lakes and backwater sloughs, which are indicative of past meandering rivers (Iowa DNR, 2000). The Alluvial Plains are generally associated with floodplains and alluvial land. Both the Missouri and Mississippi Alluvial valleys were overtaken by glacial melt water approximately 9,500 to 30,000 years ago, and both were major sources of the widespread loess of the Midwest. The Mississippi River established its current shape when the Wisconsinan ice melted in southeastern Iowa. The Mississippi River Alluvial Plain can be described as a sandy lowland along the eastern boarder of Iowa (Anderson, 1998).

Natural Resources

Johnson County has three active limestone quarries, the Dingleberry-Ernst, Klein, and Conklin quarries. These quarries are owned by the River Products Company, Inc. of Iowa City and are the principal aggregate producers of the Iowa City area. These quarries are large producers for road and interstate paving systems, and have also contributed to the construction of the Coralville Dam. (Marshall and Fields, 2010)

The Conklin and Klein quarries produce aggregate that are also commercially used for buildings and foundations, parking lots, city streets, sidewalks and driveways, agricultural lime on fields, etc. (Marshall and Fields, 2010). Due to the higher quality of stone, the aggregate produced at the Conklin and Klein quarries can be used for a larger number of products. The high quality limestone passes requirements and specifications for the Iowa Department of Transportation, engineered building trade, and construction industry standards (River Products Company, 2015). To pass such standards the rock has to undergo chemical and physical testing.

Once through testing the rock is given a class; either class 2, 3, or 3I. There are four working ledges in the Conklin and Klein quarries (Marshall and Fields, 2010).

The upper most ledge is a Class 3I rock and is part of the Coralville Formation. This ledge is a concrete source for state projects, but it can be used for commercial paving and building projects as well. The next ledge is the Rapid Member and is primarily used for roadstone, backfill, and subbases (Figure 14). The next ledge is the Solon Member and "Solon/Davenport Breccia" (Figure 14), and the lowest layer is the Davenport and Spring Grove Members. The lowest ledge is also a class 3I rock and is also commonly used for commercial concrete use, however unlike the upper ledge, this ledge cannot be used for applications like asphalt due to the nature of the Davenport and Spring Grove Members (Marshall and Fields, 2010).

Lake MacBride State Park

Geography

Lake MacBride State Park is located in the northcentral part of Johnson County (Figure 11) and covers approximately 2,180 acres of land (Figure 11 and Figure 12). The northern areas of the park are located just 4 miles west of the town of Solon, while the southern section is located 3 miles west of solon (Figure 12). Lake MacBride is a manmade lake off that is within in the Iowa River watershed (Figure 6), and is fed by the Mill Creek and Jordan Creek streams. Lake MacBride feeds into the Coralville Reservoir and Iowa River, which eventually runs into the Mississippi River (Anderson and Fields, 2006).

The total volume of the lake is 16.6 million cubic meters, with an estimated water detention time of 0.8 years. Lake MacBride's watershed covers 16,220 acres, which makes the

watershed-to-lake ratio 20:1. The watershed is used for a multitude of purposes which includes 60% use for agriculture, 9% urban, 9% pasture, 8% timber, 8% park, 3% CRP, and 2% other. The only urban area located within the watershed is the city of Solon, which has a population of 1,177. The water quality of Lake MacBride can be described as poor and is listed in the impaired water bodies list as "fully supported/threatened", meaning that pollution exceeds the natural capacity in the lake (Anderson and Fields, 2006). Between the years 2002 and 2005 the maximum Secchi disk visibility depth was 4.4 meters and the mean was only 0.5 meters deep. Between 2000 and 2015 the mean value for chlorphyll was 35 μg/L with a maximum level of 121 μg/L in 2005, which indicates that the lake may have a lower productivity rate compared to other Iowa lakes that have a 40 μg/L average. During the same time period measurements of phosphorus were taken and showed the mean level to be 56 μg/L, with a high in 2003 of 373 μg/L. The average for Iowa lakes is 107 μg/L, meaning the lake's phosphorus concentrations are lower and indicate that the productivity in the lake may also be lower relative to other Iowa lakes (Iowa Department of Natural Resources, 2016)

Geology

The bedrock of the Lake Macbride is Devonian aged limestone, the exposed strata include rocks from the Wapsipinicon and Cedar Valley Groups (Figure 14) (Anderson and Fields, 2006). Aformentioned in the two previous sections of Devonian geology, the Little Cedar Formation is well known for its diverse fossiliferous limestones and lies over the Davenport Member (Anderson, 1998). The Davenport Member is part of the Pinicon Ridge Formation of the Wapsipinicon Group. The Davenport member that can be found in Lake MacBride State Park consists of unfossiliferous limestones and breccia (Anderson and Fields, 2006). Most of Lake MacBride State Park is taken up by water, however the Fayette soil covers the majority of the

park's land surface (Figure 13). The Fayette soil is a deep, well-drained soil formed in loess and generally have a slope between 0 to 60 percent. Fayette soil is typically found on convex crests, interfluves, and side slopes on uplands (USDA, 2006), and helps to describe the landform region Lake MacBride rests on.

Lake Macbride lies mainly within the Southern Iowa Drift Plain landform region (Figure 10). Aforementioned in the Johnson County Geology section, subsection Landform Regions of Johnson County, the Southern Iowa Drift Plain was glaciated several times between 2.2 Ga and 500,000 years ago. Due to erosion and drainage development, the landscape took form and is now characterized by steeply rolling hills. In contrast the Iowan Surface, located in the northeast corner of the park (Figure 10), displays periglacial activity that is associated with the Wisconsin glacial maximum, and is characterized by a gently sloping landscape. Deposits from the Quaternary found in east-central part of Iowa include Pre-Illinoian till overlain by Wisconsin Episode loess. The Quaternary deposits exposed in Lake MacBride are the typical characteristics seen in the Southern Iowa Drift Plain (Anderson and Fields, 2006). Other geologic features of the park include impounded water that flows over fossiliferous bedrock from the Little Cedar Formation (Anderson, 1998).

Recreational Usage

Between 2002 and 2005, Lake MacBride averaged 248,051 visitors per year, with an average spending value of $17.84 million per year, making Lake MacBride an important contributor to Johnson County's economy (Iowa Department of Natural Resources, 2016). Lake MacBride is a multiuse recreational area where many people visit each year to enjoy the woodland and lake scenery. Activities to do at the park include fishing, camping, swimming, hiking, boating, etc. Lake Macbride has two campgrounds (Figure 15), one in the northern

section and one in the southern section. The northern campground has 50 sites, some with electric hookups, while the southern, less modern, campground has 60 sites There are many trails the wind for miles around the lake that are good hiking and sightseeing. Some animals that can may be spotted include various birds, such as the American Goldfinch (Iowa's state bird), white tailed deer, box turtles, and many, many other wildlife. Many people who visit the park enjoy sport fishing to pass the time. Fish that can be found in the lake include, but are not limited to, largemouth bass, bluegill, black and white crappie, walleye, channel catfish, and more (Anderson and Fields, 2006).

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Figure 1. A distribution of bedrock geology in Iowa.

Figure 2. Shows the location of Johnson County with respect to Iowa as a whole.

Figure 3. Displays the relative population densities of each Iowa county.

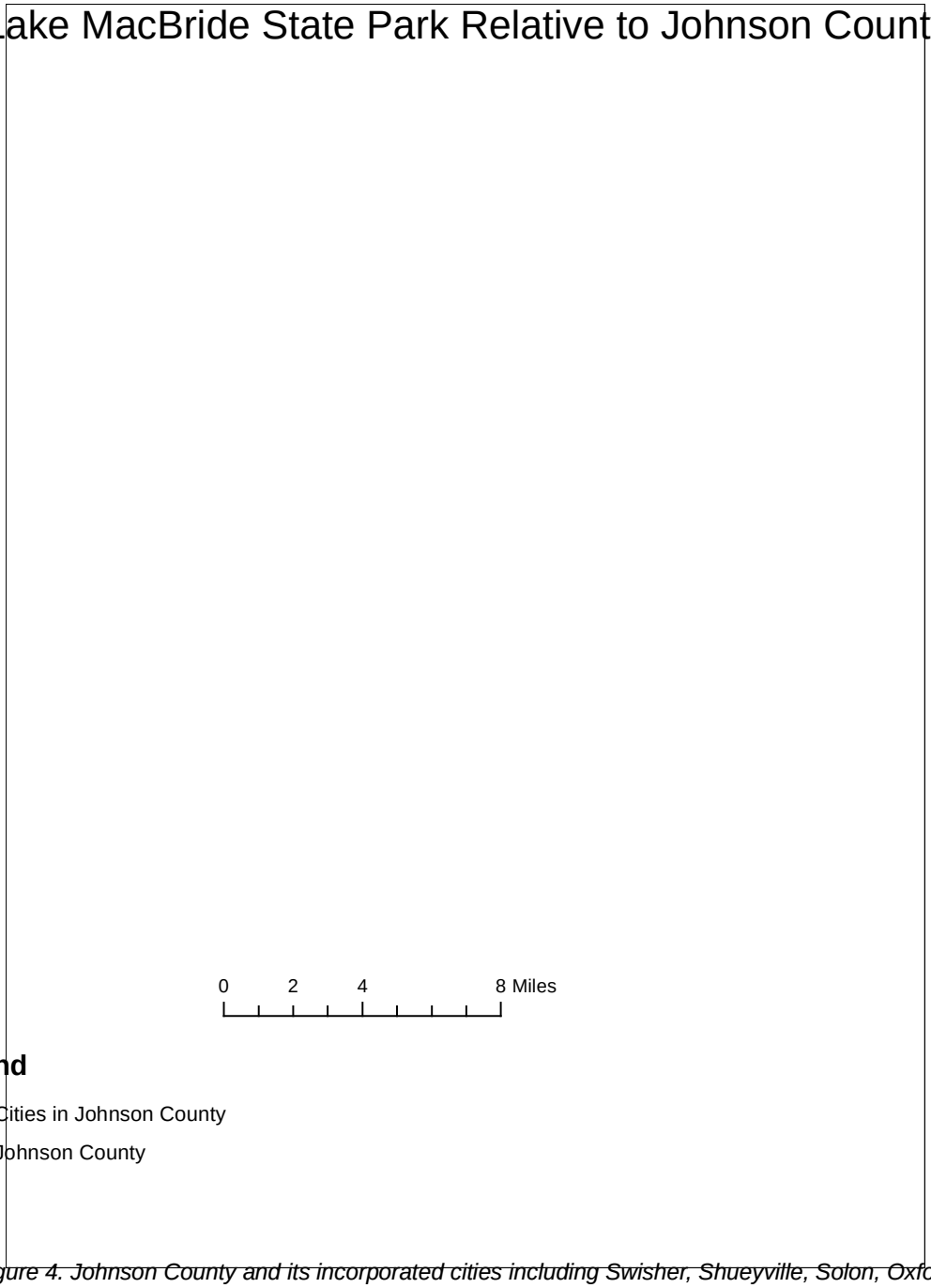

Figure 4. Johnson County and its incorporated cities including Swisher, Shueyville, Solon, Oxford, North Liberty, Tiffin, Coralville, University Heights, Iowa City, West Branch Hills, and Lone Tree

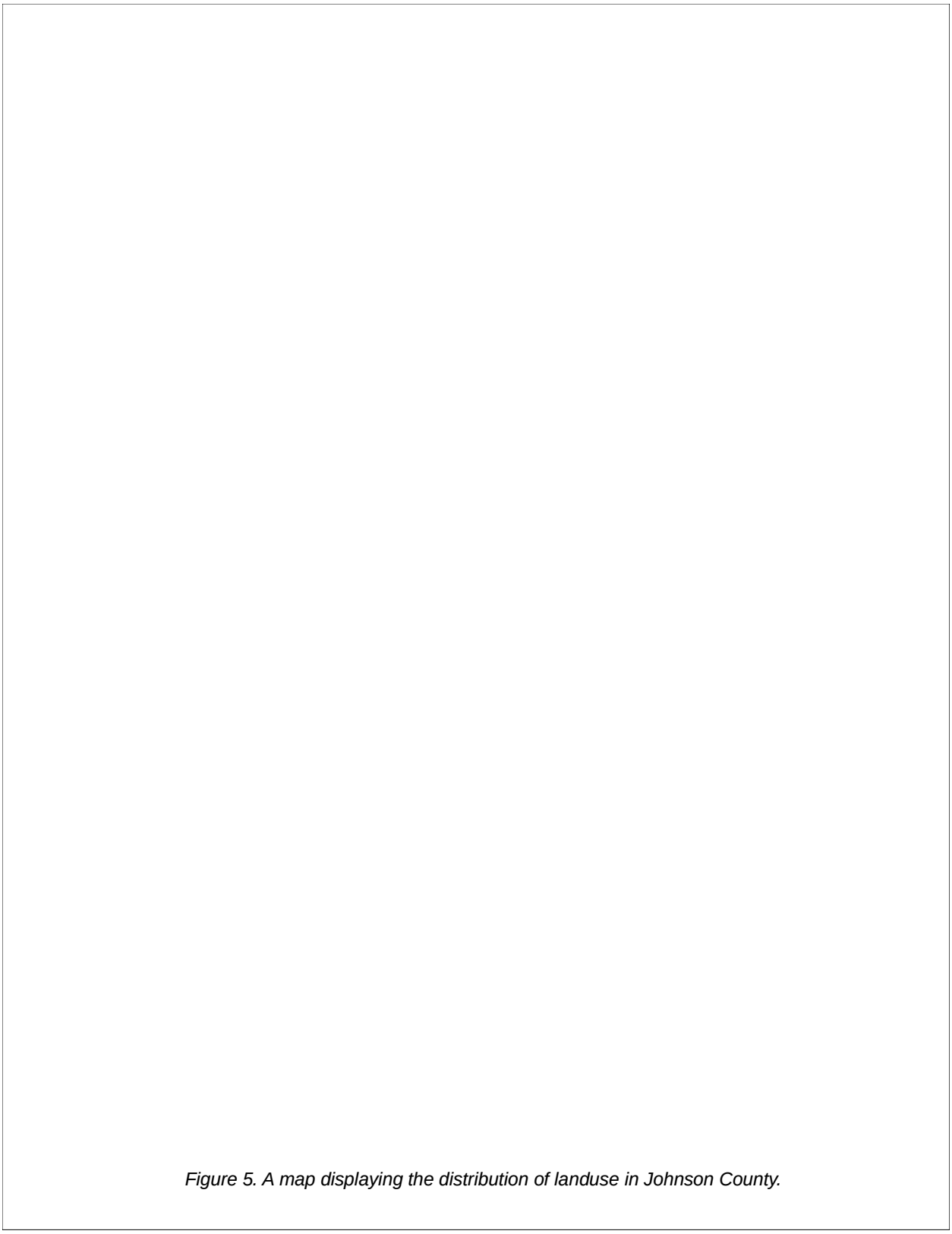

Figure 5. A map displaying the distribution of landuse in Johnson County.

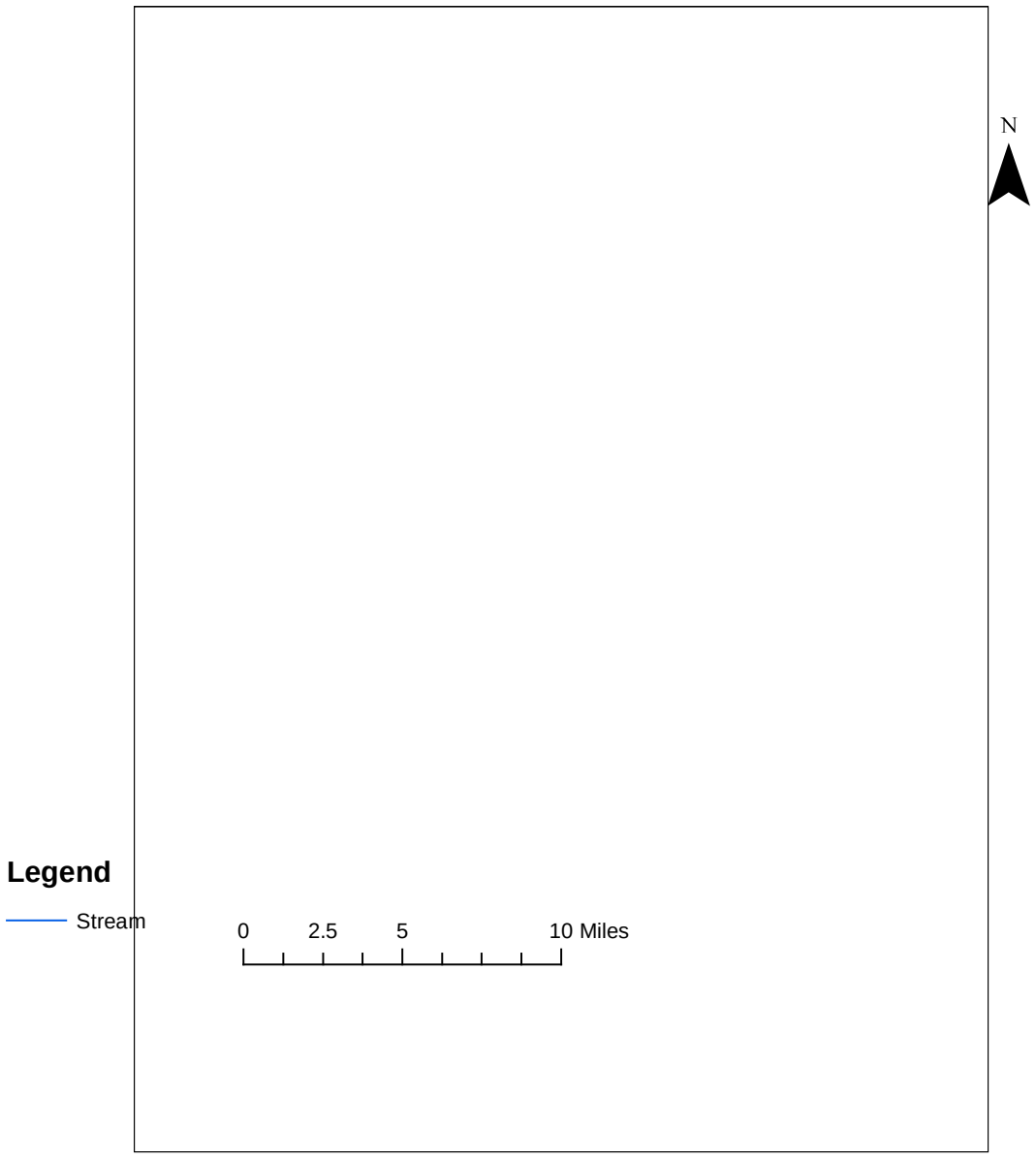

Figure 6. A map showing the stream system that is found within Johnson County, Iowa.

Figure 7. A map showing the distribution of bedrock in Johnson County, Iowa.

Figure 8. A map showing the distribution of landform regions in Iowa.
Note: the Iowa-Cedar Lowland and Mississippi Alluvial Plain are considered the same region and the East-Central Iowa Drift Plain is part of the Southern Iowa Drift Plain (Anderson, 1998).

Figure 9. The landform regions of Iowa that are found within Johnson County.
Note: the Iowa-Cedar Lowland and Mississippi Alluvial Plain are considered the same region (Anderson, 1998).

Figure 10. A map showing the landform regions that make up Lake MacBride State Park.

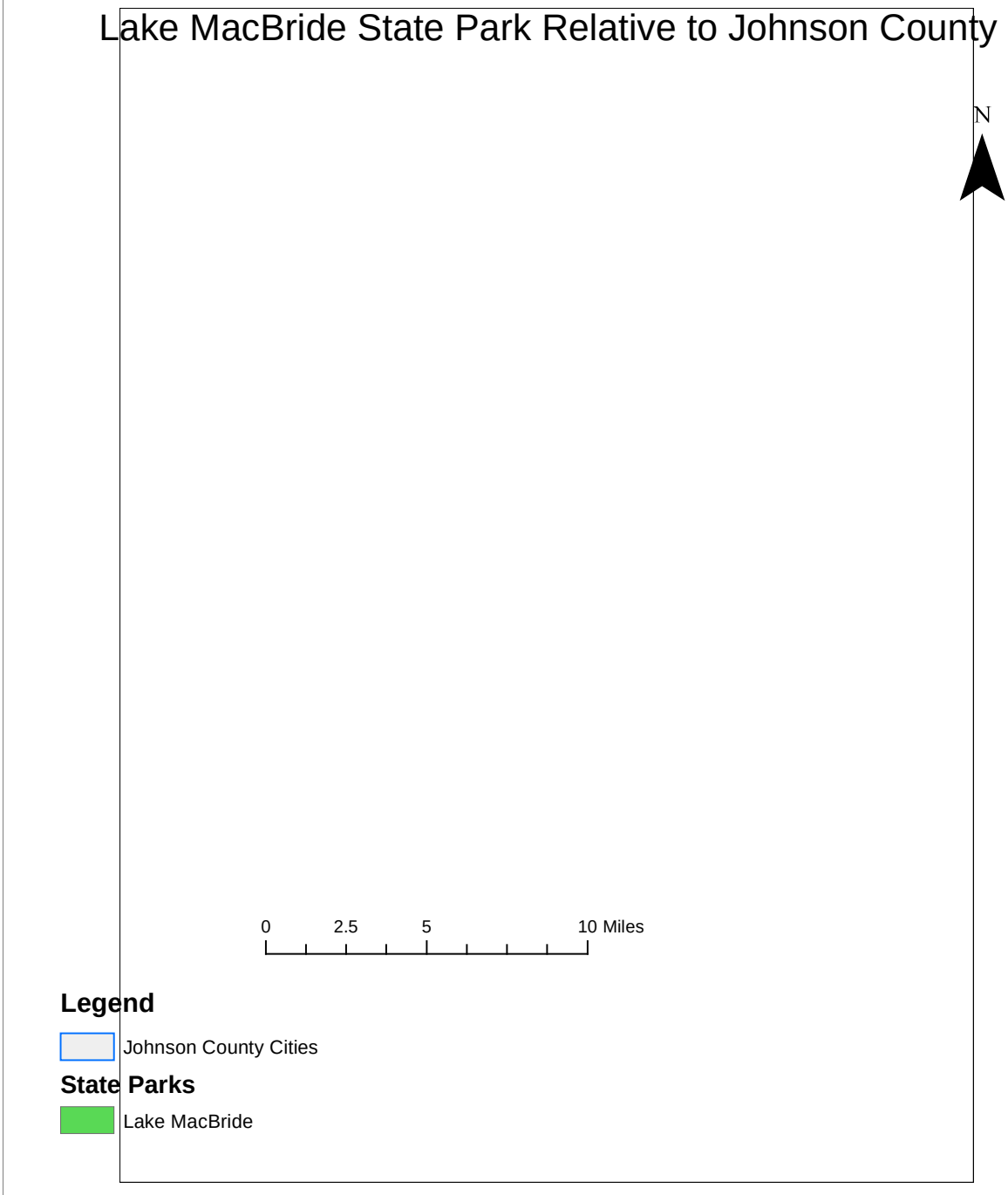

Figure 11. Shows the location of Lake MacBride State Park relative to Johnson County and its incorporated cities

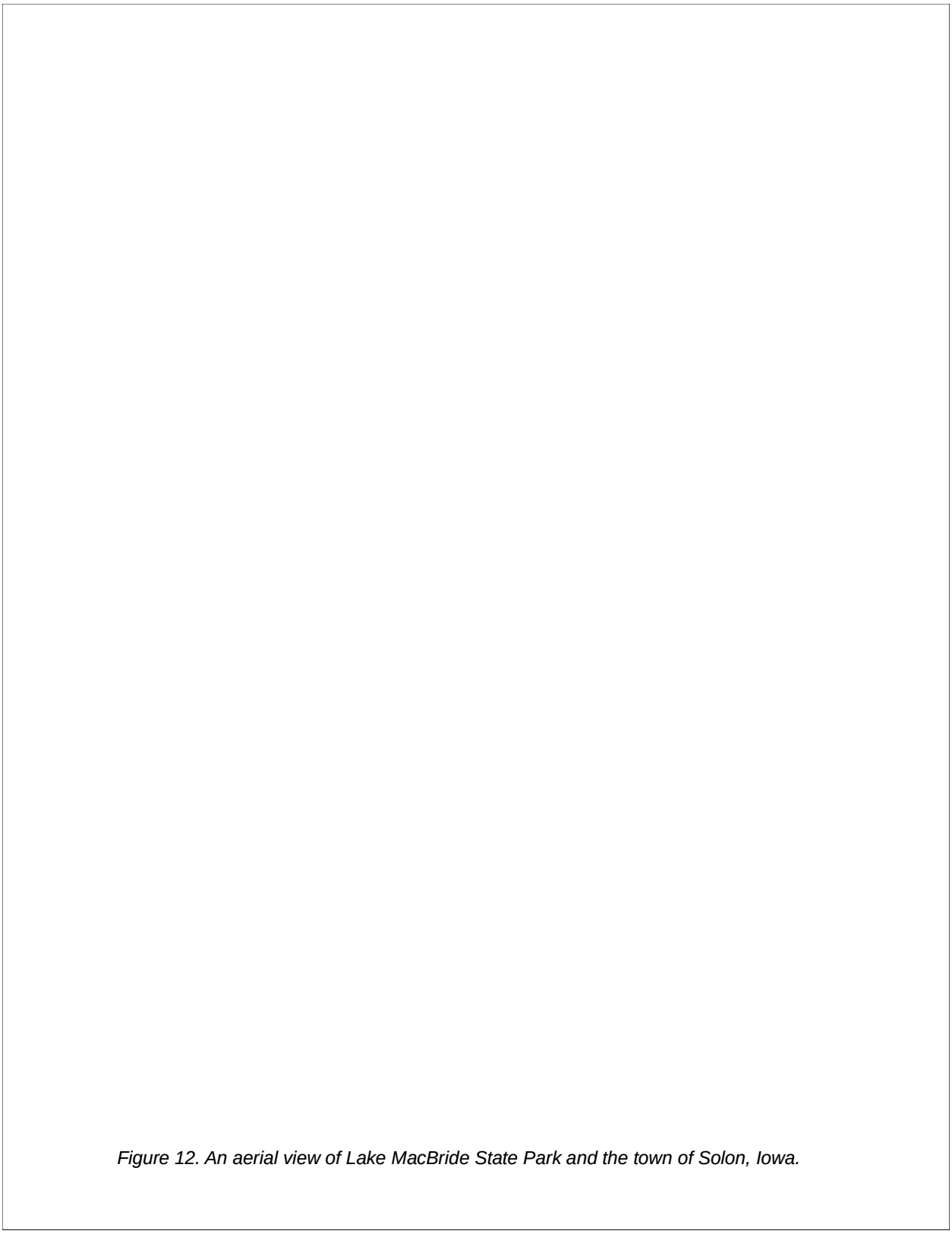

Figure 12. An aerial view of Lake MacBride State Park and the town of Solon, Iowa.

Soils of Lake MacBride State Park

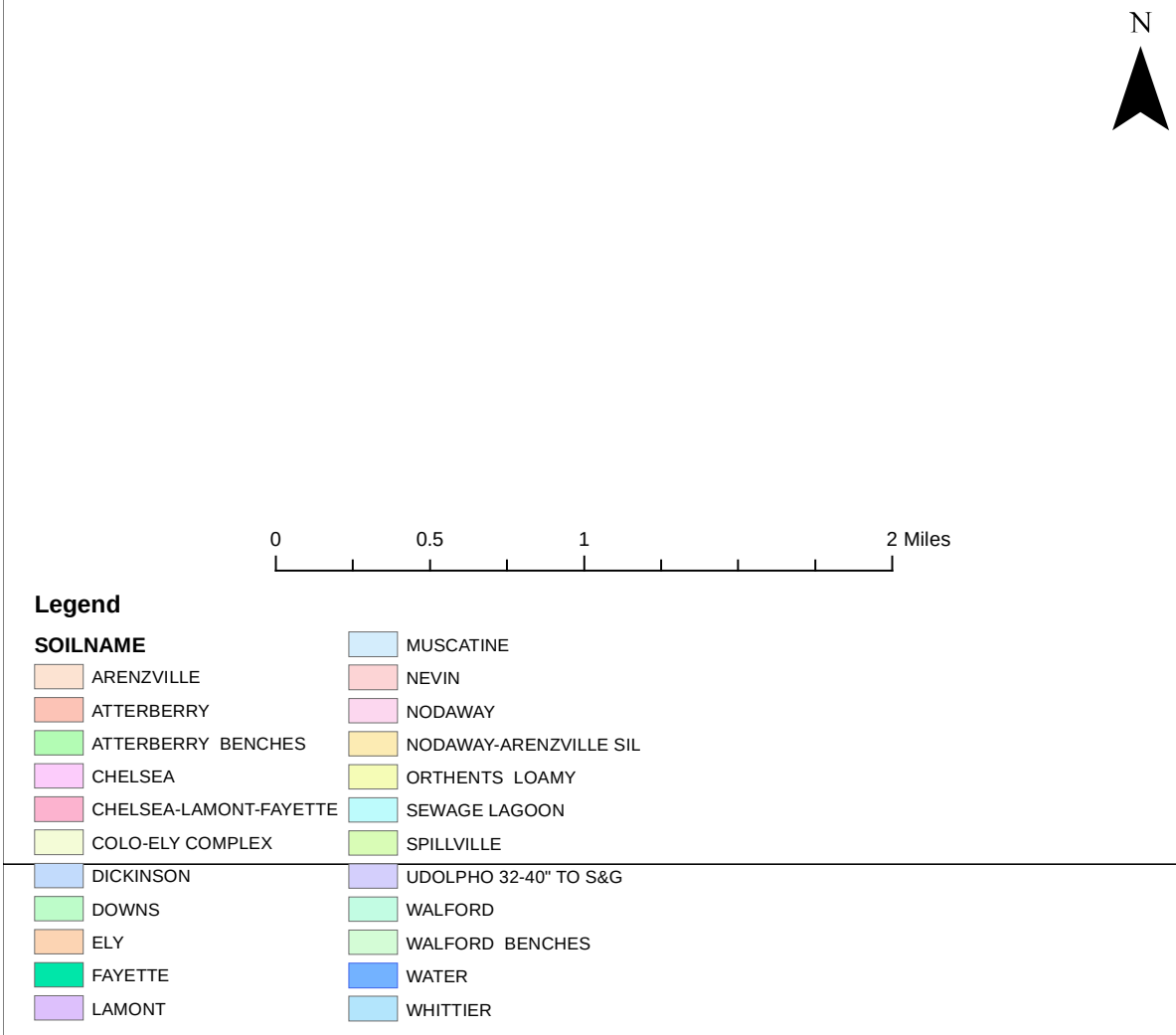

Figure 13. Shows a soil distribution of Lake MacBride State Park.

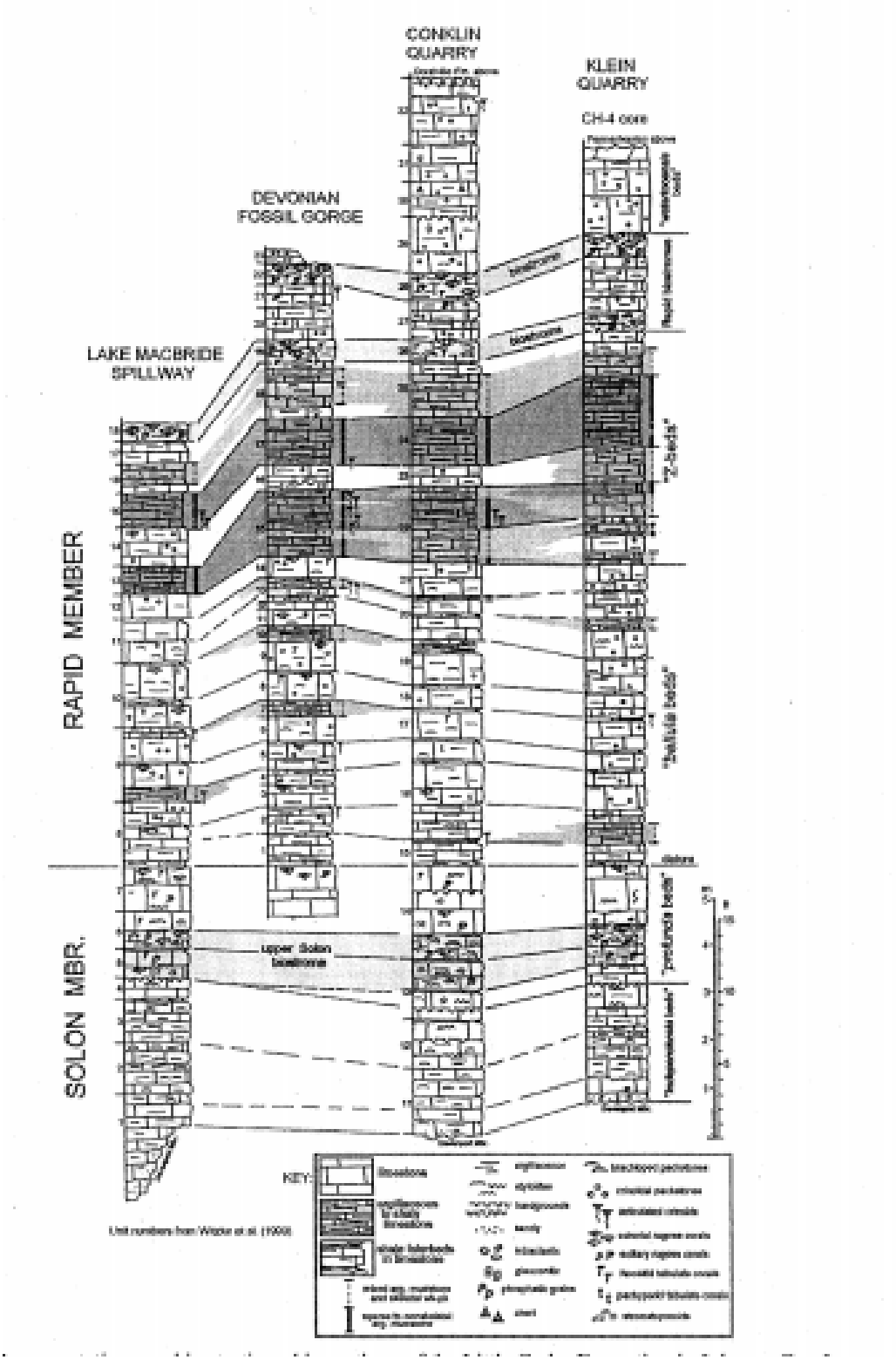

Figure 14. Shows the Devonian bedrock strata found in Lake MacBride State Park. Photo from The Natural History of Lake MacBride State Park, Geological Society of Iowa, Guidebook 79 by Raymond Anderson and Chad Fields.

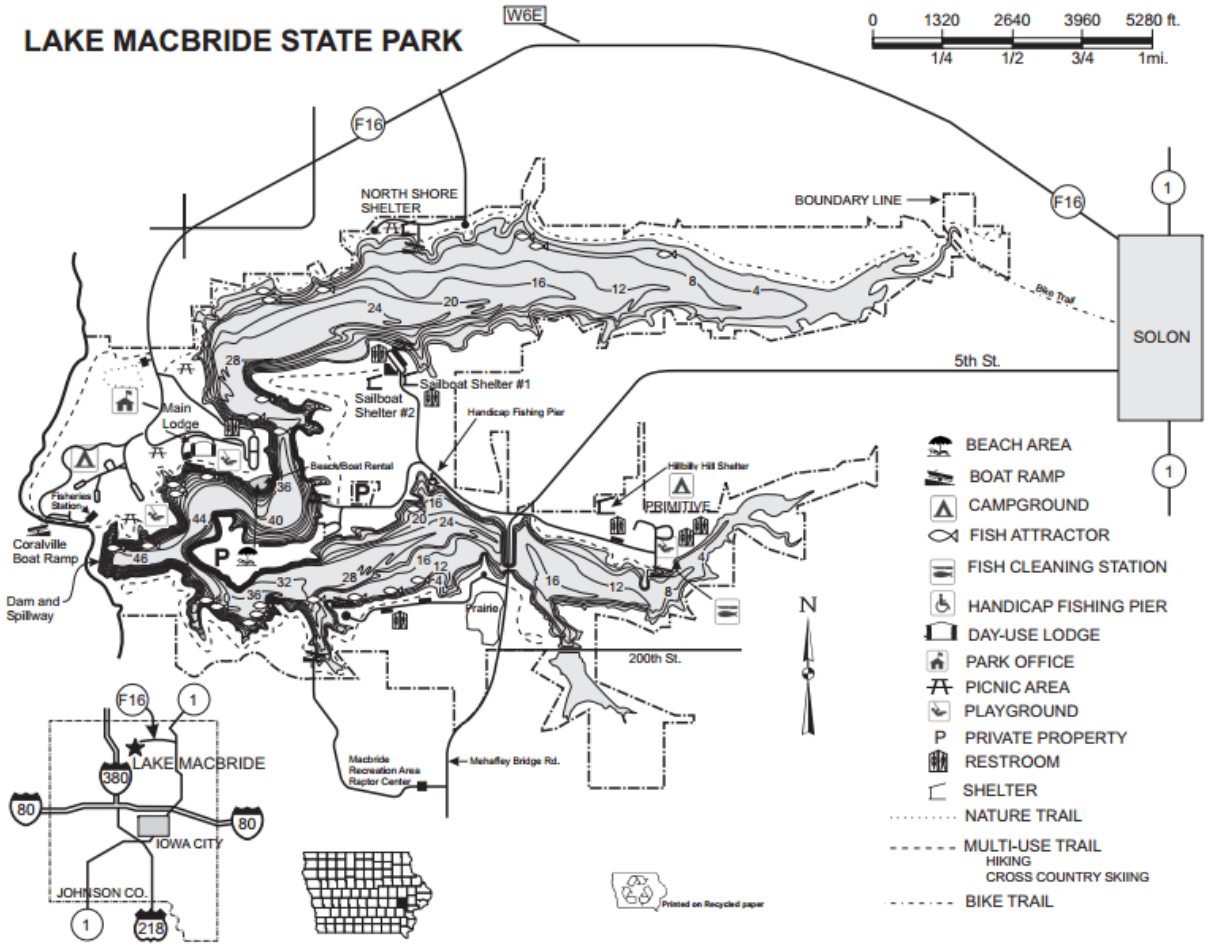

Figure 15. Shows the park layout of Lake MacBride State Park. Photo taken from the Iowa DNR website.