Chapter 2 - Geophysical

Introduction
Understanding an area’s physical environment is an integral component of proper long-range land use planning. The Geophysical chapter provides baseline information, key findings, and identification of key issues associated with the physical characteristics of the Madison area. Information documented in this report will be used as a basis for informing planning policy decisions in formulation of a Comprehensive Plan.

The physical environment’s geology, soils, hydrology, and climate all shape an area’s growth patterns. The following chapter summarizes the important attributes of the City’s natural environment, allowing City officials, land owners and citizens an understanding of those natural characteristics enhancing future development, while also drawing attention to the problematic natural characteristics of the landscape so they can be proactively addressed.

Geophysical Location
Madison is centrally located in Lake County, which lies in the eastern portion of the state and is one county removed from the Minnesota line (Figure 2.1). The City is located east of Lake Herman and northwest of Lake Madison. Silver Creek originates at Lake Herman and flows through the southern portions of the City. In the southeast portion of the City, Park creek flows into Silver Creek and eventually drains into Lake Madison.

The Madison’s area has limited amounts of elevation relief and steep slopes. The elevation difference between Silver Creek and the hills to the northwest is less than a 100 feet.

The City is located within the Central Lowland physiographic region and Coteau Des Prairies physical division (Figure 2.2). The Coteau des Prairies is a highland area between the Minnesota-Red River Lowland and the James River Lowland to the west. This landform is part of a plateau that extends through North Dakota into Canada. It slopes gently to the south and west with eastern and western slopes that are steep at the northern end and taper off on the south. Elevations range from 2,000 feet (610 m) above sea level on the north to about 1,600 feet (488 m) on the south. It is drained to the south by the Big Sioux River, whose tributary streams enter mainly from the east. West of the Big Sioux River, the surface of the Coteau is dotted with lakes and depressions, while very few lakes occur east of the river (Brinkley 1971).
Geology and Soils
Figure 2.3 illustrates the general location of the geology and landforms in Lake County. Madison’s main geologic formations are listed in descending order of coverage:

- Glacial outwash – the deposit of glacial debris which has been washed and sorted by water flowing from melting glacial ice
- Alluvium – material deposited by streams since the retreat of the glaciers and is found in the valley’s of present-day streams.
- Glacial till – the mixture of clay, silt, sand, gravel, and boulders redeposited from the flow of glaciers

Topography
The Madison area has limited amounts of steep slopes and topographic relief. The Silver and Park Creeks form two small river valleys which have the lowest elevations in the City and drain to the southeast into Lake Madison. The areas to the north and northwest are the highest elevations in the City, however the elevation difference between the City’s high and low points is generally less than 100 feet.

Figure 2.2. Map of eastern South Dakota, highlighting Lake County and showing the major physiographic divisions and locations (adapted from Brinkley 1971).
Figure 2.3. Geology and landforms of Lake County (adapted from Hammond 1991).
Surface and Ground Water

The water sources in Lake County consist of streams, lakes, and glacial and bedrock aquifers. The primary sources of surface water in Lake County are Lake Herman, Lake Madison, and Lake Brant and Silver Creek and Brant Creek (Figure 2.4). Seasonal variations in streamflow and lake levels are directly related to seasonal variations in precipitation (Hansen 1986).

The average annual precipitation of Lake and Moody Counties is 24 inches. About 97 percent of the precipitation is returned to the atmosphere by evaporation and transpiration. Approximately one percent of the precipitation becomes streamflow and about two percent percolates into the ground, becoming ground water (Hansen 1986).

Water Quality. Dissolved-solids concentration in Lakes Herman and Madison generally decrease during the spring months because of spring rainfall and snowmelt runoff. Dissolved-solids concentration in water from streams and rivers varies with volume of streamflow.

Floods. Extreme flooding in Lake County is a rare event, although valley bottoms and areas of internal drainage flood occasionally as result of spring snowmelt and rainfall runoff (Hansen 1986).

In 1993, Lake County received 38.65 inches of precipitation, well above the normal annual precipitation of 24.43 inches. In addition, Madison experienced a 5.6 inch thunderstorm on July 3, 1993. Prior to this storm event the ground was already wet and saturated from spring runoff and thunderstorms.

The July 3rd storm resulted in flooding throughout Lake County with extensive flood damage in Lake Herman, City of Madison, Lake Madison and Brant Lake areas. Homes and businesses along Park Creek and Silver Creek in Madison were directly damaged from flood waters. Floodwaters also surcharged the sanitary and storm sewer systems causing wastewater and surface water to back-up into house basements. It was determined 212 families were displaced from their homes the day after the flood and 17 families were still displaced 70 days later (Banner Associates 1995).

The City of Madison sustained substantial flood damage. The water and wastewater treatment plants were flooded, resulting in mechanical and electrical equipment damage. Sections of 18” sanitary sewer interceptor and 21” sanitary sewer outfall were washed out. Other flood impacts and costs included:

- Cleanup
- Well disinfection
- Park Creek channel restoration
- Transformer replacement
- Street and alley repair
- Sidewalk repair
- Bridge repair
- Pumping and miscellaneous emergency protective measures (Banner Associates 1995).

The City also started a buy out/relocation program to reduce the life and safety hazards within the incorporated boundaries. Sixty-seven homes were bought and 16 homes re-
ceived repair assistance, totaling $2,311,170. Pending offers to purchase or relocate homes resulted in an estimated cost of $759,655 (Banner Associates 1995).

A study completed in 1995 developed two alternative comprehensive plans to address Madison’s flooding. Comprehensive Plan No. 1 recommended the construction of two detention ponds and upsizing or modifying Park Creek, Park Creek Tributary and Silver Creek. The estimated cost of Comprehensive Plan No. 1 was $3,690,000. Comprehensive Plan No. 2 consisted of reducing the floodway by making improvements to the existing channel and replacing selected structures on Park Creek, Park Creek Tributary and Silver Creek. The estimated cost of Comprehensive Plan No. 2 was $4,168,000 (Banner Associates 1995).

**Floodplains**
The Special Flood Hazard Area (SFHA) within the City of Madison is currently depicted on the FEMA Flood Boundary and Floodway Map (FBFM) panels 460044 0001 and 0002, dated July 5, 1982. These FBFMs and associated profiles in the Flood Insurance Study (FIS), dated January 5, 1982, identify the limits of the 1% Annual Chance Flood (100-year), 0.2% Annual Chance Flood (500-Year), and the regulatory floodway. As part of a Flood Insurance Rate Map update the 100-year floodplain, 500-year floodplain, and regulatory floodways for Park Creek, Park Creek Tributary, and Silver Creek within the corporate limits of the City of Madison are being updated through a detailed study. This update project is also incorporating existing flood risk data to other parts of Lake County, but is not doing a detailed study of other parts of the County. The detailed study within the Madison corporate limits included development of a new topographic map using aerial photogrametry and HEC-RAS/HEC-1 modeling. The draft results of this detailed study are provided in Figure 2.5. The final results are expected to be officially approved in 2008 or 2009.

**Lake and Ponds**
Lake Madison, Lake Herman, and Brant Lake cover about 16 mi². The area of Lake Madison is 3.67 mi²; Lake Herman 1.67 mi²; and Brant Lake 1.33 mi² (Figure 2.4). These lakes were all formed by stagnant ice blocks positioned at the margin of the receding glacier (Hansen 1986).

Long-term records of lake-level fluctuations for the Lake Madison indicate close correlation with departure from average annual precipitation. Lake Madison was dry in 1873, 1893 (South Dakota Lakes Preservation Committee 1977), 1935, 1936, and 1940. Lake levels rose from 1941 to 1945, 1959-1965, and from 1967-1969 because of above-normal precipitation (Hansen 1986).
CHAPTER 2—GEOPHYSICAL

FIGURE 2.4

HYDROLOGY
Madison Comprehensive Plan

[Map Image]
CHAPTER 2—GEOPHYSICAL

FIGURE 2.5
ANTICIPATED FLOOD HAZARD AREAS
Madison Comprehensive Plan

(Map showing flood hazard areas with various zones and labels)

*Lake City DFRM
100-Year Floodplain
500-Year DFRM
Floodway Draft
Surface Water
Rivers
Corporate Limits
Madison Municipal Airport
Railroad
Silver Creek
Lake Herman

[Map with geographical locations and flood hazard areas marked]
Wetlands

The City of Madison and Lake County are within the prairie pothole region (Figures 2.6). The prairie pothole region is the formerly glaciated landscape in the upper Midwest, which is pockmarked with an immense number of potholes or wetlands. These potholes fill with snowmelt and rain in the spring, some are temporary, while others may be essentially permanent (EPA 2006a).

The Upper Midwest, because of its numerous shallow lakes and marshes, rich soils, and warm summers, is described as being one of the most important wetland regions in the world. The area is home to more than 50 percent of North American migratory waterfowl, with many species dependent on the potholes for breeding and feeding. In addition to supporting waterfowl hunting and birding, prairie potholes also absorb surges of rain, snow melt, and floodwaters thereby reducing the risk and severity of downstream flooding (EPA 2006a).

Besides being some of the most biologically productive natural ecosystems in the world, wetlands also store and filter water and provide recreational and hunting opportunities (EPA 2001).

Wetlands function like natural sponges, storing water and slowing releasing it. This process slows the water’s momentum and erosion potential, reduces flood heights, and allows for ground water recharge. While a small wetland might not store much water, a network of wetlands can store an enormous amount of water (EPA 2001). The combination of slower and reduced water flows can actually lower flood heights and reduce waters destructive potential (EPA 2006b).

After being slowed by a wetland, water moves around plants, allowing the suspended sediments to drop out and settle to the wetland floor. Nutrients from fertilizer application, manure, sedimentation, leaking septic tanks, and municipal sewage that are dissolved in water are often absorbed by plant roots and microorganisms in the soil.

Many of these important and highly productive wetland communities have been altered or destroyed due to increased agricultural and commercial development. As a result, only an estimated 40 to 50 percent of the region’s original prairie pothole wetlands remain undrained today (EPA 2006).
Glacial Aquifers

Five glacial aquifers are present within Lake County (Figures 2.7, 2.8, 2.9):

- North Skunk Creek
- Battle Creek
- East Fork Vermillion
- Ramona
- Howard

Glacial aquifers are those aquifers composed of materials derived from a glacier. In Lake County, glacial aquifers mainly consist of unconsolidated sand and gravel deposited as glacial outwash. Ninety percent of the water used from aquifers is from glacial aquifers and 10 percent from bedrock aquifers (Hansen 1986).

North Skunk Creek aquifer (Figure 2.7) is composed of a poorly sorted, sandy gravel northwest of Lake Madison and grades to a well sorted sand and gravel southeast of Lake Madison. Recharge to the aquifer is by infiltration of precipitation and snowmelt. Well-level and lake-level fluctuations indicate the Lakes Madison, Herman, and Brant are hydraulically connected to the aquifer. Water from the aquifer is used for municipal, domestic, and stock purposes, and is suitable for irrigation (Hansen 1986).

The Battle Creek aquifer (Figure 2.7) is composed of fine to medium sand with some fine gravel and is underlain by till. The aquifer is limited to the flood plain of Battle Creek. Recharge to the aquifer is by infiltration of precipitation and snowmelt. Water from the aquifer is mainly used for stock watering and not used for irrigation because discharge is only 1 to 3 gal/min (Hansen 1986).

East Fork Vermillion aquifer (Figure 2.7) ranges from fine to medium sand to a well-sorted coarse sand and fine gravel and clay layers as much as 10 feet thick are interbedded in the aquifer. The aquifer is limited to the flood plain of the East Fork of the Vermillion River. Recharge of the aquifer is by infiltration of precipitation and snowmelt. Water in the aquifer is used for stock, domestic, and municipal purposes and is suitable for irrigation (Hansen 1986).

The Ramona aquifer (Figure 2.8) is composed of poorly sorted, medium to coarse sand, intermixed with fine to coarse gravel. Recharge to the aquifer is by leakage from the overlain till and water-level fluctuations from observation wells do not indicate seasonal changes in recharge. Discharge from the aquifer is from domestic and stock wells (Hansen 1986).
The Howard aquifer (Figure 2.9) ranges from a medium to coarse sand and fine gravel. Recharge to the aquifer is likely by leakage from the till and probably occurs north of the county. Water from the aquifer is used for domestic, municipal, and stock purposes and is suitable for irrigation (Hansen 1986).

**Bedrock Aquifers**

The bedrock aquifers in Lake County, in order of increasing age, are:
- Niobrara
- Codell
- Dakota
- Quartzite wash (Hansen 1986).

The Niobrara aquifer (Figure 2.10) is a fractured, dark gray to white, calcareous chalk that contains numerous solution cavities. Fractures in the aquifer in the southwest quarter of the county have provided sufficient water for stock and domestic wells. Recharge is by leakage from the overlying Howard aquifer and by leakage from the overlying till. Water-level fluctuations in observation wells do not show seasonal changes in discharge or recharge (Hansen 1986).

The Codell aquifer (Figure 2.11) is composed of a white to yellow-brown, well-sorted, medium sandstone. The aquifer is the primary source of water for municipal, domestic, and stock use in northwestern Lake County (Hansen 1986).

The Dakota aquifer (Figure 2.12) is composed of fine-grained, gray to brown sandstone that contains interbedded shale layers. Discharge from the aquifer is from domestic and stock wells and uncontrolled flowing wells located in the James Basin (Hansen 1986).

The Quartzite wash aquifer (Figure 2.13) is composed of an uncemented, coarse, well-rounded, well-sorted, pink, quartzose sand. Recharge to the aquifer occurs at the Sioux Quartzite outcrop three miles east of the South Dakota-Minnesota state line. Water level fluctuations in observation wells do not indicate a definite trend or correlation with seasonal changes in recharge (Hansen 1986).
Tall Grass Prairie
Tall grass prairie is a plant community dominated by tall grasses, which grow four to eight feet high. These grasses are usually abundant in higher rainfall areas and along streams and moist valleys and typically found in eastern South Dakota, including Lake County (SDACD 2004).

Grasslands are one of South Dakota’s greatest natural resources (Figure 2.14). Grasslands are a community of plants and animals where grasses are
the predominant vegetation. Grasses and other plants found here are the base of a food chain that supports hundreds of species of wildlife as well as livestock. South Dakota is mostly mixed grass prairie and tall grass prairie. Deposits left behind by the glacier that created the Missouri River and high annual rainfall formed the basis for the tall-grass prairie. South Dakota’s grasslands are used for many things, including watershed management, recreation, wildlife habitat, and hay production. The most common use is grazing by livestock (SDACD 2004).

Climate
Madison has an interior continental climate, which is characterized with hot summers, cold winters, high winds, and periodic droughts. The average low and high temperatures between 1971-2000 were 32.5°F and 55.4°F, respectively. The average annual temperature for the same period is 43.5°F (SDSU Climate and Weather 2007). Seasonally, Madison’s temperature ranges from triple-digits highs to lows well below zero (Figure 2.15).

The majority of Madison’s precipitation falls within the growing season (Figure 2.16). The City’s average annual precipitation is 25.5 inches (SDSU Climate and Weather 2007) and the City averages 28 inches of snowfall.

The closest weather station providing wind data is in Brookings, which is approximately 25 miles northeast of Madison. The windiest conditions in this area occur between winter and spring with the strongest winds occurring in April and averaging around 14.9 mph (Figure 2.17). Winter winds prevail from the northwest (Figure 2.18) and summer winds prevail from the south to south-east (Figure 2.19).

Characteristics of the local climate include:
- Temperatures range from an average low in January of 1.8°F to an average high of 82.8°F in July
- Average annual temperature is 43.5°F
- Annual precipitation is 25.5 inches
- The month of June has the highest average precipitation of 3.12 inches
Figure 2.19. Average wind speeds reported at Brookings, SD 1985-2002 (SDSU Climate and Weather 2007)

Figure 2.20. Wind direction and speed reported at Brookings, SD for January, 1985-2002 (SDSU Climate and Weather 2007)

Figure 2.21. Wind direction and speed reported at Brookings, SD for August, 1985-2002 (SDSU Climate and Weather 2007)