The Impact of Flooding in Brookings County, South Dakota 1936-1985

Jan M. Griesenbrock

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THE IMPACT OF FLOODING
IN BROOKINGS COUNTY, SOUTH DAKOTA 1936-1985

BY

JAN M. GRIESENBROCK

A thesis submitted in partial fulfillment
of the requirements for the degree
Master of Science
Major in Geography
South Dakota State University
1986
THE IMPACT OF FLOODING
IN BROOKINGS COUNTY, SOUTH DAKOTA 1936-1985

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

Many people have made significant contributions in this very important step in my professional and academic career. I would like to express my appreciation to the Department of Geography that provided the opportunity to make this goal possible. Specifically, I want to thank Dr. Charles F. Gritzner whose professionalism, guidance and direction inspired me throughout this study. Additionally, I recognize the support from the Department of Journalism and Remote Sensing Institute.

Finally, my deepest gratitude goes to my wife, Cathy, for her support during this study and to my children; Brian, John and Jana for their understanding during the long hours away from home.
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CHAPTER I
INTRODUCTION

Flooding is the most widespread natural hazard in the world, affecting more people and causing more damage than any other natural hazard. It occurs in nearly every country in the world, yet geographic research on flooding is relatively recent.\(^1\)

The study of the impact of water upon the surface of the earth, or hydrology, has developed only within the last century. Geographically, William Morris Davis described running water as one of the keys to understanding landforms. Since that time, geographers have taken the lead in presenting theoretical concepts, directing field studies, and describing the action of water on the earth.\(^2\)

Various cultures since the dawn of civilization have retold legends in which a huge flood inundated the earth. Genesis 7:11-12 describes a global flood where, "all the springs of the great deep burst forth and the floodgates of the heavens were opened. And rain fell on the earth forty days and forty nights." One flood legend in North America has been traced to Chippewa tribesmen of North Dakota and Minnesota. They told of a mouse that gnawed through a skin where the sun's energy was trapped, releasing the heat that subsequently melted all of the ice and snow in the world, causing a great flood.\(^3\)

Biblical accounts further describe a phenomenon that has since become known as the hydrologic cycle. "All rivers run into the sea," said Ecclesiastes 1:7, "yet the sea is never full; unto a place whence the rivers come thither they return again." It is estimated that for
three billion years, the total amount of water on earth and its atmosphere has been constant; only the form—liquid, ice or vapor—changes from time to time.  

As rain falls and snow melts, water begins to move over land. As it moves down slope concentrating in streams and rivers in its race to the sea, water has an incredible ability to do work. The force that water exerts as it moves over land increases at the square of its velocity. The force of a river is four times greater at ten miles per hour than at five miles per hour. A person would have difficulty standing in moving water only three feet deep at a relatively slow two miles per hour.

Defining a flood in general terms is relatively simple. Webster defines a flood as, "a rising and overflowing of a body of water onto normally dry land," although describing a flood can be extremely complex; however, because floods are viewed differently by different people. Along the Nile River, for example, for millennia Egyptian farmers welcomed the annual floodwaters which brought rich alluvial sediments to replenish flood plain soil fertility. In other regions of the world, rising floodwaters are responsible for catastrophic loss of property and lives. As recently as 1972, Rapid City, South Dakota experienced a deadly flood when heavy rains caused a small dam to burst. The resulting inundation of the adjacent flood plain caused destruction of property and the loss of over 200 lives.

In Brookings County, spring snowmelt flooding is rather routine and usually occurs when snow accumulations from long, cold winters release water rapidly during the March or April spring melt. Damage is
usually light, inundating township roads and washing out fences across the Big Sioux River and its tributaries. There have been severe floods in the county. Such hazards have covered as much as one-fourth of the total land area of the county destroying roads, bridges and other structures and covering parts of towns located within active flood plains.

**Location of Study Area**

Brookings County is located in east central South Dakota. The county has a rectangular shape, about 34 miles from east to west and about 20 miles from north to south. It shares boundaries with the state of Minnesota on the east, and borders the counties of Hamlin and Deuel on the north, Kingsbury on the west, and Lake and Moody on the south. There are 512,640 acres included in the county or about 801 square miles (Figure 1).

![Figure 1 - Location of Brookings County, S.D.](image-url)
Study Objectives

The objectives of this study are threefold. First, the flood hazard in Brookings County is analyzed by describing the importance of geology, topography, soils, weather and climate in terms of their respective impacts on the flood problem. Second, it develops a consolidated source of information on the flood history of the county from 1936 to 1985. This 50-year period includes years of drought, the flood of record in April, 1969, and 1984 when at least three floods covered the county in one year. Finally, it identifies and assesses flood problems and those efforts that have been planned and implemented in order to reduce the impact of flood hazard within the study area.

This study is intended to consolidate flood information in sufficient detail to present the scope of the flood hazard in Brookings County over the last 50 years. During the literature review, it became apparent that while flood information is available, it was prepared by various local, state and federal agencies for specific flood-related purposes. This study is designed to discuss those aspects of flood information for a particular county with a history of flood problems in order that geographers and others can develop an appreciation for the scope of the flood problem for one county within the geographical boundaries of the State of South Dakota.

Review of Literature

Most research materials used in this study were available through the H. M. Briggs Library on the campus of South Dakota State
University. During the literature review, the author found that faculty members at the University of Colorado and University of Chicago have conducted extensive flood research and have published numerous articles that deal with national flood problems. In 1982, Linda Hillestad authored a Master of Science thesis through the Department of Geography at South Dakota State University, entitled *The Changing Impact of Natural Disasters in Brookings County, South Dakota*. Jerry Siegal of the East Dakota Water Development District, formerly the East Dakota Conservancy Sub-District, was a valuable source of regional flood information, while the Soil Conservation Service Field and Area offices provided data on specific watersheds within Brookings County. Additionally, the U. S. Army Corps of Engineers Flood Information Studies for Deer Creek and Six Mile Creek were helpful, as were data from the U. S. Geological Survey on floodstage recordings from a gauging station near the Brookings-Moody County border.

Following research on general flood information, evaluations were completed on local precipitation information for Brookings County from *Climatological Data of South Dakota*. Monthly and yearly precipitation accumulation totals were evaluated to identify specific occurrences of greater than normal rain or snowfall accumulations over a 50-year period. Dates for peak precipitation periods were noted and then investigated in the *Brookings Register*, *Volga Tribune*, and *Elkton Record*. Every attempt was made to consider as many published flood events as possible from 1936 through 1985. The author acknowledges the fact that other floods undoubtedly have occurred within the study area that were not reported, or were reported and inadvertently omitted from
this study. The flood information included in this study indicates the existence of a flood problem in Brookings County and increasing economic loss to urban and rural property owners.

This study does not emphasize the economic flood hazard loss within this study area. The published information reviewed normally did not include reference to specific economic loss. Further, Smith (1965) has noted "the true extent of loss in a flood is impossible to calculate." Several state and federal agencies estimate and disseminate loss figures from natural hazards, but these estimates are only attempts at realizing a dollar amount to be used in generalizing damage summaries and reports and in planning strategies. 8

Organization of Study

The chapters in this study can be divided into four general categories. First, chapters II, III, and IV set the stage for the study by discussing the physical characteristics of the landscape by reviewing the climate and weather conditions of the region that contribute to the flood problem, and finally by giving a detailed description of the major watersheds. Chapters V and VI are primarily historical in nature; specific flood events are presented, including the flood of record that occurred after record snow accumulations during the winter of 1968-69. Chapter VII reviews specific problems associated with the flood hazard within Brookings County. Finally, Chapter VIII presents those efforts by local, state and federal agencies to reduce the loss caused by the flood hazard.
In order to establish the flood problem in Brookings County, the following chapter will "set the stage" for this study of flooding by describing the geologic history, resulting topography and soils that cause water to move the way it does.
ENDNOTES


4 Ibid.


6 Roy Ward, p. 4.


Chapter II

GEOLOGY, TOPOGRAPHY AND SOILS

The movement of water over the land surface, or drainage, is influenced by many factors. First, the terrain determines the direction and flow of water. Water moves by gravity in a path of least resistance. The speed at which water moves over the surface of the land is determined by both volume and the slope or gradient of the landform. Water, pulled by gravity, moves faster down a steeper slope than a gentle one. The speed that water moves over land is called the velocity. Drainage is also affected by the soils of the land. Sandy soils characteristically have a coarse texture, and allow absorption or percolation into lower soil depths. Clay soils have smaller soil particles and a smoother texture that inhibits percolation. The kind and amount of vegetation or land cover also has an effect upon water drainage. If the landscape is without vegetation, water can move freely without interruption; if, on the other hand, the land has cover in the form of grass, shrubs, trees, cultivated crops or structures, the movement of water is slowed.

Brookings County is located within the Coteau des Prairies, a low plateau that extends from near the North Dakota border southward some 200 miles to near Sioux Falls. Most of the county is located within the Big Sioux Drainage Basin. The average elevation is about 1,650 feet, ranging from a maximum of near 1,990 feet in the northeastern corner of the county to a minimum of about 1,550 feet near Lake Campbell in the south central area of the county. (Figure 2):
The geology, topography and soils of Brookings County were shaped by glaciation during the Pleistocene epoch when the Nebraskan, Kansan, Illinoian and Wisconsin ice sheets advanced and receded across what is now eastern South Dakota. In Brookings County, substages of the Wisconsin ice advances contributed directly to the present-day topography. In order of occurrence, the Iowan, Tazewell and Cary glaciers left large amounts of sediment, or glacial drift. Glacial drift is a mixture of till, gravel and sand. Till is a mixture of material ranging in size from boulders to clay and is relatively impermeable. Till glacial deposits give the study area its topographic
Figure 3 - Distribution of Pleistocene Wisconsin Glacial Drift Sheets in eastern South Dakota (After Flint 1955).
relief. Outwash areas of the county were formed when flowing glacial meltwater washed away the clay, sorted out the gravel and deposited each in layers.¹

The drainage patterns of the county were formed when water eroded the land surface when the glaciers melted. East of the Big Sioux River, the landforms were shaped primarily by Iowan and Tazewell ice sheets. Remains of the Iowan drift sheet occur as wide, flat ridgetops that gradually slope to smooth hillsides ending in drainageways. There are no closed depressions, and all streams form a mature system that drains into the Big Sioux River.² (Figure 3).

The Tazewell substage drift was deposited generally five to seven miles wide, parallel and northeast of the Iowan deposits. Iowan and Tazewell drift material appear similar except the Tazewell has stronger relief with a few undrained basins.³

Cary drift is characterized by knob and kettle topography with numerous small water-filled depressions. The local relief is more rugged than other glacial deposits. End moraines rise from 80 to 100 feet above the surrounding landforms. The Cary ice sheets are believed to have entered the county from the east and west. Cary substage glacial remains also are found in the northeastern corner of the county near Lake Hendricks. Most of the alluvial outwash areas are thought to be of Cary glacial origin.⁴

In terms of drainage, Brookings County is divided by the Big Sioux River. The river was probably formed during the Tazewell substage glaciation when a long, narrow glacier-free strip allowed meltwater to escape. The river channel is narrow compared to the flood
plain that ranges in width from two to four miles in the county. The river, first named by the Indians of the area as "Ichankrandata" has been translated to mean a river that is too small for its flood plain.  

The Big Sioux River has an elevation of about 1,629 feet at its northern boundary with Hamlin County and falls steadily about 68 feet through its course to the Moody County line. The river flows about 45 miles through Brookings County. (Figure 4).

Map, aerial photography and ground truth investigations of the study area identify several significant physical differences. Most of the established drainageways of the county are east of the Big Sioux River: Peg Munky Run, North Deer Creek, Six Mile Creek, Deer Creek, and Spring Creek. These watersheds flow primarily in a south to southwest direction from higher Tazewell glacial remnants into the Big Sioux River outwash lowlands. West of the Big Sioux River, the Soil
Conservation Service has divided the western one-third of the county in half. The northern half drains primarily into Lake Poinsett, Oakwood Lakes and numerous potholes and sloughs. In the southwest area of the county the topography is similar and where water from the surface drains into potholes, sloughs and small lakes. Nearly all of the western one-third of the county is characteristic of Cary substage glacial sediment with undeveloped drainage patterns.

Lakes occupy about 7,211 acres of the county or 1.5 percent of its area. All of the lakes are natural and are of glacial origin. Brookings County lakes include the extreme southern part of Lake Poinsett in the northwest corner; Oakwood Lakes, near the village of Bruce; Campbell near the Big Sioux River at the Moody County line; Hendricks, in the northeast at the border of the state of Minnesota; Sinai, in the southwest; Oak, near Lake Hendricks; and Goldsmith near the town of Volga. All of these lakes are within Cary glacial deposits. Marshland, potholes and other depressional landforms cover about 9,381 acres or another 1.8 percent of the county's land area.6

The soils of Brookings County developed from five specific factors. These include: climate, living organisms, parent material, relief and time. The climate of the county is sub-humid, where conditions, primarily precipitation permit the growth of short, mid, and tall grasses. Parent material was primarily glacial till and to a lesser extent loess. The relief was determined by sediments from advancing and receding glaciers and the age of the soil across the county ranges from about 55,000 to 20,000 years old to recent alluvium.
Soils further have been categorized in the Soil Survey of Brookings County by texture and relative position on the land surface. In general terms, soils in the flood plains of the Big Sioux River, its tributaries and low depressional lands are poorly to very poorly drained, while soils on the terraces and uplands range from moderately to excessively well drained.

Glaciers that covered Brookings County during the Pleistocene epoch had a tremendous impact upon the present-day geology, topography, and soils. The next chapter will discuss the climate and weather of the area.
ENDNOTES


2Ibid.


4Ibid.


6Fred C. Westin, p. 9.
CHAPTER III
CLIMATE AND WEATHER

Climate is the long-term average weather condition for a given location. Climatic data are derived from statistical characterization collected over a relatively long time, usually several decades. In contrast, weather is the current or relatively recent state of the atmosphere. Both can be described in terms of temperature, pressure and winds, sunshine and cloud cover, precipitation and humidity.\(^1\)

A climatic average or mean is computed from records extending over a period of years. A mean for a particular 30-year period is called a normal by international convention.\(^2\) The normals used by the National Oceanic and Atmospheric Administration (NOAA) for climatological work are recomputed every 10 years. The first 10 years of data are dropped and the most recent years of data are added to the record for recomputation. Values for the same periods of record, therefore, are best for comparing the climates of different locations.\(^3\)

The underlying causes for variations in the earth's weather and climate conditions are heat energy from the sun, the angle at which incoming solar radiation strikes the earth's surface, and the earth's rotation. The radiant energy of the sun, or solar insolation, and the constant rotation of the earth about its axis serve to set up circulation patterns within the atmosphere. These circulation patterns carry heat and moisture from the equator to the poles, across land and sea, and over flat land and mountains. Patterns of winds, rainfall,
cloudiness, and temperature regimes tend to remain relatively stable at any given location on earth. Weather sequences tend to follow the same pattern year after year; it is these patterns that determine the climate of a place. 4

The Weather and Climate of Brookings County

Brookings County generally experiences frequent cold, dry polar or arctic air masses in winter (cPk), while warm, moist maritime air (mTw) moves northward during the summer months. Circulation around low pressure areas moving toward the east or northeast is one of the causes of the northward flow of warm gulf air into the county. The principal source of moisture is the northward flow of air from the Gulf of Mexico. The wind around the western side of the Bermuda high-pressure area, which intensifies in summer, contributes to the northward flow of air. In winter, a reverse monsoon effect caused by the outflow of cold air from the interior contributes to the generally easterly movement of cold air masses across the county. Squall lines in advance of cold fronts, and individual thunderstorms and tornadoes bring very strong, sometimes destructive winds, particularly in summer. 5

The climate of Brookings County strongly reflects continental conditions; there are no large bodies of water to affect the climate. Temperatures experience a large annual and diurnal (day to day) range. During the summer, temperatures may rise to 100 degrees (F), and drop to 20 degrees or more below zero in winter. Thermometer readings in the county reach 100 degrees or higher on an average of about once a
year in July, once in three years in August and once in five years in June. A reading of 20 degrees below zero or lower may be expected about two times a year in January and once a year in December. A 30 below zero reading may occur about once in three years in January and February. The temperature may fail to climb above zero during the day two times per year in January and about once a year in February and December. The average date of the last spring frost in the county is May 17 and the first frost in fall about September 21, giving rise to a growing season averaging 127 days.

Precipitation

Brookings County's annual precipitation totals exhibit a wide variation from year to year within the period of this study. In the late 1930's precipitation accumulations averaged about 17 inches, whereas totals during the early 1980's averaged about 24 inches. The single year highest precipitation was in 1963 when over 35 inches were recorded; the lowest occurred in 1976 when 13.26 inches were recorded.

The average precipitation by month during the calendar year also varies, but the monthly average totals are relatively constant. During the winter months, precipitation generally averages less than one inch per month, contrasted by June with the average highest accumulation over six inches (Figure 5).
The precipitation average for the county is 21.69 inches, of which 17.5 inches or 80 percent falls during the growing season from April to September. Most growing season precipitation falls in the form of convectional thunderstorms which produce a wide range of rainfall intensities. About once a year one inch or more of rainfall may be expected in one hour; rainfall of two inches or more in one hour may be
expected about once in seven years. A 24-hour rainfall of two inches or more can be expected about once a year, and four inches or more in 24 hours may be expected about once in 10 years.

Seasonal snowfall averages about 24 inches in the county, but winter season accumulations have ranged from 3.1 inches during the winter of 1930-31 to 72.5 inches during the winter of 1968-69. Strong winds often accompany snowfall, causing large drifts in sheltered areas, while open fields remain bare. Snowfall of one inch or more occurs an average of 63 days per year.\textsuperscript{8}

Hail may be expected about twice a year, though it may occur several times in one year; whereas, in some years none will fall. Hail occurs most frequently in the months of June and July.

Sunshine is an important factor in crop production. During the growing season, the county averages about 65 percent of possible sunshine. Mean percentage variation in sunshine ranges from a high of about 75 percent in July to a low of about 50 percent in December.\textsuperscript{9}

Water loss experienced by the soil and crops is indicated by the evaporation from large pans. The average annual National Weather Service Class A pan evaporation in the Brookings area is about 47 inches of which 38 inches, or 81 percent, evaporates during May through October. The pan evaporation represents a maximum of potential evaporation. Shallow lake evaporation is about 72 percent of that from the pan. The actual water loss from soil is usually less since the soil moisture supply is dependent on the amount of available soil moisture.\textsuperscript{10}
Relative humidity averages from about 70 percent in the afternoon to 80 percent in the early morning during winter and from 55 percent in the afternoon to 85 percent in early morning during summer.\textsuperscript{11}

The weather of Brookings county reflects a wide variation from year to year. The occurrence of flooding is dependent upon the intensity and duration of precipitation, surface and soil water conditions, and characteristics of drainage from county watersheds. The following chapter will discuss the major watersheds that contribute to the flood problem in Brookings County.
ENDNOTES


3 Ibid.


6 Ibid.

7 Ibid.

8 Interview with William Lytle, Climatologist, South Dakota State University, Brookings, SD, 17 January 1986.

9 Ibid.

10 Ibid.

11 Walter Spuhler, William Lytle and Dennis Moe, p. 2.
CHAPTER IV

MAJOR WATERSHEDS

The major drainageway in Brookings County is the Big Sioux River and its eastern tributaries. Of the 801 square miles in Brookings County, nearly 55 percent or over 440 square miles are drained by five of fifteen watersheds delineated by the Soil Conservation Service. These five watersheds include: Bruce-Big Sioux River Reach, North Deer Creek, Six Mile Creek, Deer Creek, and Medary Creek. The remaining ten watersheds comprise about 360 square miles within Brookings County but do not contribute significantly to the flood problem (Figure 6).

Peg Munky Run Creek enters Brookings County from Deuel County and joins the Big Sioux River about one-half mile from the Brookings-Deuel County border. Most of the land included within the lower reach of Peg Munky Run is bottomland of the Big Sioux River floodplain that do not cause major problems to agricultural lands.

Spring Creek near Elkton in the southeastern corner of the study area drains about 14 square miles of Brookings County. The watershed begins in Lincoln County, Minnesota, and extends through a corner of Brookings County before joining the Big Sioux River in Moody County. The flood damage potential of this watershed is limited because the headwaters of the creek are gently sloping and do not accumulate large amounts of runoff water.

Battle Creek Watershed has a total drainage area of 15.5 square miles in Brookings county and flows northward from near Madison.
Figure 6 - Watersheds of Brookings County

The bold solid line in the northeast corner indicates the divide that separates drainage into the Minnesota River system to the east and into the Big Sioux River to the west.

1. Bruce-Big Sioux River Reach
2. Peg Munky Run
3. North Deer Creek
4. Six Mile Creek
5. Upper Deer Creek
6. Oak-Fish Lakes Reach
7. Lake Hendricks
8. Deer Creek
9. Medary Creek
10. Spring Creek
11. Brookings-Moody Creek
12. Battle Creek
13. Volga Tribs
14. Oakwood Lakes Area
15. Dolph Creek

The western one-third of Brookings County is drained by what the Soil Conservation Service has named Volga Tributaries in the south, Oakwood Lakes Area in the north, and Dolph Creek Watershed in the extreme northwestern corner. These watersheds are glacial sediment remnants of Cary substage glaciation where drainage has not
developed and runoff water empties into marshes, sloughs and other depressional landforms. High water in this part of the study area normally does not cover roads, farmsteads or cultivated fields which would result in significant damage.

The Big Sioux River channel and floodplain cover approximately 91 square miles of Brookings County, thereby constituting the primary drainageway of the study area. The floodplain averages about three miles wide in its generally southerly path through the county.

In Brookings County, the Big Sioux River has 24 bridges, highways and other roads that act as barriers within the floodplain. Such barriers create backwater, further raising the water level during high water events. During the flood of 1969, flood inundation in the county was called "the flood by mile," where highways and township roads constricted floodwaters backing floodwaters mile by mile.2 Many of the bridges over these roads were old and narrow, and poorly designed to accommodate high floodwaters. During the flood of record in 1969, 27 bridges were washed away, and another 35 were damaged and required replacement or repair.3

North Deer Creek

North Deer Creek watershed has a drainage area of about 78,000 acres or 109 square miles within Brookings County. The runoff water starts in Deuel County and flows into the Big Sioux River about three miles southwest of the city of Brookings. The watershed is about 25 miles long and averages about five miles wide. The land surface in the
upper reaches of the watershed is rolling, then changes to gently sloping and nearly level at the floodplain of the Big Sioux River. The general land use of the watershed is about 77 percent cropland, 19 percent pasture and 4 percent other.\(^4\)

The largest floods in the North Deer Creek watershed covered approximately 6,850 acres, of which about 45 percent is cropland and the remaining 55 percent is either hay or pasture. Small floods do not generally account for significant damage. During extensive flooding, however, roads and bridges are damaged from the loss of surface, erosion of the roadside shoulders, breaching of the road and occasional complete removal of a bridge.\(^5\)

Areas in the upper reaches of the watershed show evidence of sheet erosion that can usually be controlled by local conservation and cropping practices that reduce the velocity of runoff water. There are no large gullies in the watershed, though heavy rains cause rilling in many of the waterways.\(^6\) Sediment from these erosional sources contribute to the sediment load in the Big Sioux River. There are no flood control structures on North Deer Creek. However, about four miles of channel straightening was done in the 1950's to help drain cultivated lands located several miles north of U.S. Highway 14 to the Big Sioux River floodplain.\(^7\)

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**Six Mile Creek Watershed**

Six Mile Creek Watershed extends about 22 miles from headwaters near Toronto, South Dakota, to the Big Sioux River. It drains about
48,500 acres, or 73 square miles of Brookings County. Several channels of Six Mile Creek have developed a wide floodplain that is largely responsible for flood damage in western and northwestern portions of the city of Brookings. The upper portions of the watershed are hilly and well-drained, while the lower reaches are nearly level providing poor surface drainage. The creek enters North Deer Creek about one mile upstream from the confluence of North Deer Creek and the Big Sioux River.

The watershed is composed primarily of crop and grasslands. Cropland exists where the topography is not too severe and where drainage conditions permit. Only the steeper hills and lower poorly drained lands near the channel are retained as grass and pasturelands. Economic pressure on the agricultural community dictates the cultivation of land subject to periodic flooding.

The watershed has been laid out with a typical Midwestern grid system of farm to market township roads. There are 30 road crossings and two railroad crossings in the watershed. U.S. Highway 77 crosses Six Mile Creek in a north-south direction. U.S. Highway 14 Bypass and the Chicago and Northwestern Railway both cross in a general east-west direction. Other township roads do not pose significant obstructions to floodwaters.

The City of Brookings has expanded into the Six Mile Creek floodplain with several permanent homes, industries, businesses and mobile homes subject to periodic flooding. The control of development in the floodplain was not formally regulated by the city until 1978, when ordinances for floodplain developments were adopted.
largest single source of floodwater damage is to urban property in the north and west edges of the city.

There are no flood control structures on Six Mile Creek and little work has been done to relieve flood damages. Some channel straightening was done during construction of Highway 14 northwest of the city.\textsuperscript{11}

In 1970, the Soil Conservation Service prepared a watershed investigation report on Six Mile Creek. The report recommended that two floodwater retarding structures be built, as well as 12 miles of multi-purpose channel improvements for flood prevention and drainage.

**Deer Creek Watershed**

Deer Creek Watershed is a tributary of the Big Sioux River that begins in Lincoln County, Minnesota. It has a total drainage area of about 60 square miles. Nearly 71 percent of the watershed is cropland, 23 percent pasture, and 6 percent other.\textsuperscript{12} The watershed has a gradient of 380 feet over its length of about 20 miles. Deer Creek has its source near Toronto, South Dakota, from which it flows in a southeasterly direction to a Soil Conservation Service earthen dam. This segment of the creek has been designated as the Upper Deer Creek-Lake Hendricks Watershed and empties into Lake Hendricks (Minnesota River drainage). During high discharge periods, about half of the flow drains southwesterly through the Deer Creek channel.\textsuperscript{13} Approximately five miles southwest of Brookings, Deer Creek joins Medary Creek.
The upper portion of the watershed is rolling uplands with steep valley walls and a narrow floodplain. These glacial sediments were deposited by the Tazewell substage during the Wisconsin glacial advance. The lower portion of the watershed lies within the floodplain of the Big Sioux River and is relatively flat and poorly drained.\textsuperscript{14}

Deer Creek has a broad glacial valley with numerous subchannels flowing parallel to the main channel. The floodplain is more than a mile wide and has a gradient of approximately four feet per mile, somewhat steeper than the slope of the Big Sioux River.

The city of Brookings has experienced considerable growth toward the south and east, but only a few developments have extended to the east beyond Interstate 29 and into the Deer Creek floodplain. Several homes are located near Highway 14, about two miles east of Brookings.

Very little has been done within the watershed to relieve flood damages. There are a few scattered levees constructed by farmers to protect fields or farmsteads. Approximately two miles of channel straightening was done by local landowners in the early 1950's near the abandoned Chicago and Northwestern Railway east of the city of Brookings.\textsuperscript{15} In 1966, a plan for watershed protection and flood prevention was developed for the Upper Deer Creek-Lake Hendricks Watershed. This plan included construction of a floodwater retarding structure and several miles of channel improvements.\textsuperscript{16}

\textbf{Medary Creek Watershed}

The Medary Creek Watershed comprises an area of nearly 107 square miles from Lincoln County, Minnesota, through south Brookings
County before joining the Big Sioux River in Moody County. The
topography in the upper portion of the watershed is rolling, while the
remainder of the land is sloping to nearly level within the Big Sioux
River floodplain. The general land use of the watershed is about 72
percent cropland, 22 percent pasture and 6 percent other. The towns of
Aurora, Bushnell and Elkton are located within the watershed.17

Floodwaters have the potential of damaging about 4,300 acres
that are regularly used for cropland. The remaining 2,000 acres are
normally used for hay and pasture. Roads and bridges are severely
damaged during floods primarily from the loss of gravel, erosion of
shoulders and occasional damage to bridges. Gully erosion is a minor
problem in the watershed. Heavy rains frequently cause a rilling type
erosion in waterways.18

There are approximately 9,700 acres of cropland that are poorly
drained either on or adjacent to the main floodplain of Medary Creek.
Approximately 55 percent of this land is used for pasture and 45
percent for cropland. Average crop yields are estimated to be but 60
percent of what these lands are capable of producing, and there is a
tendency to use sloping lands too extensively, thereby aggravating the
erosion problem. Adequate agricultural water management measures have
not been installed because of the frequent flood hazard threat and lack
of adequate outlets.19 (Figure 7).

Floodplain farmers are aware of farming problems in the lower
lands adjacent to Medary Creek and are interested in flood control to
improve the productivity of the poorly drained lands. On their own
<table>
<thead>
<tr>
<th>Name of Area</th>
<th>Area Within Brookings County (Square Miles)</th>
<th>Total Area in Watershed (Square Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Big Sioux River</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolph Creek</td>
<td>11.5</td>
<td>287.4</td>
</tr>
<tr>
<td>Oakwood Lakes Area</td>
<td>98.8</td>
<td>98.8</td>
</tr>
<tr>
<td>Bruce–Big Sioux River Reach</td>
<td>91.3</td>
<td>179.3</td>
</tr>
<tr>
<td>Peg Munky Run Creek</td>
<td>1.1</td>
<td>51.8</td>
</tr>
<tr>
<td>North Deer Creek</td>
<td>109.2</td>
<td>131.1</td>
</tr>
<tr>
<td>Six Mile Creek</td>
<td>73.2</td>
<td>73.2</td>
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<tr>
<td>Upper Deer Creek</td>
<td>27.6</td>
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<td>Deer Creek</td>
<td>59.3</td>
<td>69.8</td>
</tr>
<tr>
<td>Volga Tributaries</td>
<td>147.4</td>
<td>163.4</td>
</tr>
<tr>
<td>Lower Medary Creek</td>
<td>107.4</td>
<td>109.6</td>
</tr>
<tr>
<td>Battle Creek</td>
<td>15.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Spring Creek</td>
<td>14.1</td>
<td>14.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>778.7</strong></td>
</tr>
<tr>
<td><strong>Minnesota River</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oak–Fish Lakes</td>
<td>13.0</td>
<td>48.4</td>
</tr>
<tr>
<td>Lake Hendricks</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>22.3</strong></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>801</strong></td>
</tr>
</tbody>
</table>

Figure 7 - Summary of Drainage Areas in Brookings County

initiative, farmers have straightened the main channel at several locations and have improved the local drainage to some extent. In the preceding chapters, this study has developed the Brookings county flood problem by describing the landscape, climate and weather, and general drainage patterns. In the next chapter, the history of flooding is investigated as a base of information for what might be expected in the future in terms of potential flood hazard.
ENDNOTES


5 Ibid.

6 Ibid.

7 Interview with Don Voogt, Brookings County Drainage Officer, Brookings, SD, 20 February 1986.


9 Ibid., p. 2.

10 Interview with Sherry Neumann, Brookings City Zoning Officer, Brookings, SD, 4 March 1986.

11 U.S. Army Corps of Engineers, Six Mile Creek, p. 9.


13 Interview with Dee Watson, Soil Conservation Service, Brookings, SD, 7 February 1986.

14 Ibid.


16 Ibid.

17 U.S. Department of Agriculture, Appendix, p. 7-1.
18 Ibid., p. 7-2.
19 Ibid.
20 Ibid., p. 7-3.
Flooding is a common natural hazard in Brookings county. The preceding chapters have described the climate and surface of Brookings County that contribute to flooding. This chapter describes many of the high water events during the 50-year period of this study, 1936 to 1985.

The majority of flood events are a result of early spring snow melt runoff. In 1936, the first flood event occurred in early March when heavy snow accumulations melted quickly and raised the water level of county lowlands. This was the largest flood in several years and thousands of acres of crop and pastureland were covered. The water level and areal extent of Lake Campbell, in southern Brookings County, were the greatest they had been in recent years following the drought of the early 1930's in the Midwest. Elsewhere, Edwin Nelson, a farmer north of Brookings lost several calves and pigs when floodwaters covered his property to a depth of approximately three feet.1

In mid-March 1938, the Big Sioux flooded land adjacent to the river channel2 and then rose again during the fourth week of June after runoff from the north and east covered land in the Sioux bottoms.3 In March, 1939, Big Sioux River lowlands were flooded for several miles east of the river. Several farms were nearly isolated by the water.4

On the 19th of July, 1939, rain fell so rapidly that low areas became "running torrents." Water breached Highway 14 in several places.5 The Big Sioux again went over its banks in early April, 1940,
as melting snow and rains brought much needed moisture. Main Street in Volga was covered with water and an older resident said that he had never seen so much water in town at one time.  

A two and a half mile stretch north of Highway 14 was a "lake" in May 1942. Older residents reported that the 1942 flood was the worst between Volga and Brookings in many years.  

Over two inches of rain fell during a 20- to 30-minute rainstorm that flooded local creeks, roadways and farmyards on March 28, 1943. An area south of Aurora and five miles east of Elkton received the largest amounts of rain. Overall damage was light, other than flood waters removing several sections of field fences. During June of 1943, about 5,000 acres of Brookings County were under water following additional heavy rains.  

On June 17, 1946, heavy rains gave rise to two to four feet of flood water in the Brookings downtown business district. The Brookings Savings and Loan, Red Owl Store, municipal telephone office, Salvation Army, Kendall Drug, National Tea, Montgomery Wards, Coles and Prather News all received water damage. Moderate damage and extensive basement flooding were reported in rural Brookings after nearly seven inches of rain fell through the end of June.  

Heavy floods during the springs of 1951 and 1952 inundated several thousand acres in Brookings County. The floods reached the highest levels during the last week of March, 1951, when spring snowmelt water damaged property and caused livestock losses. Three-fourths of a mile length of Highway 14, three miles west of Brookings was under water. Virgil Van Mannen, a farmer four miles west of Brookings, lost 30 pigs while Chris Sorenson lost about 50 chickens.
Sorenson's farm was under two feet of water and Mrs. Sorenson had to be taken by boat to the highway. 12

In the city of Brookings during August, 1951, rainfall exceeded eight and one-half inches, a record, after more than two inches fell on the 30th. Several more inches were reported in outlying towns. Basements in downtown Brookings were flooded and an estimated 4,000 gallons of water were pumped from the cellar of the Montgomery Ward store. Old timers in the Brookings area claim never to have seen as much water in the county as was experienced during 1951. 13

Spring 1952 experienced more high water, flooding highways, fields, barns and cellars throughout much of the county. Residents from the Lake Campbell area claimed they had never seen the lake as high as it was that year. On April 8, 1952, flowing water from Medary Creek covered Highway 77 south of Brookings and a wall of water swept through the north edge of the city from Six Mile Creek. 14 Other low roads near Lake Campbell were also covered by water which fluctuated several inches from day to day. Northwest of Volga, Lake Goldsmith swelled about a mile beyond its normal banks to near the Egbert Meyer farm. 15

The Brookings business district was inundated by high water on May 13, 1956, when nearly one and one-half inches of rain was recorded in 30 minutes. 16 Motorists needed pontoons and youngsters had a holiday in water on July 30, 1952, when the city of Brookings measured about two and one-half inches of rain in 30 minutes. Approximately one and one-half feet of water covered the basement floor of Snort's Barber Shop at the corner of Fifth Street and Main Avenue. Over 20 inches of
Figure 8 - Flood Waters Surround Mobile Homes West of Brookings

Figure 9 - Spring 1985 Runoff Flood near Western Avenue
Sexauer Park is located in the trees in the upper part of the photo.
water was reported in the basement of the municipal telephone building on Fourth Street. 17

A series of heavy thunderstorms hit Brookings County on June 16, 1957. Rainfall totals following the storm varied from one and one-half to eight inches. Kenneth Odland, Brookings County Highway Superintendent, said he had counted 44 bridges or approaches to bridges that had been washed out. Estimates of repairs were reported to be near $25,000 to those bridges and over a million dollars to crops, fences, livestock and farm buildings. Elkton reported water damage to graves in the local cemetery that sank after heavy rains. 18 Passengers in Lowell Peterson's car were nearly swept away by flood waters two miles from Elkton when the auto came to rest across the creek where the bridge had been. Twenty people spent the night at the Joe Wiskur farm, near Elkton, after the raging waters from Medary Creek washed out a bridge. 19

Bruce homeowners and farmers were without several local roads after spring floods in 1960 covered about two miles of county highways. Several farms north and west of town were almost completely covered by water. 20 Snowmelt runoff water raised Lake Goldsmith to a depth of nearly four feet after the lake bed has been farmed the previous year. 21

On August 1, 1961, a heavy deluge of two and three-fourths inches struck many areas of the city of Brookings, causing flooded streets and water on ground level floors and basements of downtown businesses. 22 No damage figures were reported following this flood event.
Rain and melting snow combined to create a major flood in the Big Sioux Valley and county watersheds in late March, 1962. Flood waters crested six inches higher than in 1960, but six inches lower than in 1951. The spring flood of 1962 was the second greatest flood on record since the record flood of 1881.

About two and one-half inches of rain fell in one 24-hour period during the first week of July, 1962. County crops were damaged and basements were flooded within the city of Brookings. That rainfall amount added to the record 21.61 inches of precipitation in the county since January of that year. Those rains knocked down small grains and floodwaters spilled over county highways and roads. Numerous basements were flooded in the eastern part of Brookings and over $200 damage was reported at the Montgomery Ward store in downtown Brookings.

A 24-hour rainfall record that stood for 55 years was exceeded on June 15-16, 1967. During a six-hour period, the National Weather Service recorded 4.35 inches of precipitation. Farmers west of Aurora recorded 17 inches of rain in 15 days during that month.

Record-breaking snow accumulations occurred during the winter of 1968-69. The runoff from the melting snows brought the highest floods ever recorded in this area. Because of the severity of this event, the flood record of 1969 will be discussed in a separate chapter.

Several flood events occurred in the early 1970’s from spring snowmelt and summer rains. Several basements in Brookings were flooded after rains on June 15, 1970, while in Elkton, area residents called that storm the most severe they had seen in many years. The Big Sioux River crested at about 12 feet on March 16, 1972, then rose
again in May, 1972, to flood stage after early rains. In the spring of 1973, the Big Sioux River overflowed its banks as much as one-quarter mile during the first week of March.

Fall floods in Brookings County are uncommon, but two thunderstorms on September 10, 1975, dropped over two inches of rain. Normally, two inches of rain can be adequately drained by the existing city storm drainage system, but leaf accumulations blocked the drains, causing flooding from city water runoff.

A two-inch rain contributed to lowland flooding on March 11, 1977, pushing Six Mile Creek over its banks flooding pastures and farmland. The overflowing creek covered the Jackrabbit Golf Course north of the city, Sexauer Park west of Brookings and covered backyards of homes on Western Avenue, First Avenue and Eighth Street West. Outbuildings and machinery were under water. Six Mile Creek spread out a mile or more covering grasslands west of Brookings where North Deer and Six Mile Creeks converge. Creeks in the Elkton area overflowed their banks because ice and snow remained in the creek beds.

In June, 1977, a record 4.3 inches of rain fell in three hours in the city of Brookings. Storm sewers failed to accommodate the volume of runoff and water levels measured two feet on the 200 block of Sixth Street and Fifth Avenue near the First National Bank.

Local flooding in the Big Sioux Valley near Brookings was reported on March 24, 1978. The flood waters that covered lowland farm buildings were believed to be from Six Mile Creek, as water had not begun to flow in the Big Sioux River at either Watertown or east of Volga.
Flooding again occurred in rural Brookings County during the second week of April, 1979. Over one inch of rain fell on April 11, adding to high snowmelt water in rural fields. 38 On April 16, many fields around Brookings resembled duck ponds and the Big Sioux River crested while covering Highway 16 with six inches of flood water. 39

During June, 1980, nine inches of rainfall was recorded at the SDSU Agronomy farm northeast of Brookings. Rainfall on the 24th set a 100-year record as over five and one-half inches of water fell in a 24-hour period, sending sandbagging crews into action at downtown businesses and many city residences. Brookings County Sheriff, Gordon Ribstein, received a call from Bill Hiermeier of rural Brookings, who reported water up to the window of his car. Several federal, state and township roads were closed because of water running over their surfaces. 40 Damage to property was reported in downtown Brookings, on Faculty Drive and State Street. Cars were stalled all over town, according to Brookings Police Chief Doug Filholm. Unofficial rainfall measurements were seven inches from Aurora, two inches from Bruce, three and one-half inches from White, three and three-quarters inches from Volga and over seven inches two miles south of Brookings. 41 The record rainfall caused considerable lowland flooding along the Big Sioux River with the crest predicted to be 12.5 ft. on June 26, 1980. 42

Rains on July 15 of that same year filled a basement construction site on 12th Street South in Brookings after 2.65 inches were recorded. Four days later, rains again flooded Brookings city streets and an auto was submerged at the railroad overpass on Sixth Avenue South. Police usually barricade that location following heavy
local rains. Areas north of Brookings received 5.25 inches, and 4.4 inches of rainfall were reported south of Brookings.43

Precipitation of nearly three and one-half inches pushed the Big Sioux River over its banks in early March, 1983.44 A year later, the National Weather Service issued a flood warning for lowland areas of Brookings County when the Big Sioux River crested at nearly 11 feet on March 29, 1984.45

Rains during the first two weeks of April sustained highwater levels in the county and washed out several gravel roads. Precipitation accumulations in the county for mid-April approached five inches, or double the normal rainfall average for that time of year.46

Later in 1984, water again inundated floodprone lands of the county after nearly two weeks of steady rainfall. By mid-June the Big Sioux River was three feet over flood stage.47

South Dakota Governor, William Janklow, established a flood disaster team that mobilized state employees from the departments of Transportation; Highway Patrol; Game, Fish and Parks; and Emergency and Disaster Services. These agencies monitored high water in several counties.48 Corn and other crops in Brookings County sustained heavy damage that prompted the Brookings County Commission to apply for disaster status.49 In July, the Farmers Home Administration (FHA) denied relief to Brookings County, one of 23 counties originally submitted for low interest disaster loans.50

Lowlands flooded for the third time in October, 1984, after heavy rains again hit the county. The precipitation during the month was six and one-half inches, the wettest October on record.51
In March, 1985, water saturated soil from the previous fall and rapidly melting snow brought water levels past flood stage on many watersheds of the county. Again, early rains contributed to the high water, with March precipitation at 3.80 inches, compared to an average total of 1.70 inches for that month.  

All of these flood events indicate a consistent flood pattern in Brookings County. However, these floods were significantly less than that which occurred in March and April 1969, the Brookings County flood of record.
ENDNOTES


12 Ibid.


41 Ibid.
CHAPTER VI

THE FLOOD OF RECORD: 1969

Record snow and fewer days of sunshine and record sub-zero cold during early 1969 set the stage for record flooding in eastern South Dakota. Brookings received a record 22 inches of snow in December, 1968; the previous record was 17.8 inches in 1951. Eleven more inches of snow fell during January, 1969, and 29 inches accumulated in February to bring the total snowfall at the weather station in Brookings to 72.5 inches by March 1. The state climatologist reported that the water equivalent in that amount of snow at that date might be expected only once in 100 years.¹

The region received national attention through the news media as cold temperatures, deep snow and strong winds caused many cancellations, postponements and much inconvenience to residents. Snowplows could not keep up with the deep, drifting snows, prompting state officials to request rotary snow throwers from the U.S. military to clear transportation arteries.²

South Dakota Governor Frank Farrar asked President Nixon to declare 32 counties in eastern South Dakota a major disaster area. Brookings County was included in the request which was approved. Additionally, Nixon established "Operation Foresight" to provide federal money to aid flood susceptible communities in preparing for inundation of public facilities, and to authorize the U.S. Army Corps of Engineers to send 100 specialists into the area to prepare for
oncoming high waters. This was the first time federal money ever had been approved for disaster relief before a disaster had occurred.

The National Weather Service began publishing weekly statements on potential flooding in South Dakota near the end of February, 1969. When the flood threat was imminent, daily flood forecasts were issued.

Various county and city agencies held public information meetings and distributed press releases to inform residents of the flood threat. The first local public information meeting was organized by the Brookings County Civil Defense Director on February 6. Other agencies that had representatives at the meeting were the Brookings City and County Commissions, Soil Conservation Service, Agricultural Stabilization and Conservation Service, State Highway Department, Brookings Fire and Police Departments, East Dakota Conservancy Subdistrict, South Dakota State University and the Brookings County Township officers.

Three recommendations were announced at the meeting: (1) contact city and county residents who live in areas where it is likely that flooding will occur and advise them to make plans to evacuate; (2) request that the Civil Air Patrol make frequent spot checks of the county; and (3) ask the Brookings-Lake Telephone system for maps of its area so calls could be made to get moisture conditions at given locations.

The Brookings County Extension office, South Dakota State University Extension Service and Brookings County Civil Defense office issued numerous press releases to the news media in order to keep the public informed on flood information and preparations to reduce the
effects of flood damage. Some of the recommendations issued were to move electrical and gas-operated appliances; plug toilets, sewers and basement drains; and to move propane, fuel oil and gasoline tanks to higher ground.8

Preparations for evacuations were planned then disseminated to those living in flood-prone areas and recommendations were issued to move livestock, feeds and farm machinery. Those rural and urban residents who lived on higher ground were warned of possible isolation for a period of time, and were urged to stock such essential items as medicines, food, drinking water, fuel and clothing. Other warnings included the movement of grain from storage in low areas, removal of pesticides and herbicides that might contaminate water supplies, removal of floatable items, and instructions to watch for rats and other rodents driven from low fields into homes, barns and grain storage bins.9

Brookings Civil Defense officials ordered sandbags that were made available to area residents for approximately 20 cents each. If flooding from surface water breached the sandbags or entered dwellings below the surface of the land, the civil defense recommended flooding basements with clean water to reduce the pressure from outside water and reduce the occurrence of seepage and silt into basements and other below-ground living areas10 (Figure 10).

By mid-March, the city had concerns about the Brookings Municipal Water Plant and Sewage Treatment Plant, both located in the Six Mile Creek flood plain. The U.S. Army Corps of Engineers was asked
Figure 10 - Anticipated High Water Line During Flood of 1969
The shaded area shows the approximate location of the high water line that was anticipated during the spring 1969 flood in northwest Brookings. The original map was published in the February 22, 1969, issue of the Brookings Register.

by the city to assist in providing protective measures for those facilities utilizing federal money allocated for that purpose. Bids were let and a contractor from Sioux Falls was hired to build the dikes. Before construction was complete, the work was terminated because city officials suspected that heavy equipment would damage valves and other connections. The city also removed an old 40-foot
bridge located at the west end of Sixth Street over Six Mile Creek. It was thought that the narrow bridge could not withstand fast-moving water expected from the early 1969 snow melt runoff.\textsuperscript{13}

Temperatures were near normal at the end of March, and some melting had begun to take place. On the first of April, 19 inches of snow was on the ground at the SDSU Agronomy Farm where weather measurements are made. This amount dropped to 16 inches by the third; from the fourth through the seventh, the snow depth dropped to 15 inches as temperatures were in the upper 30's to low 40's. By the eighth and ninth, temperatures raised into the mid-50's without overnight freezing; the remaining snowpack was reduced to a trace.\textsuperscript{14}

The flood waters began building on Sunday, April 6, and continued to rise through April 9. Water from tributaries of the Big Sioux River and runoff water from the river's northern drainage areas pushed the water over six feet above flood stage at the U.S. Geological Survey gauging station near the Brookings-Moody County line. Flood waters in the Big Sioux Valley covered more than 200 square miles of Brookings County, or about one-fourth of the county's total land area.\textsuperscript{15}

Flood waters backed up mile-by-mile through the county when township, county, state and federal road embankments and narrow bridges created backwater. It appeared to release, then back up at the next east-west road embankment before moving south to the next roadway. At one point, waters spread across the Big Sioux River flood plain from the sewage treatment plant near Volga to the west end of the Brookings Municipal Airport. During the flood crest, the Big Sioux River
engulfed Highway 14 west of Brookings, and travel was impossible for several days.  

Civil defense personnel, Brookings City Police, Brookings County Sheriff's Deputies, volunteer firemen, police reserves and National Guardsmen were on duty during the flood crisis. By the morning of April 9, the Brookings Volunteer Fire Department had responded to 10 rescue missions. A Brookings man was helped from his
car after the vehicle had slipped off the road about 4.5 miles north of Brookings.\textsuperscript{17} Six of the ten rescue operations were north of the town of Bruce, all from farm homes. Two other evacuations were made, one west of Brookings near Volga and the other northwest of the Lake Campbell bridge.\textsuperscript{18}

Although most of the city escaped floodwaters, residents of the city caused a nuisance by visiting flooded areas near Eighth Street and Western Avenue where Brookings city workers were constructing a dike to protect the Prairie Bowling Alley. Twenty-seven trailer homes were removed from Melody Manor, west of the city on Western Avenue. They were transported to higher ground near the Brookings Municipal Airport. The Brookings Reserve Police assisted by patrolling the evacuated trailers to prevent looting\textsuperscript{19} (Figure 11).

During the evening of April 9, the flood waters started to recede. Highway 14 west of Brookings remained closed for several days after the flood because railroad ties and other debris littered the highway. Other roads in the county were closed because of damaged or washed out bridges. Sections of gravel roads were eroded and water had removed the roadbed from under oil surfaces on several roads in the county. Interstate 29 was threatened but was not closed by flood waters near the Brookings-Moody County border, south of Brookings.\textsuperscript{20}

By April 12, the flood crisis was over and the Civil Defense office announced that the Big Sioux River could flow over flood stage for several weeks. Dale Brchan, Civil Defense Director, said that although a few livestock were killed, no human lives were lost. He
added, "no one in the county has ever seen that much water; it broke all records, we got out of it lucky"\textsuperscript{21} (Figure 12).

Damage estimates to the public road system in the county were set at about $500,000. In the 18 townships receiving the most damage, 27 bridges valued at $170,000 were washed out by flood waters. Thirty-five bridge approaches were damaged and 85 culverts added to the loss by $26,150. Replacement gravel for eroded gravel roads was valued at

\textbf{Figure 12 - Flood Waters Begin to Recede}

Flood waters begin to recede from the Six Mile Creek and Big Sioux River flood plain during the record flood of April 1969. This photograph was taken over the Big Sioux River, looking east toward the city of Brookings in the upper portion of the photo. The Brookings airport is at right-top. From Roll 69-4, Remote Sensing Institute, SDSU, April 10, 1969.
$78,000.\textsuperscript{22} In the Big Sioux Basin, a colonel from the U. S. Army Corps of Engineers put the damage from the 1969 flood at about $10 million, compared to a total loss of $19 million from 1951 to fall, 1968.\textsuperscript{23}

Flood insurance was largely unavailable after the flood of 1969. In March, 1969, Senator George McGovern asked the Secretary of the Department of Housing and Urban Development (HUD) to expedite implementation of legislative authority to develop a flood control insurance program.\textsuperscript{24}

About the same time, HUD announced the beginning of a $2.5 billion federal program for insuring communities willing to take prescribed flood control measures. Under the program, HUD made flood insurance available for up to $35,000 per dwelling or $60,000 for other structures plus $65,000 personal property coverage. HUD shared the risks with the National Flood Insurance Association in which 97 insurance companies created a $50 million insurance pool.\textsuperscript{25}

Floods of great magnitude, such as the flood of 1969, and others before it, bring to the forefront many flood problems. The next chapter will discuss specific problems related to flood events.
ENDNOTES


3 Ibid.


7 Ibid.


14 Walter Spuhler, William Lytle and Dennis Moe, Climate of South Dakota (Brookings, SD: Agricultural Experiment Station, November, 1971), p. 52.


16 Interview with Jerry Siegel, Manager of East Dakota Conservancy Development District, Brookings, SD, 25 March 1986.

18 Ibid.


20 Ibid.

21 Ibid.


Flooding and flood problems in Brookings County are random events caused specifically by the action of water on land areas that are not suited to high water levels. About one-fourth of the county is susceptible to flood damage. During the past 100 years, the Big Sioux River has flooded more than 80 times. Ten of these floods, including the flood of record in 1969, were general in nature and affected the river basin throughout its 400-mile length. All but one of these floods were caused by snowmelt and ice breakup.¹

The primary damaging agent is water overflowing natural channels and inundating land, utilities, buildings, communications and transportation facilities, equipment, crops and goods that were not meant to operate in or withstand the effects of water. Additionally, debris carried by water batters structures, people and goods. Debris and silt carried by water and left behind as the water recedes act as further agents of damage.²

Loss of life is the most dramatic impact of flood damage. In Brookings County, loss of life is unusual during flooding, but occasionally a life is lost when canoeing for recreation during snowmelt runoff flooding.

Flood problems related to high water are flood frequency, magnitude, rate of rise, seasonality and duration.
Frequency

Floods in Brookings County can occur nearly every year. The occurrence of a flood can be predicted with reasonable accuracy if stream flow data are available for a long period of time. At Brookings, the U.S. Geological Survey operates a gauging station near the Brookings-Moody County border that records the elevation of the Big Sioux River at that location. These records can be used to diagram flood frequency curves where a given discharge can be expected over a period of time, usually years (Figure 13).

![Flood Frequency Curve for the Big Sioux River near Brookings, South Dakota](image)

Figure 13 - Flood Frequency Curve for the Big Sioux River near Brookings, South Dakota
From the Hydrologic Atlas of East Dakota Conservancy Subdistrict.
Magnitude

Magnitude of a flood may be expressed either in its physical or probabilistic characteristics. The physical measures are rate of flow measured in cubic feet per second (cfs), or stage in feet or meters above some reference point. Both of these methods require established and accurate measuring procedures to obtain reliable data. Peak flows for the Big Sioux River have been available since 1954 (Figure 14).

<table>
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<th>Gauge Height (ft)</th>
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<th>Date</th>
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Figure 14 - Big Sioux River Peak Flows: 1954–1985
Recorded at gauging station 06480000 near Brookings, South Dakota.
The probabilistic measure is a statistical method of showing various magnitudes of flow; it also states the probability that a given flow will be exceeded. Under this procedure, an imaginary line is drawn on an adjacent stream or riverbank to illustrate the general elevation at which a given flood might be expected to reach in a period of time. For example, near the channel, waters might rise to a point every two years. At a slightly higher location, that level might be expected to be reached one in five or ten years. Other lines can be drawn to show the peak magnitude at a 25, 50, 75, 100 or even 500 year flood.

**Rate of Rise**

Rate of rise is the time from flood stage (zero damage stage) to flood peak and can be an indication of the intensity of the flood. The period between flood stage and flood peak is an adjustment time for those affected by flooding to initiate activities to lessen the damage. In most cases, people will not respond to the danger of flooding until at least flood stage, thereby making this a critical period. There is a relationship between the nature of the drainage basin and the flood water rate of rise. Upstream areas will have a more rapid rise and shorter duration of high water than will downstream areas.

**Seasonality**

Seasonality is one of the most significant factors for agricultural damage. The flood hazard economic impact is higher when
flood waters damage or destroy crops during the growing season than if floods cover agricultural lands early, such as during snowmelt. In Brookings County, flooding is more common during snowmelt when crop and other damage is less significant. Growing season floods, however, can occur in any month from May through October. Such floods increase the economic loss on floodplain or adjacent lands that are used for agricultural production.

Duration

The period of inundation for floods can vary from a few minutes to several weeks. The amount of time that flood waters cover a particular area is correlated to the rate of rise and fall of the maximum height of the water. Flood duration is dependent upon the source of runoff, slope and surface conditions, and the nature of obstructions and man-created controls, such as reservoirs, levees and channelization.

In agricultural areas, damage involves the inundation of land accompanied by erosion or loss of crops. Water damages structures, farm equipment and stored materials, such as feed, seed and fertilizer.

Urban facilities are subject to water and force damage to buildings of all kinds, including public facilities, utilities, transportation routes, homes, businesses and open space. Machinery, manufactured goods and household furniture can all be damaged by water, debris and silt.
Indirect flood problems are generally associated with health and general welfare. Those aspects of culture such as scenic values, recreation and wilderness preservation should also be considered. Public health services are subject to greater pressure when transportation, utilities and especially water supplies are disrupted. Contamination and pollution are more likely. Stagnant water can have an impact on food sources and shelter, both of which can affect the health conditions within the flood area.\(^7\)

The social impact of flooding may be felt at each of five levels: the individual, family, organization, local community and the region. A flood may disrupt the family unit by threatening the economic security, or causing death or injury to family members.\(^8\)

In many ways, the communities suffer the most serious effects of flooding. Community buildings, schools and public services are damaged, and the destruction of private property results in a diminished tax base. Marginal businesses damaged by flooding may not decide to rebuild in the community causing temporary or permanent loss of revenues for the community and personal income from workers.\(^9\)

In Brookings county, early spring flood waters normally destroy fences and damage pastures and cropland, thereby slowing or temporarily halting spring field preparation. The flood may significantly reduce the opportunity for maximum crop yield. Severe growing season thunderstorms can ruin row crops, small grains and pasture, resulting in catastrophic loss of income. During the current fragile economic climate of agriculture, flood losses can force farmers to avoid the risk of planting marginal lands which could reduce income, thereby
possibly forcing farmers to leave the land. This would have a very negative impact on the future of small rural towns and villages.

Weeds and insects are secondary problems of flooding in Brookings County. During high water in early spring, weed seeds that were dormant over the winter are transported by water to wetlands, sloughs and cultivated fields in or adjoining floodplains of the Big Sioux and its tributaries. After the flood waters recede, the seeds are deposited in wet, rich alluvial soils that offer an excellent environment for germination. Weeds that pose significant problems for farmers include Canada thistle, cocklebur, velvet leaf and wild cane. Weed growth is fast because of lack of competition from other plants that were covered by water and weather conditions in spring which are favorable for weed growth.10

Flooding also promotes a higher occurrence of insect infestations, especially on lands where the surface water remains after the high water has receded. Among the insects that are more prevalent following high water are mosquitoes; various varieties of gnats, especially the buffalo gnats; black flies; and cutworms. These types of insects tend to migrate into areas that are climatically suitable for survival, and acquire food from cultivated crops, weeds, grasses and soil. Another problem occurs when standing water increases numbers of biting flies and other insects where eggs are deposited on calm, warm waters that are normally present following flooding of low-lying fields. During a growing season when accumulated water is available, generation after generation of these insects develop to become a nuisance to farmers, livestock and the urban population.11
Flooding also has an impact on wildlife and rough fish populations in county lakes. Wildlife is least affected by flooding during snowmelt as most species leave the wooded floodplain for cover and higher ground. Later, flooding can damage nesting areas and destroy pheasant and other eggs as was evidenced in 1984 when flood waters rose in May and June. The biggest problem during flooding affects Brookings County wetlands, sloughs and lakes when rough fish such as carp, buffalo and bullheads move with high waters into lowlands, sloughs and lakes. These fish degrade recreational fishing, disrupt the fragile slough ecosystem and create a less desirable aquatic environment.

An additional problem in Brookings County is a high water table. High ground water levels occur when surface water is unable to percolate through an impermeable layer beneath the land surface. This impermeable layer is usually clay which resists percolation to greater depths and acts as a shield forcing water to move laterally through the ground. As water accumulations build on top of this barrier, the ground water level raises near or even to the surface. Houses and other buildings that are built into the ground often become surrounded by water-laden soil, forcing water through openings or cracks in basement floors or foundation walls.

The high water table can rise as much as six or seven inches after only one inch of rainfall. The water pressure from the high watertable has caused foundation walls to collapse when construction of those walls was not adequate. Methods used to reduce water in basements and other subterranean structures include waterproofing the
foundations, installing a sump pump or adding tile around the outside of the foundation. 13

Many problems are associated with the flood hazard in Brookings County. Water has the potential of killing or causing injury, destroying homes, cultural facilities and leaving standing water that creates an opportunity for animal and human sickness that can extend for weeks or months after the flood waters recede.

Efforts by local, state and federal agencies to reduce the occurrence and effects of flooding are discussed in the following chapter.
ENDNOTES


3 Ibid., p. 267.

4 Ibid.


6 Gilbert F. White, p. 268.

7 Ibid., p. 266.


9 Ibid.

10 Interview with Leon Wrage, Extension Weed Specialist, South Dakota State University, Brookings, SD, 27 March 1986.

11 Interview with Ben Kantack, Extension Entomologist, South Dakota State University, Brookings, SD, 11 July 1986.

12 Interview with Spencer Vaa, Brookings County Conservation Officer, Brookings, SD, 18 March 1986.

13 Interview with Chuck Ullery, Extension Water Specialist, Brookings, SD, 18 March 1986.
CHAPTER VIII
EFFORTS TO MINIMIZE FLOOD HAZARDS

Efforts to reduce flooding and flood losses in Brookings County have been coordinated by agencies at the local, state and federal levels. Locally, both the Brookings City and County Commissions receive flood-related recommendations from the City and County Planning Commissions, the County Drainage Officer and the Civil Defense Coordinator. At the state level, county flood information is coordinated by the South Dakota Department of Water and Natural Resources, Emergency and Disaster Services, Extension Water Specialists and the East Dakota Water Development District. The U.S. Department of Agriculture Soil Conservation Service, U.S. Army Corps of Engineers, U.S. Geological Survey and National Weather Service are involved in flood related activities at the federal level.¹

When evaluating the frequency, seasonality and extent of flooding, specific efforts to solve flood related problems have been actively considered only within the last two decades in Brookings County. Prior to 1969 efforts were primarily directed toward flood control. Since the record flood of 1969, however, rural and urban property owners have sought solutions to floodplain management, improving flood warnings and securing flood insurance.² Soil Conservation Service technicians encourage a variety of methods to reduce the effects of runoff water following early spring snowmelt and summer convectional thunderstorms. In the upper reaches of most watersheds, water runoff can be reduced with inexpensive land
management techniques such as contour farming and terracing. Vegetation roots and cover hold rain water, reducing the rate of runoff. Dugouts have been used satisfactorily to collect and retain runoff water. Dugouts are small excavated catch basins that are normally built in lower areas of fields to retain water for watering livestock.  

Several studies have been completed on two major watersheds in Brookings County. The U.S. Army Corps of Engineers prepared two flood information reports on Six Mile Creek and Deer Creek for the City of Brookings and the South Dakota Water Resources Commission. The reports were prepared to determine the flood hazard potential and make land use and other land management decisions.

The reports included a brief flood history of the watersheds and the estimated areal inundation that could be expected from a 100-year flood and the estimated greatest flood that could be expected. These were called the Intermediate Regional Flood and the Standard Project Flood, respectively. The reports included profile maps of a study area within the watersheds near the City of Brookings to illustrate the estimated level of flooding during an Intermediate Regional and Standard Project Flood.

The Soil Conservation Service (SCS) has proposed several projects in Brookings County to reduce flooding on the Big Sioux River and its tributaries. In 1972, the Soil Conservation Service and U.S. Army Corps of Engineers proposed a 15-mile lake from an 8,300 foot long, 79 foot high dam near the town of Flandreau in Moody County. The lake would extend approximately to near Lake Campbell in Brookings.
County, covering about 12 square miles. Local opposition from landowners, local businesses and county officials was strong; they concluded that too much valuable crop and pastureland would have been taken out of production and that the lake would be a water storage facility for the City of Sioux Falls, doing little to reduce flooding in upstream watersheds. Planning for this project was eventually discontinued.6

Two flood water retarding structures were planned near White in northeastern Brookings County by the Soil Conservation Service in early 1974. Both sites were proposed within the Six Mile Creek floodplain, one north and the other about two miles south of White. The northern structure was designed to be a 350-acre recreation and flood retarding facility. It was estimated that both dams would account for a 42 percent reduction in peak flood flows in the Six Mile Creek floodway north and west of the City of Brookings.7 These two projects were not completed, primarily because further investigation showed an insufficient cost-to-benefit ratio.8

In 1974, the Soil Conservation Service dedicated a watershed project that took over 16 years to complete. The Upper Deer Creek-Lake Hendricks Watershed project cost about $300,000 and included channel improvements on drainageways on 11,000 acres in the extreme northeastern corner of the county. The project was developed to reduce flooding on Lower Deer Creek that joins Medary Creek before entering the Big Sioux River. After the installation of a dam and a small reservoir, runoff water could be diverted into Lake Hendricks to help
stabilize the lake level and eventually would drain into the Minnesota River system.9

The City and County of Brookings sponsored research and a report entitled "Hydrology Analysis and Preliminary Alternates for Storm Drainage from the City of Brookings South to the Big Sioux River," that was completed in 1985. The need for this study was due to the expansion of the city to the south where there had been a history of water runoff problems, high water table and poor drainage. This seven and one-half square mile area generally has a low gradient and nearly two-thirds of the area is within the Big Sioux River floodplain. The land within the study area is subject to flood backwater from the Big Sioux River during snowmelt and after heavy local rains.10

The study was designed to provide for an organized drainage plan to alleviate blocked drainage, to evaluate existing drainage structures, to investigate the occurrence of flooded basements from flood backwater and high water table and to identify drainage and water problems that have caused related problems to landowners in the study area.11

Improvements recommended in the study provided for the construction of an open channel drainage ditch to carry storm water from the southern part of the city near the Camelot Square Addition and a means for draining the lower part of the study area during periods of high water. The drainage ditch was proposed to be either a grassed waterway or built of some other nonerodable material.12
Another agency that is involved in flood management is the East Dakota Water Development District with headquarters in Brookings. The South Dakota Legislature established six water development districts within the State of South Dakota in 1984 to assist property owners in the conservation, management and development of water resources. The Brookings office serves nine and one-half counties in the Big Sioux River Basin. Additionally, the Brookings office coordinates a program that was initiated in 1966 to identify historical flooding of the Big Sioux and its tributaries. There are 65 high water marks placed throughout the county. The purpose of the program is to provide flood crest information for use in planning improvements in areas affected by flood flows (Figure 15).

Figure 15 - Example of a High Water Mark
This high water mark used by the East Dakota Water Development District is located northeast of the City of Brookings on Six Mile Creek and recorded the crest of the 1969 flood on April 7, 1969.
Flood Warnings

More effective flood warning would promote a significant reduction in the social disruption and damage to structures and their contents during periods of flooding. Until recent times, there existed a gap in regard to flood forecasting. During the flood of 1969, for example, adequate warning was given up to the flood event, but floodplain residents did not realize the scope of the impending inundation until it was too late. The Brookings County Emergency and Disaster Coordinator has established improved flood warnings for the county as one of his goals.  \(^{15}\)

The Soil Conservation Service is assisting states in developing plans for a flood warning system. The agency is providing technical assistance to local officials by providing flood inundation maps, flood evaluations and assistance in floodplain management.  \(^{16}\) In the future, technological advances no doubt will enhance the capability of early warning for flood flows. The National Weather Service (NWS) has developed an automated flood warning system that utilizes microcomputers to upgrade data collection systems of floodwaters. The system that is currently being tested is called ALERT (Automated Local Evaluation in Real Time), as part of a pilot project. Radio messages from monitoring equipment transmit precipitation and river levels to a National Weather Service River Forecast Center. The data are processed then relayed to local flood warning stations.  \(^{17}\)

The National Oceanic and Atmospheric Administration (NOAA) meterologists have tested a Geiger counter to predict flooding in the
Midwest where the water content of the accumulated snowpack has a great influence on spring runoff flooding. This technique involves the use of an airborne Geiger counter that measures natural radiation from the earth, primarily from the upper eight inches of the soil. Both snow and soil moisture weaken the reflected radiation as it passes through the soil and snow. From these readings, researchers can determine how much water is in the snow, available for spring runoff. In the past, the water content from a snowpack had to be measured on the ground. Due to the large areas within many of the drainage basins, funding was not adequate to determine the amount of water in the accumulated snows. It is thought that the NOAA developed procedure for determining the water content of the snow will provide a faster and more accurate picture of the water content of the snowpack, increasing the accuracy of flood forecasting, thus reducing loss from early spring runoff flooding. 18

**Insurance**

Over the last 30 years, the federal government has assumed a major role in easing the impact of flood damage on individuals and communities. The National Flood Insurance Program (NFIP) was established by the National Flood Insurance Act of 1968 and made federally subsidized flood insurance available to property owners in flood prone areas that had previously been unable to obtain flood insurance coverage. Flood insurance does not reduce flood damage; rather it spreads the economic loss over a larger segment of the
Figure 16 – Flood Zone Map for Brookings County

The shaded area represents areas within the county that are subject to flooding in a 100-year flood. Information for the map was adapted from the 1977 Flood Hazard Boundary Map prepared by the U.S. Department of Housing and Urban Development.

property is in an area of flood hazard, and ensures that those who occupy the areas of special flood hazard assume responsibility for their actions.22

Many agencies at various levels of government have been directly involved in reducing losses that are attributed to the flood hazard. The next chapter will offer conclusions on this study of flooding in Brookings County from 1936-1985.
1 Interview with Lonnie Bayer, Brookings County Civil Defense Coordinator, Brookings, SD, 21 March 1986.

2 Interview with Sherry Neumann, Brookings County Zoning Officer, Brookings, SD, 11 April 1986.

3 Interview with Dee Watson, Soil Conservation Service, Brookings, SD, 7 February 1986.


8 Interview with Dee Watson, 7 February 1986.


11 Ibid., p. III-2.

12 Ibid.

13 Interview with Jerry Siegel, Manager East Dakota Conservancy Water Development District, Brookings, SD, 25 March 1986.


15 Interview with Lonnie Bayer, 21 March 1986.


Flooding in Brookings County over the 50-year period of this study probably has not been any more or less severe than during the preceding 1,000 years. The impact of flooding, however, has changed significantly. As humans have altered the physical landscape to meet the needs of civilization, the natural movement of water has been disrupted. Where water has challenged human cultural activities, economic loss has resulted. If there was no encroachment onto land susceptible to flooding, there would be no damage, no losses and no problems.

As the last Pleistocene glacier receded, water began eroding the land to form natural drainageways. In Brookings County, the runoff water flowed in three distinct patterns: first, in the Minnesota River Lowlands, the drainageway finally empties into the Mississippi River system; second, the greatest percentage of the county is drained southward by the Big Sioux River and its major tributaries; finally, there are areas in the western one-third of the county where no specific drainageways have developed and this part of the county drains into lakes, wetlands and sloughs.

The most severe flooding problems in the study area are located adjacent to and within the active floodplains of the Big Sioux River and its eastern tributaries: Six Mile Creek, North Deer Creek, Deer Creek and Medary Creek. Urban flood damage coincides with developments on the western edge of the town of Bruce in the Big Sioux River
floodplain and north and western Brookings in the Six Mile Creek floodplain.

The climate has significant impact on the flood problem in Brookings County. Long, cold winters and accumulated snows release water in March or April, causing lowland flooding on an average of about eight in ten years. The most extreme floods result from a decaying snowpack in combination with early spring rains.

The seasonality or timing of flood events has a direct relationship on the extent of damage by flood waters to agricultural crops. Early spring snowmelt flooding in the Big Sioux River floodplain and its tributaries normally does minimal damage to the land, but often washes out fences and poorly constructed township roads and can cause some damage to structures located within the floodplains. Urban flood problems during early season snowmelt are usually more of a nuisance than a major factor contributing to economic loss. Growing season convectional thunderstorms that produce intense rainfall over a brief period of time are responsible for the greatest loss to both rural and urban property owners. Heavy runoff has the potential of washing away row crops and small grains in areas of low fields. In urban areas, heavy rains overtax the drainage systems constructed for "average" rainfall amounts. Urban flooding has greater potential for damage because of the close proximity of the population, structures and facilities.

Record snowfall during the winter of 1968-69 set the stage for the flood of record in Brookings County. Flood waters spilled over the banks of the Big Sioux River and its tributaries, covering an estimated
200 square miles, or about one-fourth of the total land area of the county. Although high waters were anticipated, and many agencies distributed flood warnings, ten evacuations were performed by rescue teams. Flood damage was heavy in many areas, and a total of 27 bridges, 35 bridge approaches and 85 culverts were destroyed by flood waters, at a cost of nearly three-quarters of a million dollars.

Many problems are associated with flood waters, but the most catastrophic would be the loss of human lives. Although the county has experienced many floods over the period of this study, no record was found of any loss of life as a direct result of flood waters. The extent of damage is dependent upon flood frequency, magnitude, rate of rise, seasonality, duration and location in relationship to human settlement and land use.

Efforts to reduce losses from flooding have been directed by agencies at the local, state and federal levels. Historically, these agencies have focused their attention on the control of flood waters. Recently, however, efforts have been directed toward the improvement of floodplain management, research on more accurate flood warnings and securing flood insurance.

Nearly seven percent of the total land area of the nation and 25 percent of Brookings County are subject to frequent or occasional flooding, yet rural and urban cultural activities continue that result in flood loss. Humans cannot totally control flood waters; rather we must learn to live with them and attempt to minimize their hazard.
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