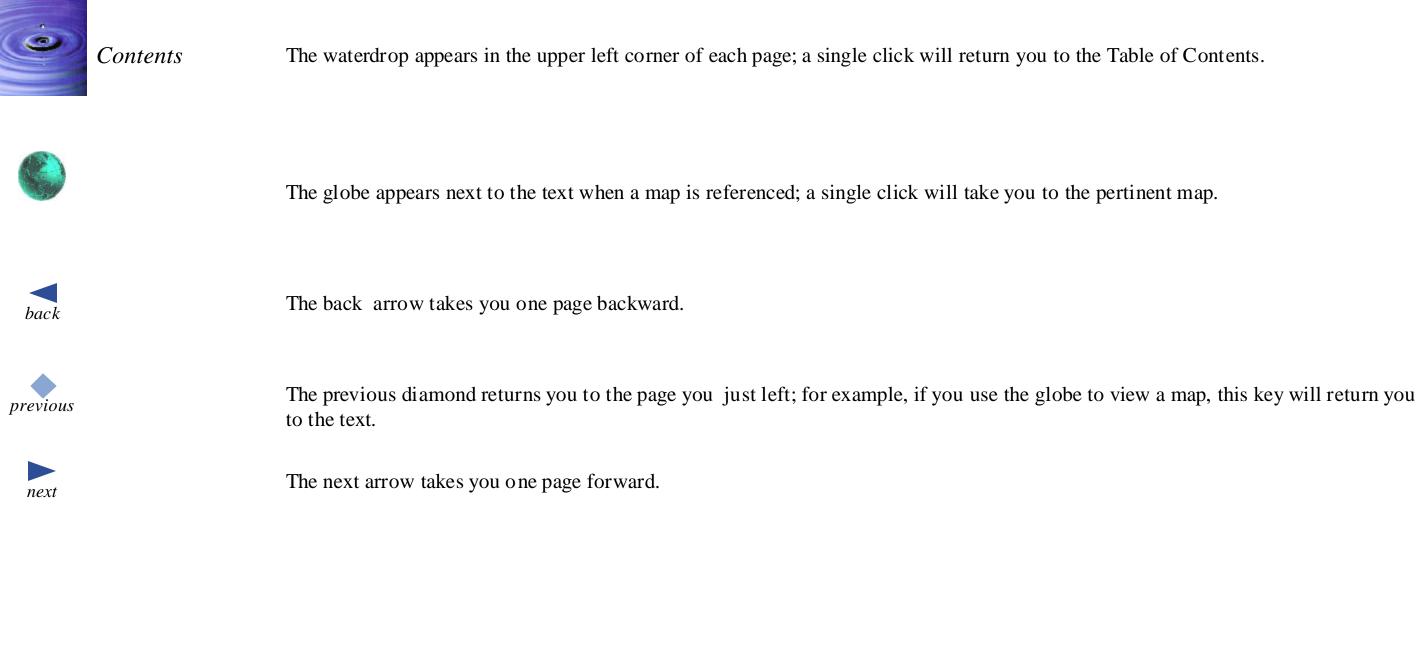


GEOGRAPHIC INFORMATION SYSTEMS DEPARTMENT OF LANDSCAPE ARCHITECTURE UNIVERSITY OF MINNESOTA DATA COMPILED AND MAPPED IN THE DEPARTMENT OF LANDSCAPE ARCHITECTURE AT THE UNIVERSITY OF MINNESOTA. FUNDING FOR THIS WORK WAS PROVIDED BY A GRANT FROM THE ST. CROIX WATERSHED RESEARCH STATION OF THE SCIENCE MUSEUM OF MINNESOTA



## Navigating the Atlas

The following symbols have been added to this virtual version of the Atlas of Watershed Structure in Browns Creek and Valley Creek Basins. These navigational icons are to assist you, the reader, in finding your way around the Atlas and are only visible on-screen; they will not appear if the atlas is printed.



## An Atlas of Watershed Structure in the **Browns Creek and Valley Creek Basins**

This atlas was created by the Department of Landscape Architecture at the University of Minnesota as part of **Objective 2** for a project entitled "Relation of Hydrology to Land-use and Other Spatial Data in the Browns Creek and Valley Creek Watersheds." The project was undertaken by the St. Croix Watershed Research Station of the Science Museum of Minnesota with funding provided by the Twin Cities Water Quality Initiative of the Metropolitan Council.

An inter-agency working group assisting the Valley Branch Watershed District Citizen's Advisory Committee provided valuable insight on the organization and usefulness of the information compiled for the atlas. Special thanks are extended to Julie Westerlund, Metro Trout Stream coordinator for the Minnesota Department of Natural Resources (MNDNR) and Jason Moeckle, fisheries biologist with the Metropolitan Division of MNDNR.

Jim Almendinger, project manager for the St. Croix Watershed Research Station, also provided insightful commentary on information contained in the atlas.

**Geographic Information Systems Department of Landscape Architecture University of Minnesota** 

The geographic information contained in the atlas was compiled by David G. Pitt, Rhonda Bell, Diane Whited and Steve Roos. The atlas was written by David G. Pitt. Rhonda Bell and Steve Roos produced the maps, graphics and text layout for the atlas.



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## INTRODUCTION

The Atlas of Watershed Structure in the Browns Creek and Valley Creek Basins discusses the physical, hydrologic and land cover characteristics of the land area contained within the Browns Creek Watershed District and a portion of the Valley Branch Watershed District. The districts are located in central Washington County, Minnesota. Both districts relate to streams that flow into the St. Croix River, a component of the National Scenic and Recreational River System. The land area contained within each district includes the watershed or land area that contributes directly to flow in the respective streams. The districts also include land area outside the directly contributing watersheds because these areas are believed to be hudrologically connected to the streams via sub-surface flow.

The Atlas presents information pertaining to physical characteristics of the watershed districts including geology, topography and soils. The Atlas discusses hydrologic characteristics of the watersheds, examining surface drainage patterns in the two watersheds as well as hydrologic relationships within the watersheds' soils and geologic material. Finally, the Atlas presents information relating to land cover within the two watersheds. The Atlas discusses the distribution of these phenomena within the contemporary patterns of the two watersheds, and it also discusses the historical evolution of these patterns.

## **Purpose of the Atlas**

The Atlas is part of a series of products created for the Twin Cities Metropolitan Council under a project entitled "Relation of Hydrology to Land-use and Other Spatial Data in the Browns Creek and Valley Creek Watersheds." Undertaken by the St. Croix Watershed Research Station of the Science Museum of Minnesota and the Department of Landscape Architecture at the University of Minnesota, the project had three objectives:

- a) to compile and summarize hydrologic flow and water quality data for the two creeks over the 1998 and 1999 calendar years.
- b) to compile geographic information pertaining to physical, hydrologic and land cover structure of the two watersheds.
- c) to examine relationships between hydrologic and water quality measures within the creeks and structural characteristics of the watersheds contributing to the creeks.

The Atlas of Watershed Structure in the Browns Creek and Valley Creek Basins represents a presentation of information compiled to characterize the watersheds' physical, hydrologic and land cover structure.

## Geographic Extent of the Atlas

### Valley Creek

When asked to identify the location of Valley Creek, most people would undoubtedly point to a creek and its tributaries that enters the St. Croix River immediately to the north of Afton, Minnesota. Almost all of the creek's tributaries are identified on USGS 7-1/2 minute Topographic Quadrangle maps as being within the political jurisdiction of the City of Afton. The perennially flowing portions of the stream are entirely with the city's boundaries. As defined by the land area over which the Valley Creek Watershed District has management jurisdiction, however, the watershed extends well beyond the political boundaries of Afton. The Watershed District includes large portions of the City of Lake Elmo, and it extends in a northwesterly direction toward White Bear Lake.

The Valley Creek watershed has an ambiguous definition. This ambiguity is produced by surficial geologic conditions that affect surface drainage patterns within the watershed; management of the watershed's surface hydrologic resources also affects the watershed's definition. A large portion of this area is within the ground water basin of Valley Creek. Along with surface runoff from the immediate watershed of the stream, this area apparently contributes to the base flow of the Valley Creek.

Most of the landscape within the Valley Creek Watershed District that is located north of the Interstate 94 highway, and a portion of the watershed south of the highway, contains poorly developed surface drainage patterns. Within these locales, it is difficult to predict the exact pattern of surface flow since many of the streams, wetlands and ponds in the area have no apparent outlets. In constructing Interstate 94, the Minnesota Department of Transportation (MnDOT) altered surface drainage on the northern side of the highway so that drainage now flows into a detention basin that discharges into the St. Croix River. In the portion of the watershed possessing poorly developed surface drainage on the southern side of I-94 (i.e. the Falstrom Lakes area), MnDOT installed a pipe and valve system. This engineered drainage system allows floodwater accumulating in emergencies to pass under the higway and enter the drainage system on the northern side of the highway. Taking into account the complexities of natural and human-influenced surface hydrology of the Valley Creek Watershed District, the maps contained in the Atlas pertain to those sub-basins defined by the District that are located south of Interstate 94. The combined spatial extent of these basins includes a large portion of the City of Afton, portions of the West Lakeland Township and the northeastern corner of the City of Woodbury. In total, this area amounts to 4505 hectares, or approximate-ly 11,130 acres.

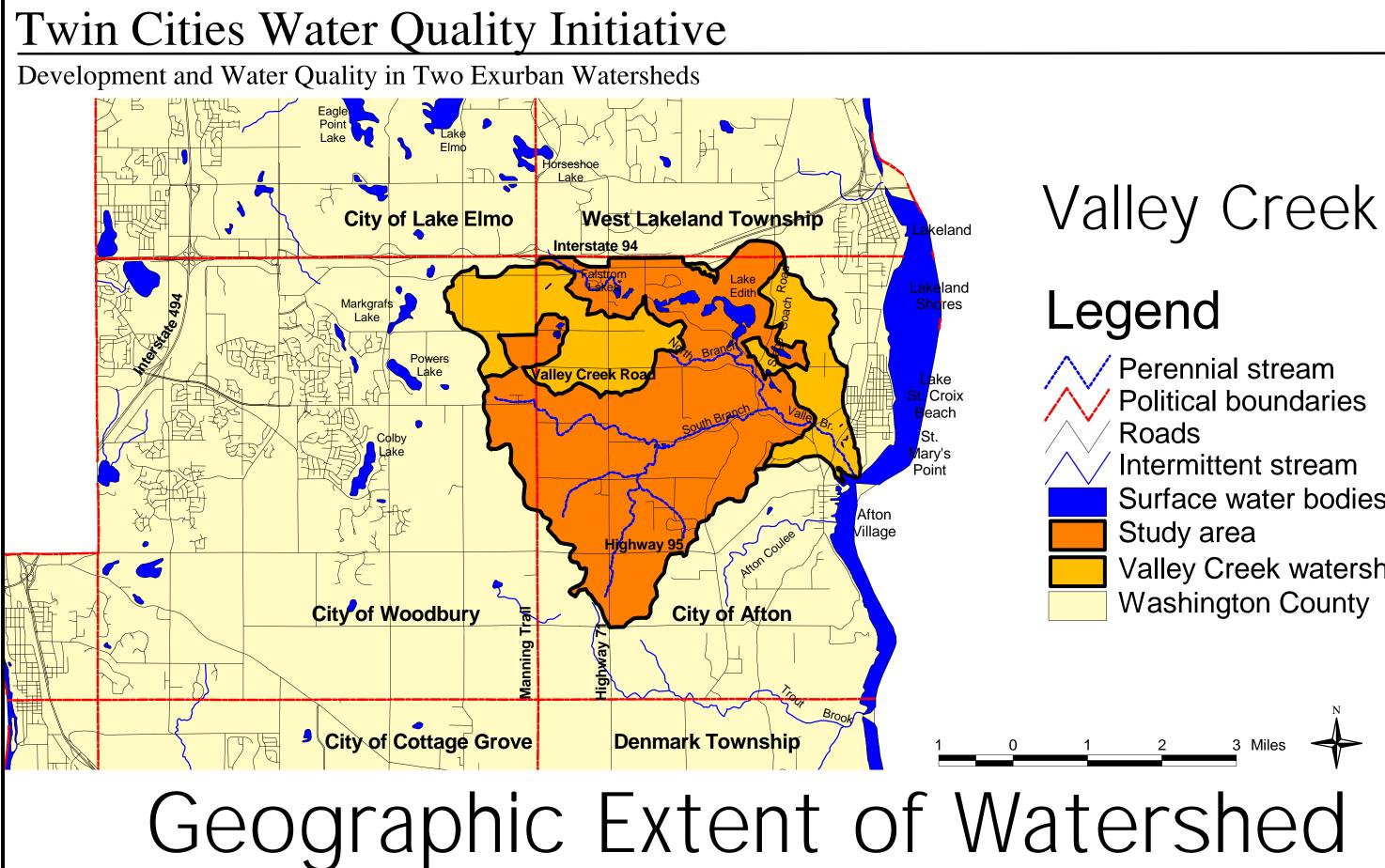
The map entitled "Geographic Extent of Watershed: Valley Creek" illustrates the geographic extent of the portion of theValley Creek Watershed District that is mapped in the Atlas.

### **Browns** Creek

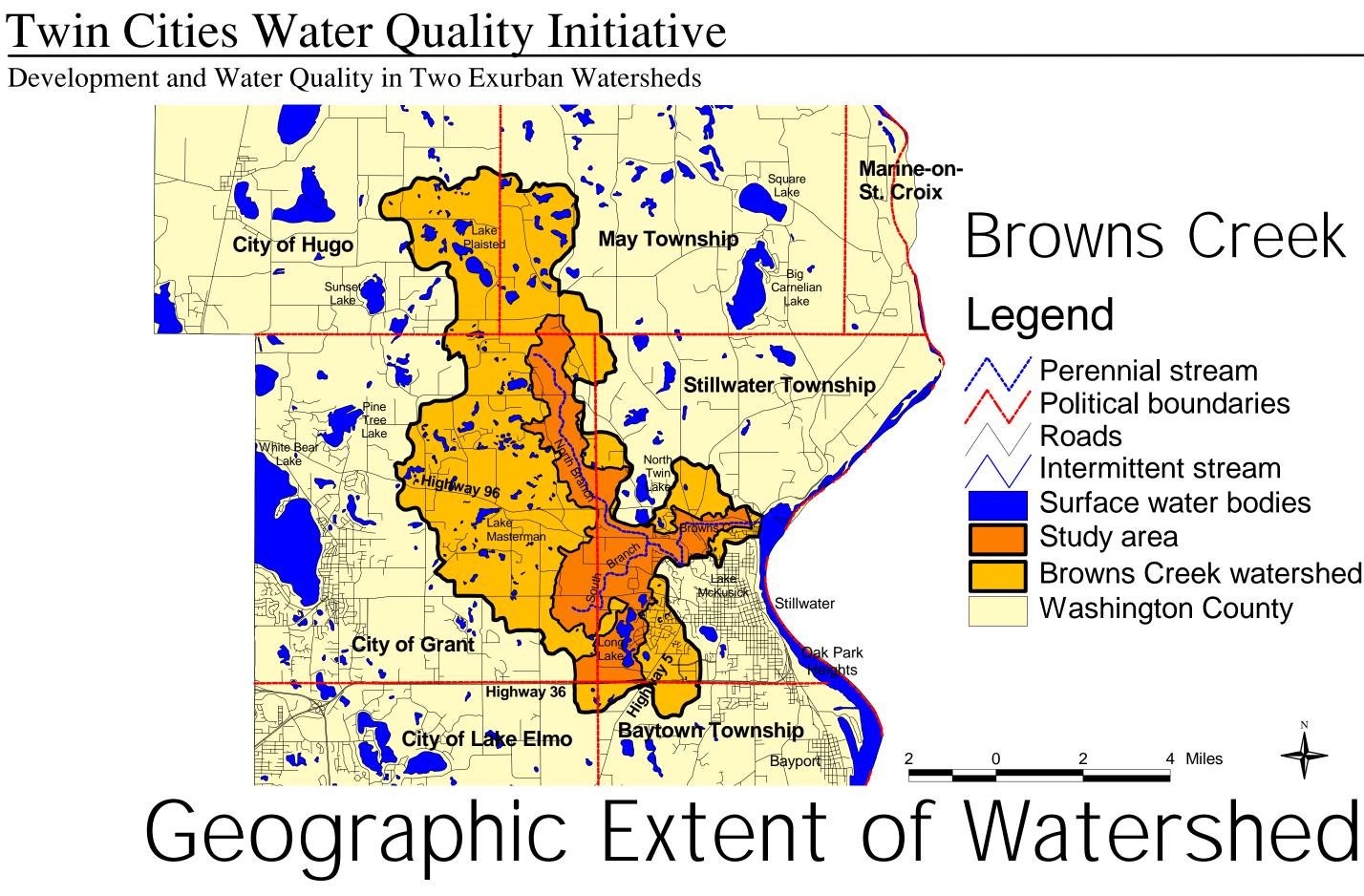
The legal definition of the Browns Creek Watershed District contains three appendages that extend in easterly, southerly and northerly directions from the intersection of Highways 64 and 15, on the Grant-Stillwater Township boundary in Washington County. These appendages are attributable to the division of the creek into three portions, the mainstem, the North Branch and the South Branch. Each of these components has a different compass orientation as it flows from its headwaters areas into the St. Croix River. The North Branch flows in a southeasterly orientation from its headwaters area near Withrow through the northeastern portion of the City of Grant. The South Branch flows from its headwaters area located in Oak Park Heights in a northeasterly orientation. The North and South Branches come together at a point just south of Highway 64 and west of Neal Avenue in Stillwater Township. From this point the mainstem of the creek flows generally in an easterly direction until it joins the St. Croix River at the "Boom Site" located just north of the Stillwater city boundary.

Land area contained within the Browns Creek Watershed District that is not within the stream's watershed includes the central and northern portions of the City of Grant, the southeastern corner of the City of Hugo, and the southwestern corner of Forest Lake Township. In total, the Browns Creek Watershed District includes 7479 hectares, or approximately 18,480 acres.

The map entitled "Geographic Extent of Watershed: Browns Creek" illustrates the geographic extent of the Browns Creek Watershed District as mapped in the Atlas.



- Surface water bodies
- Valley Creek watershed
- Washington County



## **Compilation of the Atlas**

The geographic information contained within the atlas was compiled from a number of sources. The Data Dictionary contained in the appendix to this atlas outlines the sources and procedures used in compiling each of the atlas' map themes.

The compilation, processing and analysis of the themes as well as the preparation of the maps used geographic information system (GIS) software produced by the Earth Systems Research Institute (ESRI) of Redlands, California. The ESRI product known as Arc-Info<sup>TM</sup> provided the technology for compiling, processing and analyzing spatial information, while ESRI's ArcView<sup>TM</sup> product provided the technology for producing the map displays contained in the atlas. Both systems operated on a Dell Dimension XPS T850r<sup>TM</sup> platform using a WindowsNT<sup>TM</sup> operating system, and map production occurred on a Hewlett Packard DeskJet<sup>TM</sup> 1220c color inkjet printer.

## Structure of the Atlas

The atlas presents physical and cultural characteristics from both a thematic and a historic perspective. Hopefully, the reader will obtain a sense of what is contained within each watershed and how these features came into existence. The atlas also seeks to chronicle the complex forces--some similar, some dissimilar-- and their divergent impacts on the two watersheds. Material presented in the atlas is organized into the following topical areas:

- a) the location of sampling sites used in gathering the surface water quality data, the location of the wells from which ground water samples were taken, the location of the basins contributing runoff to each of the surface water quality sampling sites, and the location of the traces along which ground water is speculated to flow into the sampled wells.
- b) the evolution of the watersheds' bedrock and surface geology;
- c) the development of the watersheds' surface drainage patterns that have cut down into the watersheds' geology;
- d) the effects of the geologic and hydrologic processes on creating topography within the contemporary landscape of the watersheds;
- e) the development of vegetative cover within the watersheds;
- f) the evolution of soils in different landscapes of the watersheds;
- g) the development of the current pattern of land use, land cover and cultural settlement in the watersheds;
- h) a data dictionary explaining the derivation of each of the mapped themes.

## SURFACE AND GROUND WATER SAMPLING POINTS

Gathering the surface and ground water quality data for the study entitled "Relation of Hydrology to Land-use and Other Spatial Data in the Browns Creek and Valley Creek Watersheds" involved definition of sampling stations in the Valley Creek watershed and the Browns Creek watershed. Gathering the watershed structural characteristics for the study involved defining those portions of the watersheds that contribute to each of the surface and ground water quality sampling stations.

## **Surface Water Quality Sampling Points**

Surface water quality sampling occurred in two types of surface water systems: streams and lakes. Within these two surface water systems, two types of sampling stations were established: periodic stations that were sampled on a monthly to bimonthly or a flow-related basis; and grab sites that were sampled once or twice during the course of the project. Grab samples were taken at all lake stations while the stream stations were sampled on both a periodic and grab sampling basis.

### **Stream Sample Stations**

Stream water samples were gathered from a total of 25 stations in the two watersheds. Nineteen of the stations were located in the Valley Creek watershed while six were located in the Browns Creek watershed. All of the Browns Creek stations were sampled on a regular basis. Of the 19 Valley Creek stations, 5 were sampled on a regular basis.

The locations of the 25 stream sample stations are illustrated in the map entitled "Sample Points." This map also illustrates the location of areas in each of the watershed districts that contribute directly to one or more of the 25 stream stations. As a frame of reference, these areas are shown on all other maps in the atlas. Data describing the physical, hydrologic and cultural characteristics of basin areas contributing to water flows at each stream station were derived from these areas.

### Lake Sample Stations

Lake water samples were gathered from a total of 15 stations in the two watersheds. Eight of the stations were located in the Valley Creek watershed while seven were located in the Browns Creek watershed. All of the lake stations were sampled using a grab sample protocol.

The locations of the 15 lake sample stations are illustrated on the map entitled "Sample Points." This map also illustrates the location of areas in each of the watershed districts that contribute directly to one or more of the 15 lake stations. As a frame of reference, these areas are shown on all other maps in the atlas. Data describing the physical, hydrologic and cultural characteristics of basin areas contributing to water flows at each lake station were derived from these areas.

## **Ground Water Quality Sampling Points**

Ground water was sampled in the watersheds using two strategies. Ground water samples were gathered from a total of seven piezometers located in the two watersheds and 18 bedrock wells.

### **Piezometer Stations**

At four of the regular sample stream water stations in the Valley Creek watershed and three of the regular stations in the Browns Creek watershed, shallow piezometers were driven by hand near the stream edge to a depth of three to five feet below the stream bed. Water flowing from the piezometers was sampled at the same frequency as was stream water at the station.

The watershed areas contributing flow to the piezometers was presumed to approximate the basin area contributing water directly to the stream stations. The areas contributing flow to the piezometers are contained within the definition of the study area on the previously mentioned map labeled "Sample Points."

### **Bedrock Well Stations**

A total of 13 bedrock wells were sampled on a grab sample basis within the Valley Creek watershed. Five wells were sampled in the Browns Creek watershed. The location of these 18 wells is illustrated on the map labeled "Groundwater Traces."

The "Groundwater Trace" map also illustrates the allignment of ground water flow pathways into each of the sampled wells. The pathways or traces contained on this map were plotted based on ground water flow patterns calculated by Almendinger, et al. (1999). The traces represent an area of land that extends outward from the actual trace pathway for a distance of 100 meters. To the extent that surface conditions within the two watersheds affect water quality flowing in the ground water trace pathways, it is likely that conditions contained within the 100 meter buffer of the pathways exert the greatest influence on ground water quality. Since many of the ground water traces flow outside of the limits of the two watersheds, the physical, hydrologic and cultural conditions within these traces are represented in maps that follow the respective themes for the entire watershed areas.

## Summary of Water Quality Sampling

The following table summarizes the water quality sampling protocol used in this study.

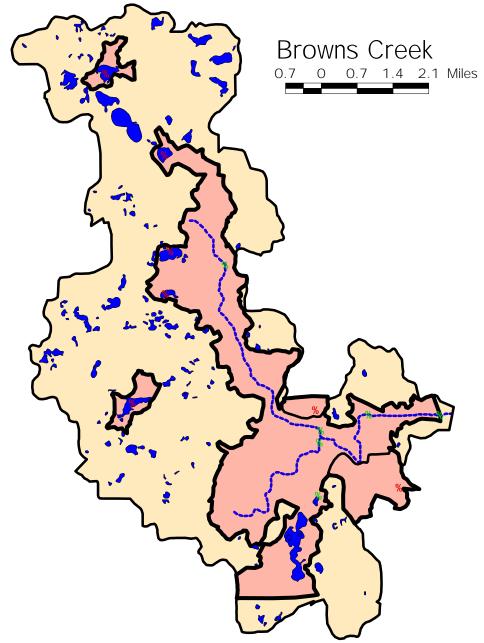
### Type of station

Stream station Regular sampl Grab sampling Lake station Ground water stat Piezometer sam Well trace sam

Totals

	Number of stations		
	Valley Creek	Browns Creek	
	•		
ling	5	6	
g	14	0	
0	8	7	
ation			
mpling	4	3	
npling	13	5	
	44	21	

Development and Water Quality in Two Exurban Watersheds



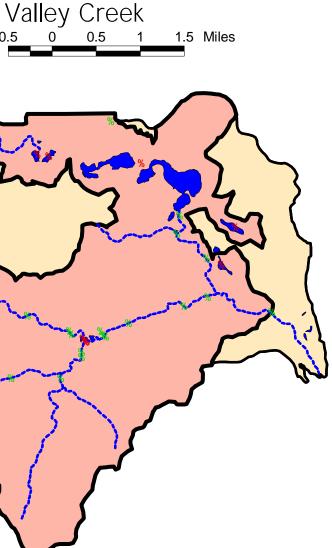
Legend

- Lake water
- Surface water %

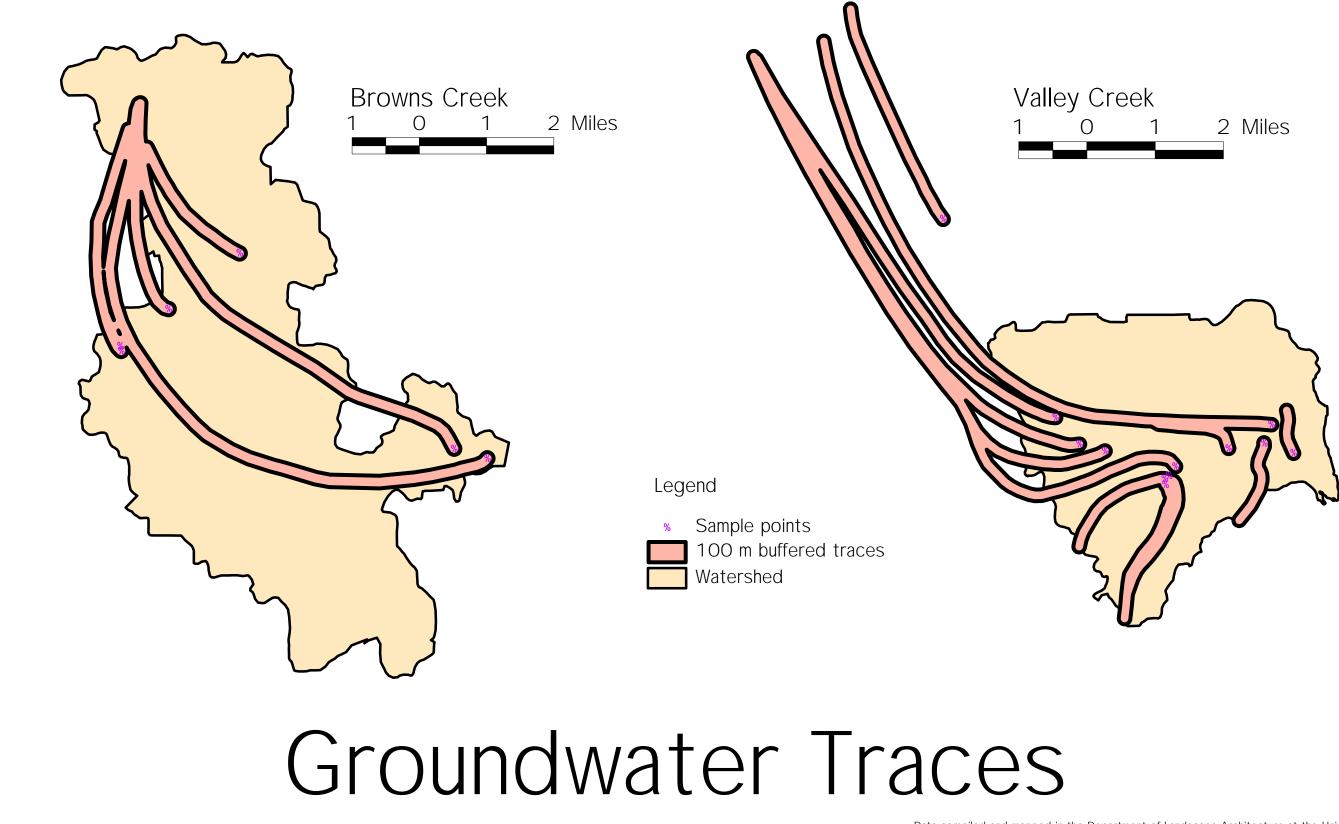
# Sample Points

Drainage

Modern lakes Study area Watershed boundary



Development and Water Quality in Two Exurban Watersheds



## GEOLOGIC HISTORY OF VALLEY CREEK AND BROWNS CREEK WATERSHEDS st divide time since creation of planet Earth into eras, periods, Market Market

Geologists divide time since creation of planet Earth into eras, periods, and epochs. Figure 1 illustrates that the Precambrian Era extends from the Earth's origin (some 4500 to 5000 million years ago) to approximately 600 million years Before Present (BP). The Precambrian Era is divided into three periods: the Early Precambrian spans the time from the Earth's origin to 2700 million years BP; the Middle Precambrian extends to 1700 million years BP and is generally considered the time during which life first emerged on Earth (Ojakangas and Matsch, 1982); and the Late Precambrian spans time from 1700 million years BP to 600 million years BP. The period from 600 million years BP to 225 million years is known as the Paleozoic Era. Of the Paleozoic's seven periods, the Cambrian (600 - 500 million years BP) and the Ordovician (500 - 435 million years BP) are most important to the geologic history of the Browns Creek and Valley Creek watersheds. The Mesozoic Era extends from 225 million years BP to approximately 70 million years BP. Finally the Cenozoic Era (extending from the present time back some 70 million years) and in particular the Quaternary Period of the Cenozoic are considered the recent past of geologic time.

Five sets of geologic activity shaped the evolution of the watersheds' landforms as they exist today. A series of three events occurring in the Late Precambrian, the Cambrian and the Ordovician Periods, respectively, created the bedrock geology of the watersheds. Two events during the Pleistocene Epoch and one event occurring in the Recent Epoch of the Quaternary Period shaped the watersheds' surficial geology.

## **Development of Bedrock Geologic Formations**

The history of the watersheds' bedrock geology involves two sets of activity that were separated from one another by over 600 million years. The first set of activity involved movement of the earth's crust occurring approximately 1.1 to 1.2 billion years BP while the second set involved inundation of the earth's surface by a large inland ocean during periods extending 550 million to 450 million years BP.

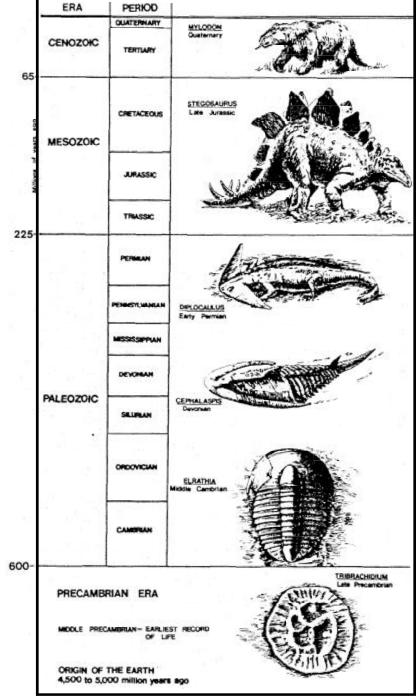


Figure 1. Geologic time is divided into eras, periods and epochs. (Ojakangas and Matsch 1982, p.11)

### **Precambrian Upheaval: Creation of the Mid-Continental Rift**

During the Precambrian Era, Minnesota experienced three periods of substantial volcanism (Ojakangas and Matsch 1982). The most recent of these periods of volcanism, occurring between 1200 and 1100 million years BP, is associated with the development of a mid-continental rift or crack in the earth's surface that extended northeasterly from eastern Kansas through eastern Minnesota and northwestern Wisconsin (see Figure 2). The rift evolved as the North American continent attempted to separate into two plates. This rift separated what is now Hudson, Wisconsin from Wayzata in Hennepin County (Bray 1977). Lava rose up through faults or cracks created by the mid-continental rift and flowed across the surface of the land. The upwelling of lava resulting from the mid-continental rift process produced a geologic feature known as the St. Croix Horst (Morey and Mudrey 1972). Basalt flowing out of cracks in the earth's surface that were created by the up-thrusting action of the St. Croix Horst produced what are now known as the Keeweenawan volcanic rocks. This geologic formation extends from southern Minnesota between Albert Lea and Austin up through Rice County and the St. Croix Valley, into northwestern Wisconsin. It extends into Lake Superior via Minnesota's North Shore and the Keeweenaw Peninsula of Michigan's Upper Peninsula (Morey and Mudrey 1972).



Figure 2. The Mid-Continental Rift zone extended between northeastern Kansas and the north and south shores of Lake Superior. (Ojakangas and Matsch 1982, p.52) In some areas, this basaltic lava flow was as much as 6100 meters deep (Morey and Mudrey 1972). Throughout Minnesota, it appears at the land surface only in limited areas of the St. Croix River valley and Pine County and along Lake Superior's North Shore. The Dalles at Taylor's Falls and the rock bluffs on the Wisconsin side of the St. Croix just south of Franconia are comprised of Keeweenawan volcanic rocks. These formations were exposed when the St. Croix River incised a new channel after it overtopped an ice dam immediately following the last period of glaciation. In addition, a fault line associated with the Mid-continental Rift is apparent in the Washington County landscape just south of where Trout Brook enters the St. Croix River at Afton State Park.

### **Oceanic Inundation and the Sedimentary Rocks** of the Watershed

Following the volcanic activity of the late Precambrian Period, the middle of the North American Continent began to subside. The subsidence of the St. Croix Horst produced a depression that was eventually filled, in part, by what is today called Lake Superior (Ojakangas and Matsch 1982; Bray 1977).

As the land surface subsided, large continental seas spread inland. By the late Cambrian Period (approximately 550 million years BP), the inland seas reached the Hollandale Embayment, a broad shallow depression existing in southeastern Minnesota, western Wisconsin and northern Iowa (see Figure 3). All of Washington County was inundated by the Hollandale Embayment (Bray 1977, Morey 1994). Within Minnesota, the embayment included all of the southeastern counties within a line running in a northeasterly direction from Martin County through Wantowan, Brown, Sibley, McLeod, Wright, Mille Lacs, Kanabac and Pine Counties, respectively.

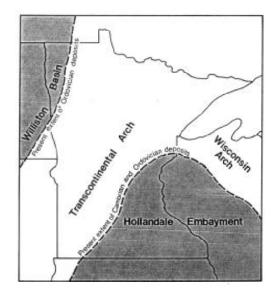
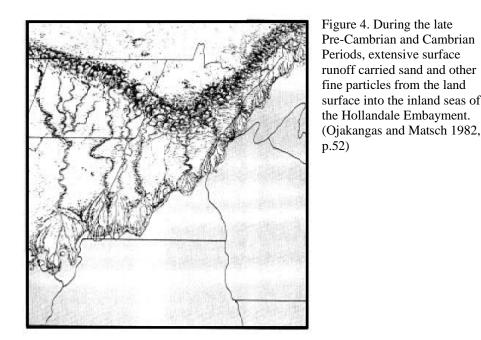


Figure 3. An inland sea extended into the Hollandale Embayment in soutneastern Minnesota and northwestern Wisconsin during the late Cambrian Period. (Ojakangas and Matsch 1982, p.67)

Late Cambrian St. Croixan Sedimentary Formations. An initial inundation by the continental sea resulted in the deposition of four sedimentary formations. These four deposits and their approximate thickness are: the Mt. Simon Sandstone (as much as 100 meters thick); the Eau Claire Formation (nearly 60m thick); the Galesville Sandstone (30m thick); and the Ironton Sandstone (14m thick) (Ojakangas and Matsch 1982). Following a temporary retreat of water levels, a second inundation during the late Cambrian Period into the Hollandale Embayment produced three additional sedimentary depositions: the Franconia Formation (varying in thickness between 30m and 60m); the St. Lawrence Formation (20m thick); and the Jordan Sandstone (25 to 35m thick). The Jordan Sandstone and the St. Lawrence and Franconia Formations are the most prevalent St. Croixan Formations that exist as the uppermost bedrock within both the Valley Creek and the Browns Creek watersheds. The Jordan sandstone is white to yellow in color and medium to coarse grained in texture, and its sandstone granular components are round and well-sorted. The St. Lawrence Formation, on the other hand, is a dark colored dolomite that contains clay, silt and sand. The Franconia Formation, like the Jordan formation is fine-grained quartz sandstone. The St. Croixan sedimentary formations are largely silicon in content reflecting the fact that deposition in the Late Cambrian Period was largely a product of surface runoff carrying sand and other fine soil particles from land into the seas of the Hollandale Embayment.



Ordovician Dolomites. In the later portion of the Cambrian Period, the continental sea that filled the Hollandale Embayment retreated, and the land area of the Valley Branch watershed was once again above water. However, in the early portions of the Ordovician Period (approximately 475 million years BP), the continental seas returned to Minnesota, and

the watersheds were once again inundated with water. In contrast with the late Cambrian inundation, the continental seas of the Ordovician Period were rich in marine life (Ojakangas and Matsch 1982). The abundance and diversity of marine life in the Ordovician seas produced sedimentary formations that have a higher carbonate content, since accumulation of sediment during much of the Ordovician Period consisted of marine life remnants being deposited on the ocean floor.

Marine life deposition during the Ordovician Period produced carbonate formations known as dolomite. Most of the central portions of the Browns Creek and Valley Creek watersheds are underlain by Ordovician dolomites from the Oneota and Shakopee formations of the Prairie du Chien Group. These dolomitic formations are tan to gray in color, and they are fine textured (Ojakangas and Matsch 1982). The upper portions of the Prairie du Chien Group are commonly sandy and thin bedded while the lower portions are massive and thickly bedded (Mossler and Bloomgren, 1990). The Oneota and Shakopee Formations of the Prairie du Chien Group are approximately 70 meters thick (Ojakangas and Matsch, 1982). Escarpments of the Prairie du Chien Group are evident along the perennial mainstem of Valley Creek as it flows in a direction parallel to Valley Creek Road and at the Boom Site on the St. Croix River at Stillwater.

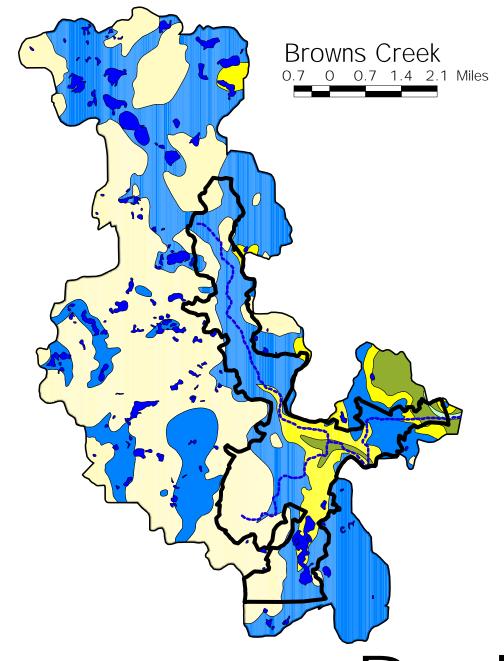
center of that watershed.

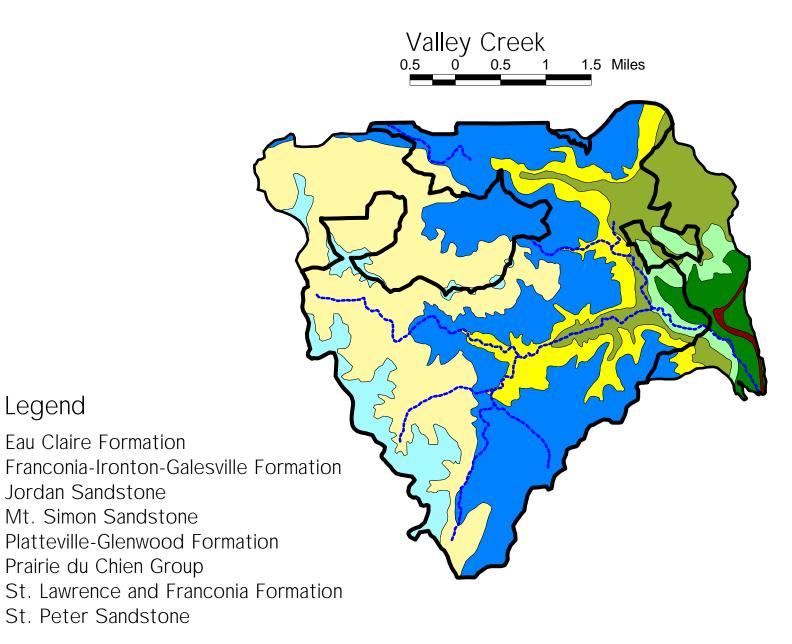
The maps entitled "Bedrock Geology" and "GW Traces: Bedrock Geology" illustrate the spatial distribution of the various bedrock geologic formations.

The western portions of the watersheds contain an Ordovician formation known as the St. Peter Sandstone. The St. Peter Sandstone, though not a limestone, was deposited during the Ordovician Period. It is almost pure white in color, and it is the formation that dominates the cliffs of the Mississippi River as it flows through St. Paul. The St. Peter sandstone is rich in silicon, and it is more similar in appearance to the St. Croixan Sandstones (principally the Jordan deposit) than it is to the Ordovician dolomites. The existence of the St. Peter sandstone reflects a brief period of time during which the continental seas of the Ordovician Period receded. During this inter-oceanic interlude, sedimentary deposition was again largely a product of sediment transported by surface runoff The return of the Ordovician sea is marked by the presence of the Platteville-Glenwood Dolomite in the far western edge of the Valley

Creek watershed. The Platteville-Glenwood dolomite is gray to green in color (Ojakangas and Matsch 1982). These formations are especially prominent in the higher elevations of the watershed. County Road 15 (known locally as Manning Trail) in the Valley Creek watershed traverses much of the Platteville-Glenwood Formation. The road alternates between lower elevations associated with the St. Peter Sandstone and the higher Platteville-Glenwood Formation. The Bissels Mounds, also in Valley Creek watershed, are pronounced erosional remnants of the formation sitting on top of the St. Peter Sandstone in the

Development and Water Quality in Two Exurban Watersheds



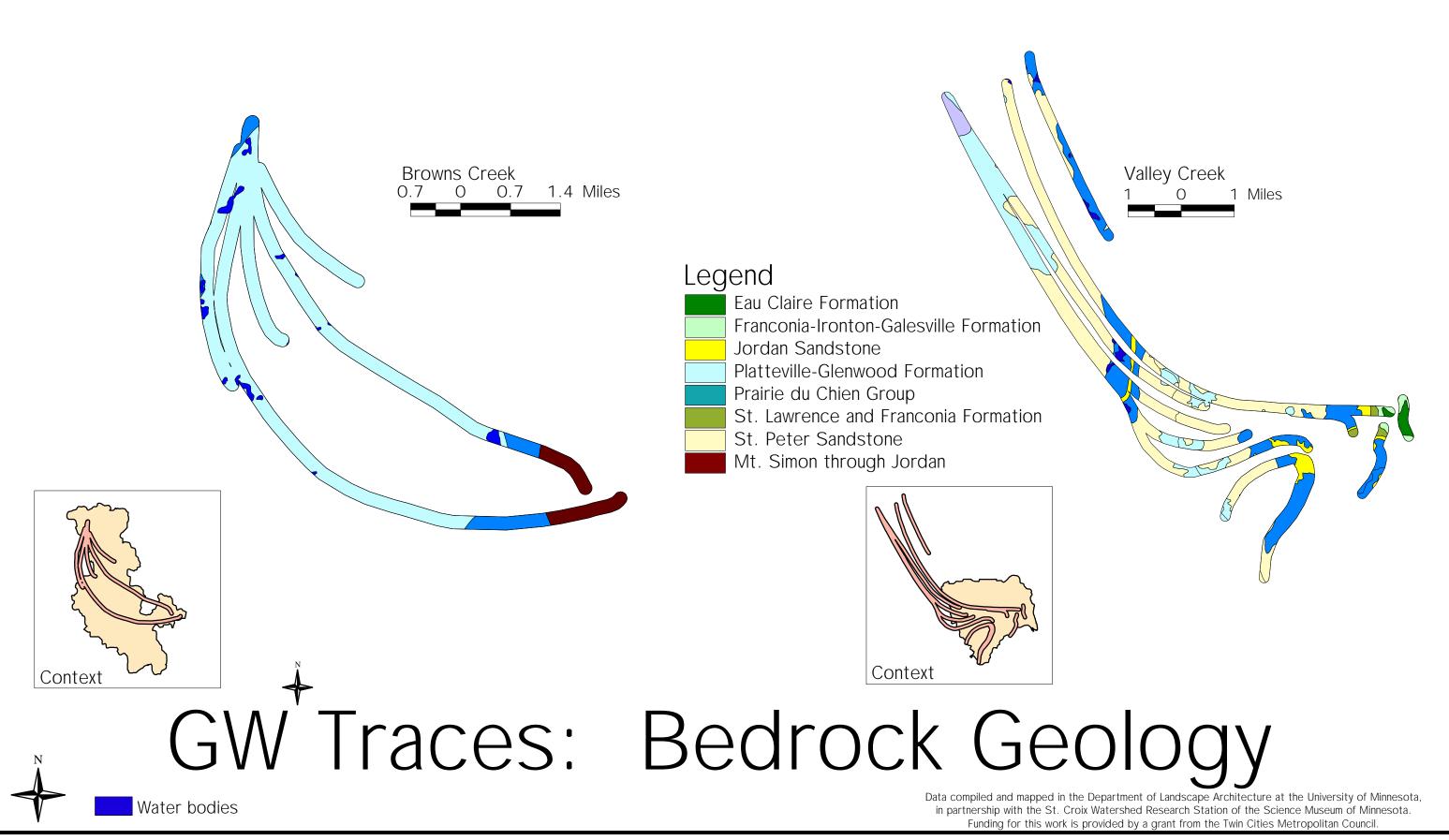


# Bedrock Geology

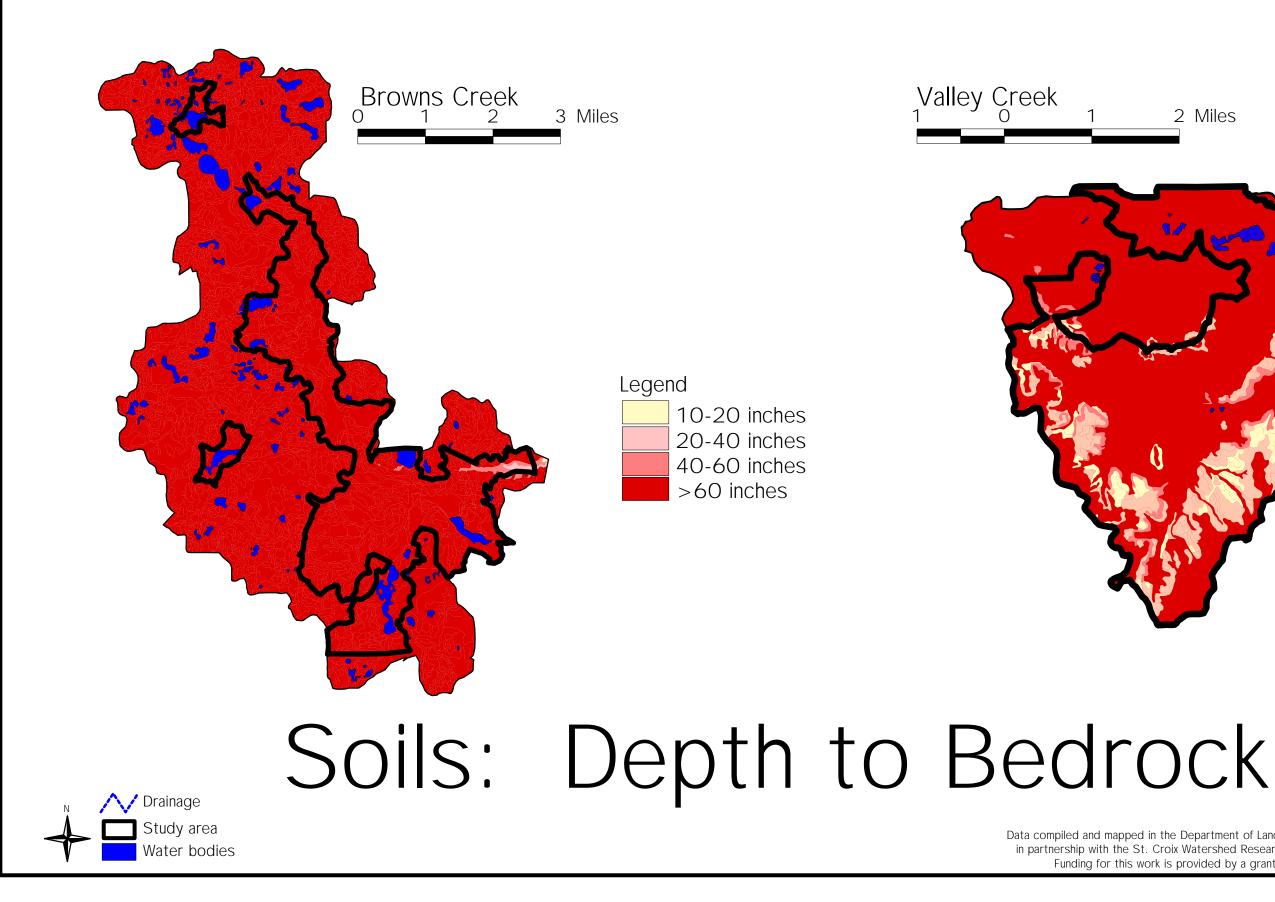
Legend



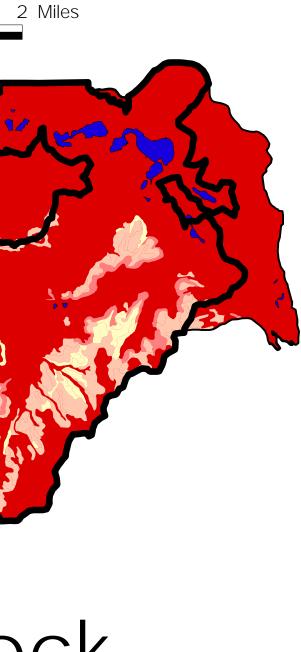
Development and Water Quality in Two Exurban Watersheds



Development and Water Quality in Two Exurban Watersheds



Valley Creek



### **Depth to Bedrock**

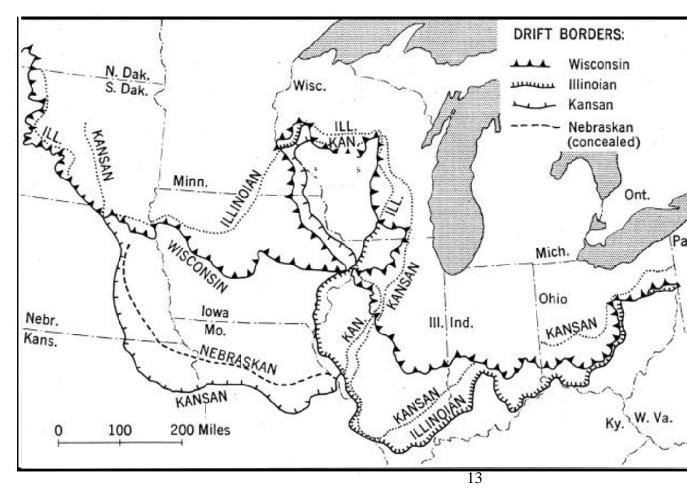
Throughout both watersheds, deposits of glacial material produced during the Pleistocene Epoch cover bedrock. These deposits vary in thickness, ranging from areas where bedrock is exposed at the surface to areas containing over 100 meters of glacial drift (Patterson et al. 1990). The areas of bedrock outcropping or extremely shallow bedrock are evident in the landscape as isolated hilltops that are not in agriculture or patches of uncropped areas within agricultural fields. The areas of deepest glacial till are located along Browns Creek immediately north of Lake Mckusick (45-75 meters deep) and along the mainstem of Valley Creek in the vicinity of the Belwyn Foundation (up to 105 meters deep). The present course of Valley Creek, especially the north branch, the Lake Edith area and the landscape to the northwest of Lake Edith extending toward Horseshoe and Sunfish Lakes exists within a pre-glacial river channel. Depths of sediment within this buried river channel range from greater than 100m near the confluence with the St. Croix to 35 to 50m near Horseshoe and Sunfish Lakes, respectively. Similarly, the south branch of Valley Creek also occupies a buried valley containing sediment depths of between 30 to 50m (Patterson et al. 1990). The "Depth to Bedrock" map illustrates a generalized pattern of the distribution of the various depths to bedrock existing in both watersheds. These maps were derived from soils data, and they show the locations of areas where depth to bedrock is less than five feet.

## **Glaciation of Surficial** Landform

The next period in geologic history to produce a lasting influence on the character of the Browns Creek and Valley Creek landscapes is the Pleistocene Epoch of the Quaternary Period. Known as the "Ice Age", the Pleistocene Epoch actually witnessed four periods of glaciation (see Figure 5). Of these, the last two periods, the Illinoian glaciation (approximately 300,000 to 130,000 years BP) and the Wisconsinan glaciation (35,000 to 10,000 years BP) have directly influenced the character of both watersheds. A short discussion of the influences of glaciation on the landform creation is presented as a prelude to describing the effects of the Illinoian and Wisconsinan glaciation on the watersheds' landscape.

### Landform Development as a Product of Glaciation

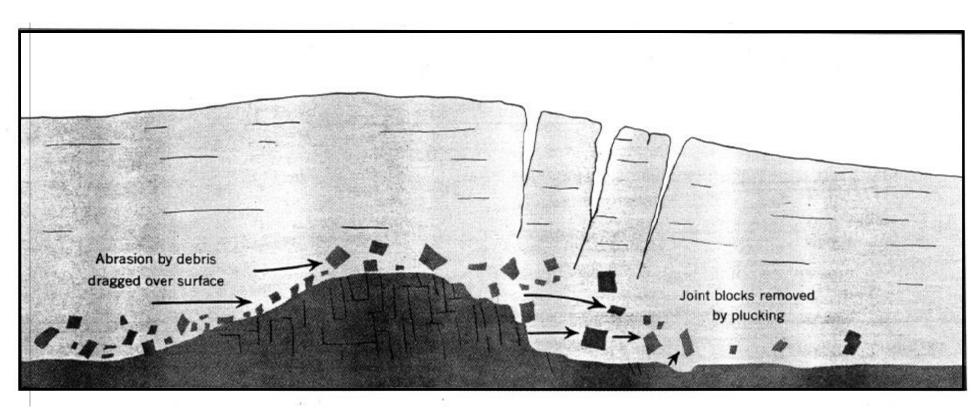
Continental glaciation, as it occurred during the Illinoian and Wisconsinan glaciations, affected surficial landform development through erosional as well as depositional processes. Glacial deposition was more influential than glacial erosion in creating the landscapes of the Browns Creek and Valley Creek watersheds.

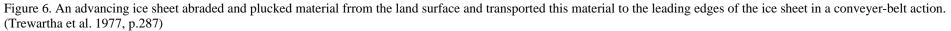


Glacial Erosional Features. As continental glaciers move across the surface of the land, the massive ice sheets and the debris they transport are capable of scratching striations and grooves into the most resistant of bedrock surfaces. Glacial bedrock quarrying may occur wherein bedrock weakened by fractures is plucked out of its original formation and transported to another location. Individual rock fragments carried far from their bedrock origins and deposited on the land surface are known as glacial erratics. The scouring action of the ice sheet and its debris sometimes creates whalebacks or roches moutonnees. These are small mounds of bedrock carved into "whale-like" forms having a blunt and irregular end created by ice approaching the mound and a smooth lee side carved as ice moves over the mound (Strahler and Strahler 1984; and Ojakangas and Matsch 1982).

Glacial Depositional Features. Continental glaciation occurs when global temperatures permit polar ice packs to form more rapidly than they melt. As ice accumulates in the Polar Regions of the globe, it flows away from its sources. As the ice sheet advances over the land surface, debris in the path of the glacier is plucked, scraped and carried forward (see Figure 6). The plucking, scraping and pushing actions are the result of two forces that operate simultaneously. The leading edges of the ice sheet behave as if they were giant bulldozers, scraping and carrying debris as they move. Expansion of the ice sheet from the polar sources keeps the under-surface of the sheet in perpetual motion, and this surface behaves as if it were a conveyer belt. The continually moving undersurface plucks and scrapes the land, and it carries debris to the leading edges of the ice sheet (see Figure 7).

Figure 5. Glaciation of the North American continent during the Pleistocene Epoch involved four advancements of ice sheets. Of these only the last two advancements, the Illinoian and the Wisconsinan affected landform development in the Browns Creek and Valley Creek watersheds. (Strahler and Strahler 1984, p.362)





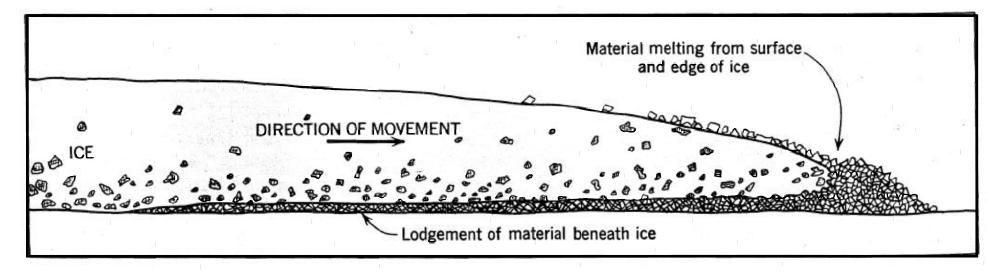


Figure 7. Material plucked and scraped from the under-surface of the ice sheet was transported toward the ice margins. Together with material buldozed by the leading edges of the sheet, this glacial till was lodged as ground moraine under the ice or as end and lateral moraines at the ice margins. (Trewartha et al. 1977, p. 288).

Glacial drift is a term applied to mineral debris that was transported by and deposited in close association with glaciers. Drift created as a heterogeneous mixture of rock, sand, silt, and clay is known as till. Glacial till was produced by the plucking and scraping of the land surface as the ice sheet moved as well as by the bulldozing effect of the leading edges of the ice sheet.

Till was deposited in many forms by a glacier. As global climatic patterns created conditions where glacial melting equaled ice formation, the ice sheet stopped its forward movement, and the till at its edges was deposited as an end or terminal moraine. The linear hill systems created by deposition of till at the edge of the ice sheet often contain both rises and depressions, and many of the depressions became lakes as they filled with water melting from the ice sheet. These linear hill systems or morainal ridges are often described as "kettle and knob" landscapes in reference to the multitude of hills and depressions (some of which were lakes or ponds) that they contain. Generally, the topographic contours created in a kettle and knob landscape paralleled the orientation of the ice sheet edge from which they were produced. The orientation of the morainal landscape was also generally perpendicular to the direction of ice sheet advancement.

terminal edges.

Ground moraine resulted when till was deposited as the ice sheet advanced across the land surface. Ground moraine landscapes tended to be flat to gently undulating because the ice sheet scraped the land surface as it advanced. Any material deposited on a ground moraine was therefore subjected to subsequent scraping by successive movement of the ice sheet.

As an ice sheet melted, water flowing over, through and from the melting ice carried debris gathered by the ice sheet during periods of advancement. As the speed of travel for this meltwater slowed down, sediment carried in the flow was deposited on underlying surfaces, much as a stream in the landscape deposits sand and silt into its channel or onto its floodplain when its velocity slows down. As the speed of travel in the meltwater flow continued to decrease, the size of the particle that could carry by the flow also decreased. Thus, layers of sediment having varying particle sizes dropped out of meltwater flow depending on the flow's speed of travel. This type of glacial drift was known as stratified drift, and it usually contained silt, sand or gravel whose particle size varied depending upon the speed at which the meltwater was traveling.

As the speed of meltwater flowing off a melting ice sheet onto an adjacent land area slowed down, a sandy outwash plain was created. If the meltwater flowed through a valley depression either on the surface of the ice, within the ice or on adjacent land surfaces, a meltwater channel formed, and a linear channel of stratified drift was deposited in the landscape.

Occasionally, the melting ice sheet broke into a series of ice blocks, and the flow of meltwater became more localized with respect the location of the ice block. Melting blocks of ice often produced depressions in the land surface, and this pockmarked landscape was known as a pitted outwash plain. Many of the depressions filled with meltwater creating ice block lakes. Figure 8 illustrates the advancement and recession of an ice sheet and the diverse landforms that might have resulted from this activity.

Similar morainal deposits occur at the lateral edges of ice sheets. Lateral moraines tend not to create as much relief as end moraines since the lateral edges of the ice sheet tend not to contain as much till as do the

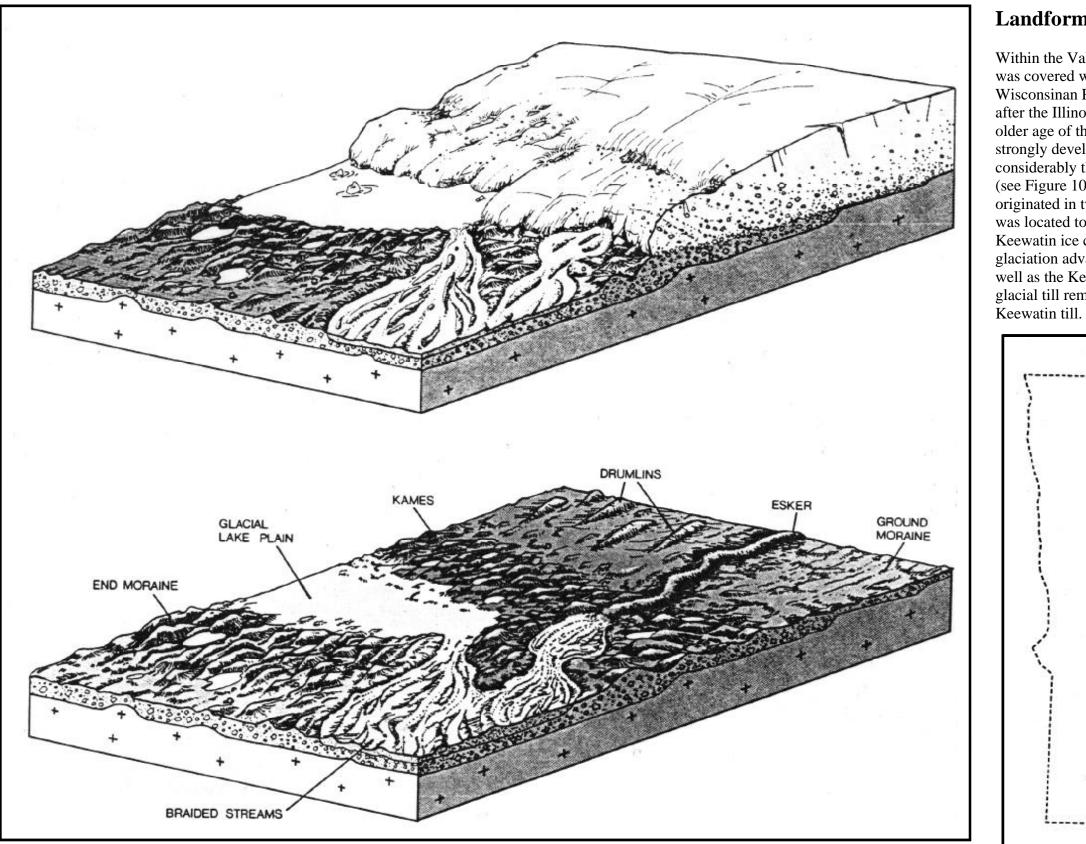


Figure 8. An advancing ice sheet created ground, end and lateral moraine landforms. As the ice melted, stratified drift deposits created outwash plains that often contained braided stream channels, meltwater channels, glacial lake plains, and large areas off sandy conical-shaped hills called kames (Ojakangas and Matsch 1982, p.101).

### Landforms of the Illinoian Glaciation

Within the Valley Creek watershed, the area south of the south branch was covered with ice during the Illinoian glaciation but not during the Wisconsinan Period (see Figure 9) which occurred at least 100,000 years after the Illinoian ice advancement (Myer et al. 1990, Martin 1965). The older age of the Illinoian landscape means that surface drainage is more strongly developed, and soils and surface geology overburden are considerably thinner than that in the northern half of the watershed (see Figure 10). Continental ice sheets during the Illinoian glaciation originated in two areas of northern Canada. The Labradorean ice center was located to the northeast of Minnesota and Wisconsin while the Keewatin ice center was located in northwestern Canada. Illinoian glaciation advanced from the Labradorean ice source to the northeast as well as the Keewatin ice source to the northwest (Myer et al. 1990). The glacial till remaining in the Illinoian landscape is predominately

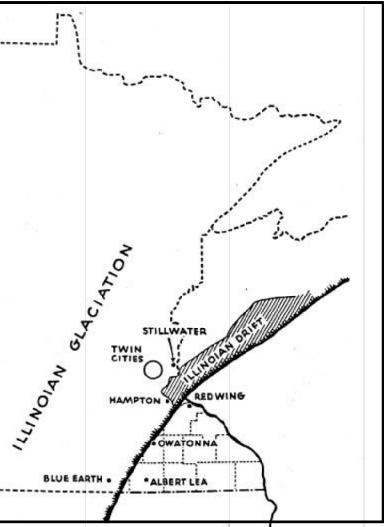
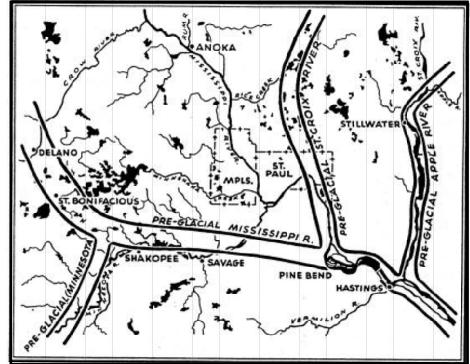
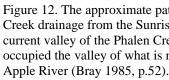


Figure 9. The southern portion of the Valley Creek watershed was covered with ice during the Illinoian glaciation but not during the Wisconsinan, and it is at least 100,000 years older than the Wisconsinan landscape (Bray 1977, p.34)





The advancing Superior Lobe of the Labradorean Ice Sheet disrupted drainage from the north and west into Glacial Lake Duluth (the precursor of Lake Superior), and created two inland lakes, Aitkin and Upham, respectively. Both lakes drained originally to the south through the Mississippi River drainage. Similarly, Glacial Lake Duluth drained originally to the south and west through the Brule and St. Louis Rivers and eventually into the St. Croix River. However, the Des Moines Lobe, a Keewatin ice sheet advancing from the northwest reached the approximate location of the Twin Cities Metropolitan Area. An offshoot of this sheet, the Grantsburg Sublobe, extended in an east-northeast direction reaching its maximum extent approximately 16,000 years BP (Wright 1972).

The advancing Des Moines Lobe captured Mississippi River drainage flowing out of Lakes Aitkin and Upham, while the Grantsburg Sublobe disrupted surface drainage flowing from Glacial Lake Duluth through the St. Croix drainage system. The capturing of these two drainage systems by the ice lobes resulted in the creation of Glacial Lake Grantsburg, a lake that lasted for 2000 years (Wright 1972). At its greatest extent, Lake Grantsburg covered the landscape in Minnesota from Milaca, Hinkley, Braham and Pine City to Grantsburg, Cloverton and points east in Wisconsin (Bray 1985) (see Figure 13).

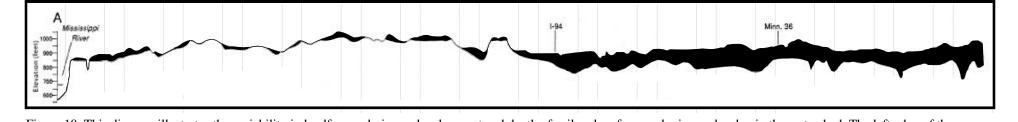


Figure 10. This diagram illustrates the variability in landforms, drainage development and depth of soil and surface geologic overburden in the watershed. The left edge of the diagram represents the Mississippi River while the right edge is located to the north of Highway 36 in Grant Township. Interstate 94 is in the center of the diagram. The well developed drainage and shallow overburden of the Illinoian landscape is typified by the left half of the diagram while the right half exemplifies the poorly developed drainage but deeper overburden of the Wisconsinan landscape (Meyer et al. 1990).

### Landforms of the Wisconsinan Glaciation

During the Wisconsinan glaciation, the Superior Lobe advanced over the Browns Creek and Valley Branch watersheds from its Labradorean source. The Superior Lobe flowed from the northeast directly across both watersheds, reaching its maximum extent around 20,000 years BP (Bray 1985; Wright 1972). The furthest extent of this lobe is marked by the St. Croix terminal moraine, which extends through Dakota County (see Figure 11). A lateral element of the St. Croix moraine extends throughout the higher elevations of the Valley Creek watershed sitting approximately over top of the Platteville-Glenwood Formation. The St. Croix moraine

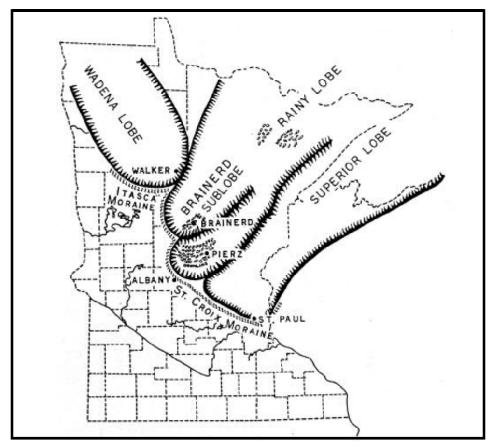


Figure 11. The Superior Lobe reached its maximum extent about 20,000 years BP creating a terminal moraine in Dakota County and a lateral moraine in the western edge of the Valley Creek watershed (Bray 1977, p.41).

also exists in several locations throughout the Browns Creek Watershed District. Most notable extents of the moraine exist as the creek flows east from Highway 64 toward the St. Croix River, in the vicinity of Long Lake, in a southwesterly to northeasterly orientation extending through the central portions of the City of Grant, and in the northern portion of the District near Lake Paisted and the School Section lakes.

As the Superior Lobe began to melt after achieving its maximum advancement, meltwater flowing from the St. Croix moraine in an easterly direction created an extensive outwash plain. Within the Valley Creek watershed, this outwash plain occupies an area of relatively flat slopes (i.e. less than six percent) in the vicinity of Bissels Mounds and extending northerly toward Interstate 94. Within that portion of the watershed's north branch residing in the buried river channel, the landscape is pockmarked with kames or sandy conical shaped hills and depressions. This pattern is indicative of localized drainage produced from blocks of ice breaking away from the main ice sheet (Patterson 1990). Outwash exists within the Browns Creek Watershed District in four principal extents, including: the southeastern corner of the district where Highway 36 bisects the southern portion of the district; the southeastern corner of the City of Grant; the Kismet Basin in the vicinity of Pat Lake; and the in the area extending northeasterly from Benz Lake.

### **River Terraces of the Post-Glacial Period**

Prior to advancement of the glacial ice sheets during the Pleistocene Period, the St. Croix River departed from its present course at the Sunrise River, flowing up what is now called the Sunrise valley and connecting to the Mississippi River drainage via the Rice Creek drainage system (Wright 1972). Figure 12 illustrates that the landscape of the lower portion of the St. Croix valley below the confluence of the Apple River is, however, over 100,000 years old, having been the location of the pre-glacial Apple River (Martin 1965, Bray 1985).

Figure 12. The approximate path of the pre-glacial St. Croix River followed the Rice Creek drainage from the Sunrise River, and it eventually drained down through the current valley of the Phalen Creek drainage system. The pre-glacial Apple River occupied the valley of what is now the St. Croix River below its confluence with the

Lake Grantsburg finally overtopped the ice dam created by the Grantsburg Sublobe in the vicinity of the present-day Dalles at Taylor's Falls, and it quickly cut a new course that joined with the pre-glacial channel of the Apple River. At this point in time, the St. Croix River was draining Glacial Lake Grantsburg as well as Lakes Aitkin, Upham and Duluth. River stages during this period were more than 60 meters higher than the present 200m pool elevation at Stillwater. Five sets of river terraces were created in the St. Croix Valley as the stage of the river receded from its post-glacial high. The highest terrace is found at an elevation of 250 to 270m while the second highest terrace is 240 to 250m above the river. The third highest terrace exists at elevations of between 230 and 240m feet and the fourth highest terrace is at an elevation between 220 and 230m. The lowest terrace is found at elevations ranging from 210 to 215m. The maps entitled "Surficial Geology" and "GW Traces: Surficial Geology" illustrate the distribution of surface geology deposits created by glacial and post-glacial activity within the Browns Creek and Valley Creek watersheds.

While the predominate types of surfical geologic formations in the two watersheds parallel one another, the pattern of these formations varies between the two watersheds. In the Valley Branch watershed, a central outwash feature is surrounded by the St. Croix Moraine. In Browns Creek, the pattern of the two predominate formations consists of alternating bands of till and outwash occurring in a southwest to northeast orientation. The Browns Creek watershed also contains a higher proportion of glacial lake beds and organic deposits than is true in the Valley Branch watershed.

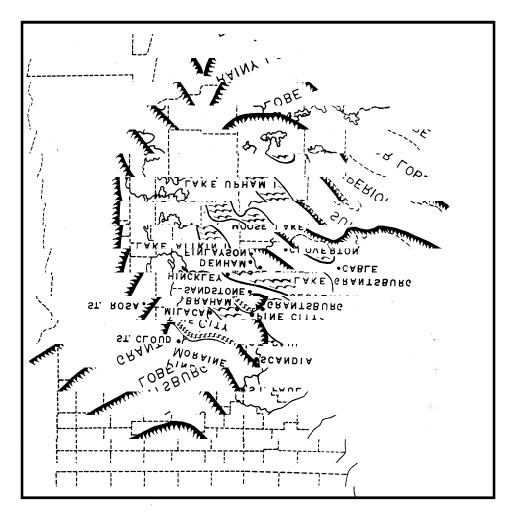
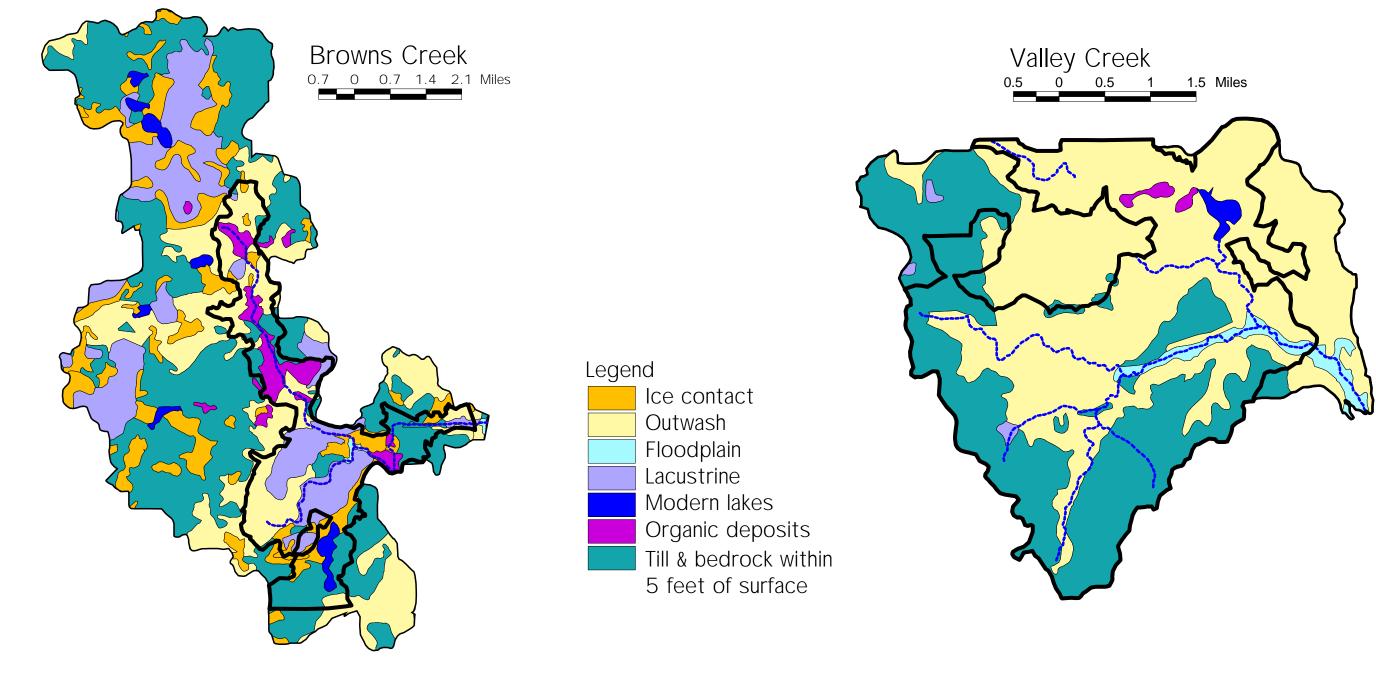


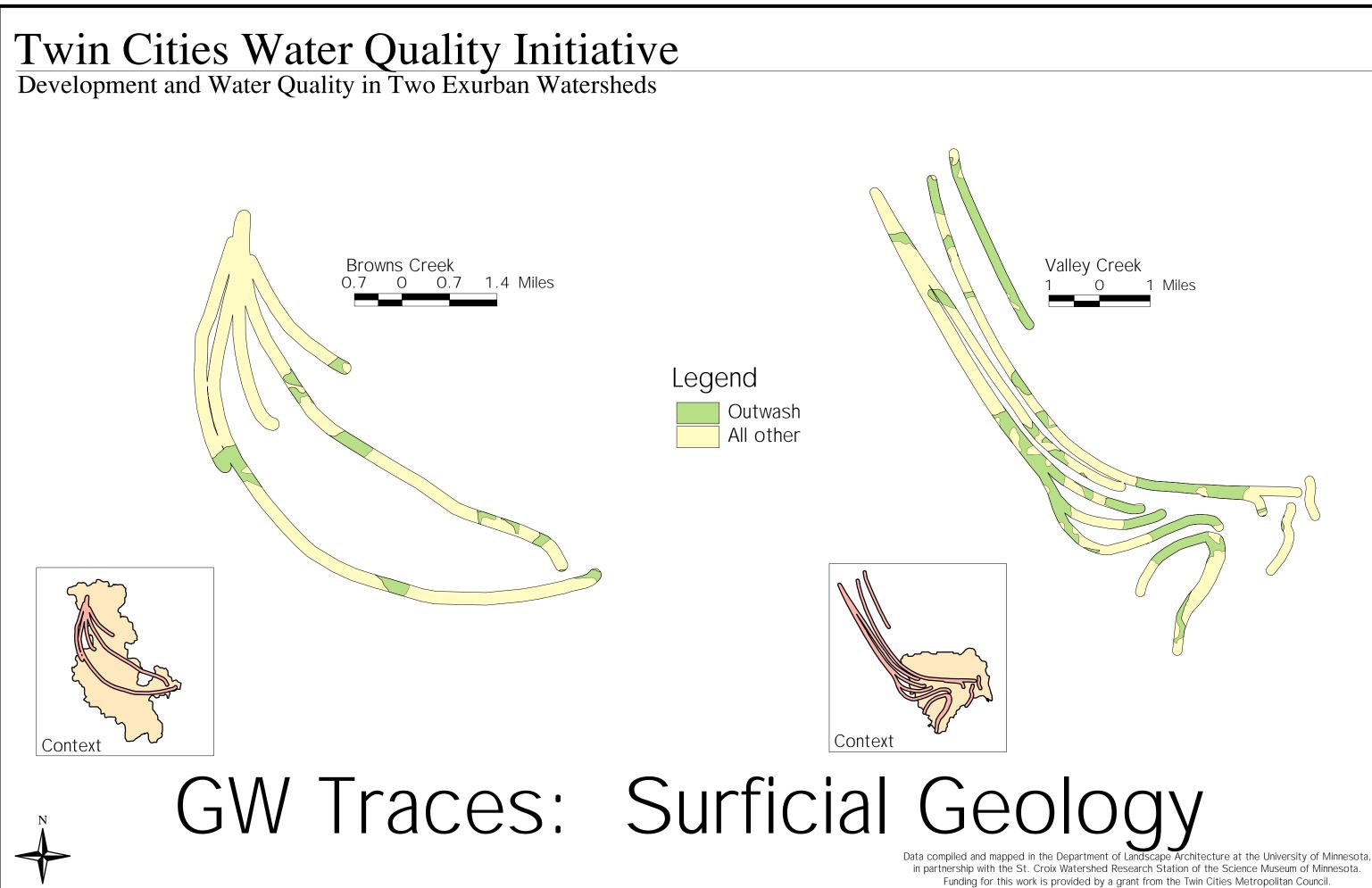
Figure 13. Drainage from Glacial Lakes Duluth, Upham, Aitkin and Grantsburg resulted in the creation of a series of five river terraces along the course of the post-glacial and present St. Croix River (Bray 1977, p.43).

Development and Water Quality in Two Exurban Watersheds



# Surficial Geology





# **SURFACE DRAINAGE PATTERNS**

## Variable Age of Drainage **Patterns**

As noted previously, the southern portion of the Valley Creek watershed below the south branch was glaciated during the Illinoian Period, but not during the Wisconsinan Period. In contrast, the northern half of the Valley Creek watershed and all of the Browns Creek watershed were glaciated during both the Illinoian and the Wisconsinan Periods. The increased age of the Illinoian landscape means that the southern half of the Valley Creek watershed has experienced the dissecting and erosional effects of weathering and surface runoff for a longer period of time (i.e. at least 100,000 years) than has the northern half of the Valley Creek watershed or any portion of the Browns Creek watershed. As evident in the map entitled "Surface Drainage," the Illinoian landscape has a much better developed surface drainage network. All first and second order streams that carry water on an intermittent basis have an eventual network connection to the permanently flowing fourth and fifth order streams.

## **Effects on Presence of Wetlands** and Surface Water Bodies

The effects of the varying ages of the Illinoian and Wisconsinan landscapes on surface drainage in the Valley Creek Watershed are especially evident in looking at the map entitled "Surface Hydrology". In addition to portraying the surface drainage network of the two watersheds, this map depicts wetland areas identified from aerial photographic reconnaissance, areas contained within the 100-year floodplain as mapped by the Federal Emergency Managment Agency, and sites included in the National Wetlands Inventory conducted by the US Fish and Wildlife Service.

Youthful landscapes, such as the Wisconsinan landscape, are characterized by the presence of extensive systems of wetlands and water bodies. Over time, sediment from the surrounding landscape fills these depressions and these areas become connected to a larger regional drainage pattern. The surface hydrology map of the Valley Creek watershed reveals the complete absence of wetlands and water bodies below the south branch, and an extensive system of both wetlands and lakes that runs diagonally from the southeast toward the northwest through the Wisconsinan landscape. This system generally occurs within glacial outwash that filled a river valley in existence prior to the

advancement of the Superior Lobe. Blocks of ice sitting in the shifting sediment of the buried valley became detached from the main lobe. As these blocks melted, they created the lakes and wetland systems that characterize this landscape (Patterson et al. 1990).

A fragmented drainage system, similar in nature to that found in the northern portion of the Valley Creek watershed, also characterizes the Browns Creek watershed, a landscape that is entirely a product of Wisconsinan glaciation. Within the morainal portion of the watershed, high points and depressions alternate with one another to create a "kettle and knob" pattern. Many of the depressions contain water produced as a result of glacial ice melting that created wetlands or ice-block lakes. The complex of wetlands and lakes within the outwash of Browns Creek is also a product of ice blocks that became detached from the melting Superior Lobe ice sheet.

## **Deranged Versus Well Developed Drainage Systems**

Youthful landscapes are also characterized by having drainage systems with no apparent direction. Known as deranged drainage, these systems may have single channels that are isolated from other channels. Two or three channels may even begin to form a drainage network that eventually leads into a wetland or a surface water body that has no outlet. In contrast to this youthful pattern, older drainage systems have welldeveloped networks that drain extensive land areas, providing an outlet for the watershed into a larger stream. The surface hydrology maps of the Browns Creek and Valley Creek watersheds reveal extensive areas of deranged drainage in the Wisconsinan landscape of Browns Creek and northern Valley Creek, and an extensive branching pattern of drainage in the Illinoian landscape of southern Valley Creek that flows eventually into the St. Croix River. The Illinoian drainage pattern is hierarchical in the sense that many first order streams join together in the upper reaches of the watershed to create second order streams. These streams in turn join together to create third order streams. By the time the mainstems of Browns Creek and Valley Creek flow into the St. Croix River at their respective confluences, they are both fifth order streams.

## **Effects on Topographic Elevation** and Slope

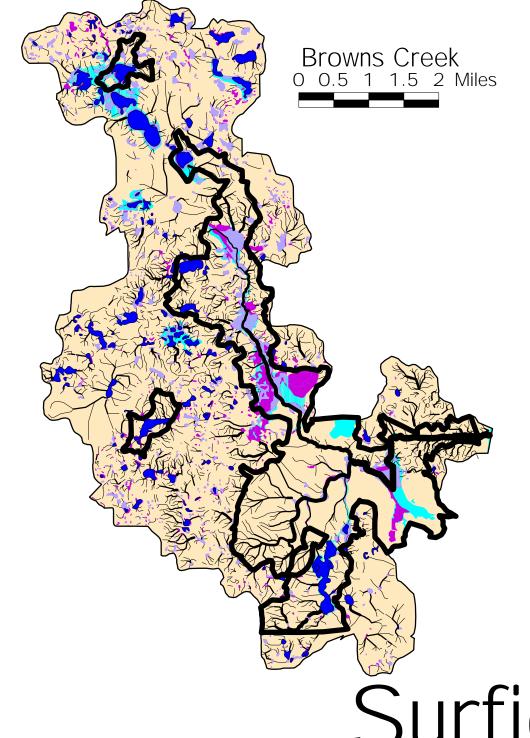
The physical characteristics of the Browns Creek and Valley Creek 20

watersheds have been subjected to two countervailing forces. On the one hand, processes contributing to the development of bedrock geology have increased the elevation of the land surface. Similarly, the inundation of glacial ice sheets during the Illinoian and Wisconsinan glaciations also contributed to the building of the land surface. On the other hand, weathering and erosion have acted to tear down the land surface and move sediment from the land surface into the St. Croix River.

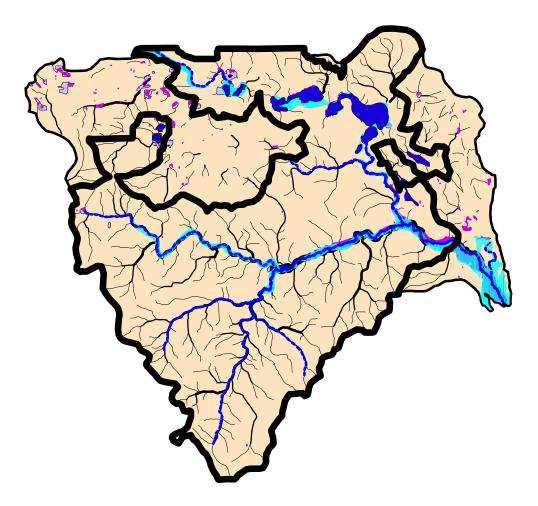
The actions of the geologic processes in building landform elevation and the weathering and erosional processes in diminishing landform elevation have produced an interesting topography. The "Topographic Elevation" map of the two watersheds reveals that elevations range from approximately 210 meters at the mouths of Browns Creek and Valley Creek, to 305m in the highest areas of the Browns creek watershed and 320m on top of the Platteville-Glenwood Formation in the western portions of the Valley Creek watershed. The "Topographic Slope" map reveals that extensive areas containing topographic slopes of less than six percent exist throughout the outwash plain in the central and northern portion of the Valley Creek watershed. Yet, Bissels Mounds, the erosional remnants of the Platteville-Glenwood Formation, rise 30m above this extensive area of level to undulating topography. Slopes greater than 12% are associated generally with transitions between the Platteville-Glenwood formations and the Prairie du Chien Group in the western part of the watershed, areas immediately adjacent to the north or south branches of Valley Creek and with the pitted outwash area in the eastern portion of the watershed.

In comparison to Valley Branch, the Browns Creek watershed contains less land area that is steeper than 12%. The areas less than 12% tend to be more highly fragmented and geographically dispersed in Browns Creek than is true in Valley Creek. This pattern is attributable to three factors. The Browns Creek landscape is younger than the Valley Creek landscape, and it has experienced less erosion. Less erosion means less opportunity for steep slopes to evolve. The Browns Creek watershed contains a greater extent of the "kettle and knob" landscape of the St. Croix moraine than does Valley Creek. This landscape tends to contain more undulation than is true of most of the Valley Creek watershed. Finally, the Valley Creek outwash deposits contain predominately smooth outwash deposits, in contrast to the pitted outwash deposits of Browns Creek. Pitted outwash landscapes are characterized by debris dropping out of the ice sheet under the influence of gravity as opposed to debris moving off the ice sheet under the influence of flowing meltwater. Debris dropping out of the ice sheet creates more mounding of landform with stronger topographic relief than is true of the smoother and flatter land surfaces created by the deposition of stratified drift.

Development and Water Quality in Two Exurban Watersheds







# Surficial Hydrology

Legend

Wetlands

Drainage Order

Water bodies

Floodplain soils

Inventory Site

National Wetlands

1st order drainage

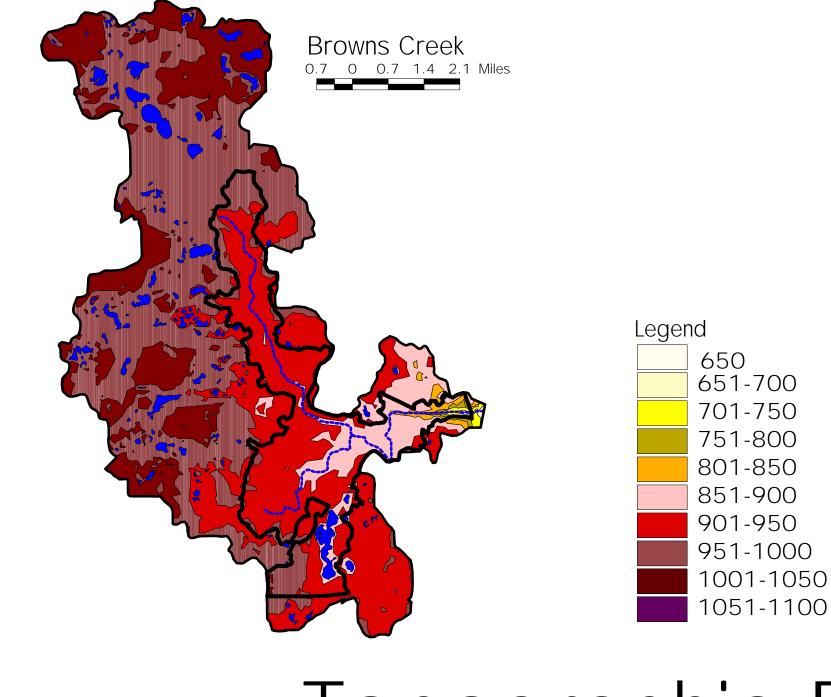
2nd order drainage

' 3rd order drainage

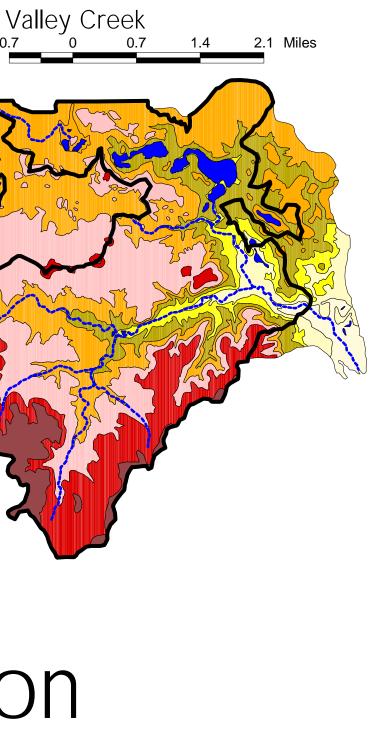
4th order drainage 5th order drainage



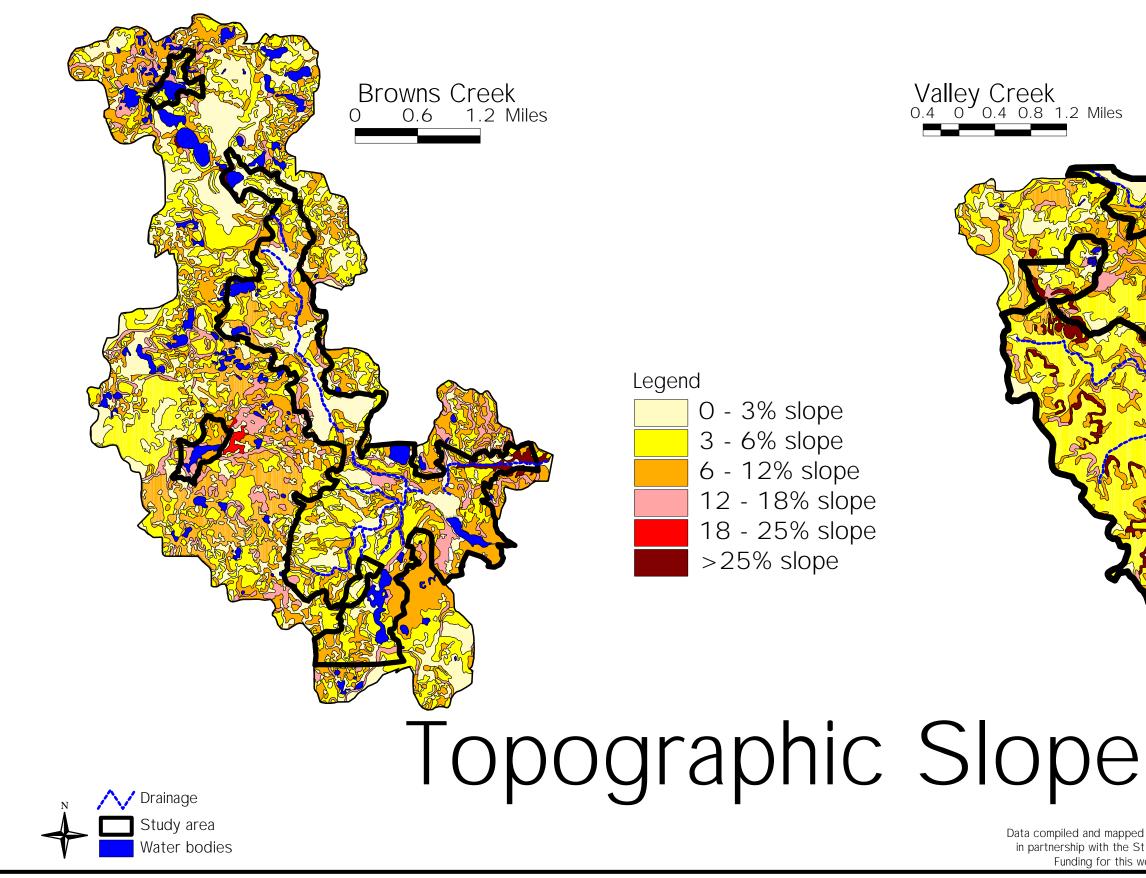
Development and Water Quality in Two Exurban Watersheds

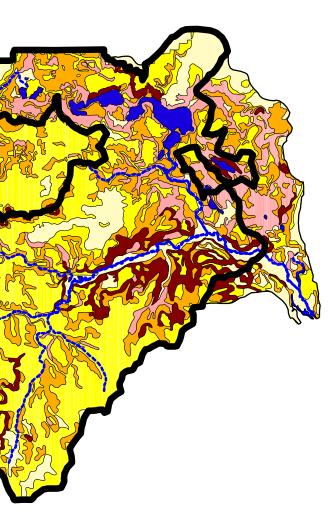


Topographic Elevation



Development and Water Quality in Two Exurban Watersheds





## **BIOGEOGRAPHICAL HISTORY OF VEGETATION IN THE WATERSHEDS**

The vegetative history of the two watersheds undoubtedly extends far beyond the inundation of the continental ice sheets during the Pleistocene Epoch of the Quaternary Period. However, its recorded effects on the contemporary Browns Creek and Valley Creek landscapes were all but obliterated by the intervening phases of glaciation.

## **Revegetation of the Post Glacial Landscape**

A rise in the mean annual temperature of the Earth's atmosphere, which occurred at approximately 13,000 years BP (Ojakangas and Matsch, 1982) spelled the end of the Ice Age, and by 10,000 years BP, the Earth's evolution entered the Modern Epoch (also known as the Holocene) of the Quaternary Period. The state of Minnesota was free of all ice from the Wisconsinan glaciation by 11,500 years BP (Wright 1972).

## **Advancement of the Post-Glacial Forest**

As the ice retreated, the landscape was clothed in tundra vegetation, a herbaceous plant community similar to what exists today in sub-polar regions of the Arctic or above treeline in mountainous landscapes. Continued climatic warming produced a boreal spruce forest in southeastern Minnesota by 11,500 years BP (Wright 1972). Pollen analyses conducted on bog sediments near St. Paul suggest a plant community between 12,000 and 10,000 years BP that may have been as much as 60% spruce. Birch became a component of the community by 11,500 years BP, and Jack Pine, Red Pine, Elm and Oak were part of the community by 11,000 years BP. At 10,000 years BP, the community may have been as much as 30% birch, but the birch quickly yielded to pines, elm and finally oak as the most abundant woody species (Ojakangas and Matsch 1982).

## **Development of the Prairie Community**

A warmer, drier climate continued to prevail, and by 8,000 years BP, prairie vegetation had spread to central Minnesota (Wright 1972). Prairie, perhaps enhanced by hunting practices of humans, reached almost as far north as Duluth by 7200 years BP (Ojakangas and Matsch 1982), and by 7000

years ago, the prairie-forest border was 75 miles northeast of its present position (Wright 1972).

## The Advancing Forest and the Development of the "Tension Zone"

At approximately 7000 years BP, the climate once again began to cool, and coniferous forests invaded deciduous forests that had migrated into northern Minnesota. Similarly, deciduous forests invaded prairie vegetation and the prairie-forest boundary or "tension zone" (Curtis 1971) migrated south to its present location (Wright 1972). The previously mentioned analyses of pollen from bog sediments near St. Paul suggest that at 9500 years BP, spruce, pine, birch, elm and oak may have accounted for approximately 85% of the surrounding plant community. By 7000 years ago, the same species may have accounted for less than 40% of the vegetation as prairie species reached their

highest levels of abundance. By 5000 years BP, spruce, pine, birch, elm and oak once again may have accounted for over 50% of the plant community. By 2500 years BP, oaks may have accounted for almost 50% of the vegetation, and spruce, pine, birch and elm may have accounted for another 20% of the vegetation (Ojakangas and Matsch 1982).

## **Presettlement Vegetation of the Watersheds**

Maps prepared from the field notes of people involved in the Public Land Survey of the St. Croix valley reveal an interesting vegetative pattern in the Valley Creek watershed at approximately 1850. From Prescott to approximately St. Mary's Point, the landscape was predominately "oak openings" and "oak barrens". This cover type contained some white oak and black oak, but it contained predominately bur oak that "had a scattered spacing, growing as individuals or grouped in loose clumps and forming a park like savanna within the open grasslands" (Finley 1976). Marschner (1974) also notes that the oaks tended to have a "scrubby form with some brush and thickets and occasionally with pines". The highest elevations of the watershed contained isolated patches of prairie. Just south of Afton and in the Valley Creek lowland area to the north and west of Afton, a pocket of "Big Woods" existed within the oak openings. Dominant tree species in the Big Woods include sugar maple, basswood, red oak, white oak and black oak (Finley 1976). The river terraces south of Bayport and extending to St. Mary's Point contained a riverbottomland forest of elm, ash, cottonwood, box elder, soft maple and willow (Trygg 1964). Prairie was the dominant vegetation in the areas west of the bottomland river terrace forests in the area between Bayport and Stillwater (Trygg 1964; Marschner 1974; Finley 1976).

Oak openings and oak barrens were the predominant vegetation within the Browns Creek watershed at the time of the Public Land Survey. A patch of "Big Woods" existed in the southeastern corner of the watershed. Marschner (1974) identified wet prairie extending along the west side of Highway 15 between Highway 96 and 110th Street in the City of Grant. A conifer bog existed along Lansing Road immediately south of Withrow.

## **DEVELOPMENT OF SOILS IN BROWNS CREEK AND VALLEY CREEK WATERSHEDS**

Soil consists of granular mineral components of varying sizes, organic material, water and air space. Soils develop in response to a number of factors. The geologic parent material of a soil imparts chemical properties to the soil that may affect such factors as fertility and water holding capacity. The extent and nature of weathering undergone by the parent material affects the size and shape of the granular components of soil. The extent of erosion experienced by the parent material also affects the location of the soil particle relative to its parent material. Topographic position and cardinal orientation or aspect within the landscape will affect the moisture content of the soil, and the steepness of the slope upon which the soil resides affects its propensity for erosion. Surface and subsurface hydrologic regimes will affect soil development by moderating the frequency and duration of conditions during which the soil is saturated with water. Prolonged saturation reduces the amount of oxygen available in the soil and this in turn moderates chemical reactions in the soil. Finally, the amount and type of organic material present in the soil affects conditions related to air and water relationships as well as soil fertility.

## Soil Parent Material Within **Browns Creek and Valley Creek Watersheds**

The Soil Survey of Washington and Ramsey Counties in Minnesota (Vinar1980) notes that soils in the Browns Creek and Valley Creek watersheds formed under numerous landscape conditions. The map entitled "Soil Parent Material" illustrates the parent material conditions from which the various soils in the watersheds formed. Soils created principally in glacial outwash plains and terraces are underlain by fine sand to gravelly coarse sands. Soils from outwash tend to be level and well drained to excessively well drained. These soils are found in Valley Creek on the outwash plain in the center of the watershed that surrounds Bissels Mounds. These soils extend in a southerly direction following the southern-most branch of Valley Creek, and they also extend throughout the northeastern corner of the watershed. Outwash soils exists within the Browns Creek Watershed District in the southeastern corner, in the southeastern corner of the City of Grant, in the Kismet Basin in the

vicinity of Pat Lake and the in the area extending northeasterly from Benz Lake.

Soils formed predominately in glacial till were created in upland conditions. Since these soils formed in glacial till, they tend to be loamy in texture (i.e. consisting of sand, silt and clay particles). The loamy nature of this upland soil produces good drainage. In Valley Creek, these soils are located in the northeast corner of Woodbury and the northwest corner of Afton. They also extend along both the southwestern and the southeastern boundaries of the watershed. Soils formed under ground moraine conditions (i.e. from material deposited beneath the Superior Lobe as opposed to being deposited at the margin of the sheet) are located in the eastern portion of the Valley Creek watershed In Browns Creek, these loamy, morainal till soils are found in the eastern end of the watershed, in the vicinity of Long Lake, in a southwesterly to northeasterly orientation extending through the central portions of the City of Grant, and in the northern portion of the District near Lake Paisted and the School Section lakes.

Soils formed on glacial lake bottom sediments are found on level to moderately sloping sites. In Valley Creek, these soils are found most prominently within the watershed near the intersection of Interstate 94 and County Road 15 (Manning Trail). In Browns Creek, these soils are scattered throughout the watershed. Concentrations of lake plain soils exist in the vicinity immediately west of the south branch in Stillwater Township, in the southeastern corner of the City of Hugo near South School Section Lake and in the soutwestern corner of May Township.

Many of the steepest slopes within the watershed contain soils formed from fragments of Prairie du Chien or Platteville-Glenwood dolomite that collapsed and moved down-slope. This form of soil parent material exists in the western portion of Valley Creek watershed along the eastern edges of the Platteville-Glenwood formation as well as in the central portion of the watershed along the bluffs overlooking the south branch of Valley Creek. These soils do not exist in Browns Creek watershed.

Finally, numerous areas exist in the Valley Creek watershed where soils formed in a wind-blown silt mantle with an underlying material of till or bedrock. Silt was blown into the watershed during a period of global warming between 7000 and 3000 years BP. The silt originated in the

Dakotas, and it was blown into the watershed by prevailing westerly winds. These silt-mantled bedrock soils are found predominately in the southern portion of Valley Creek watershed. Many of the drainage channels extending across the outwash plain in the central and northern portions of Valley Creek watershed contain soils formed from wind-blown silt. Significant portions of the outwash plain also were covered with wind-blown silt. Soils in these areas tend to be found on level to moderately sloping sites, and they are well drained. Soils formed in windblown silt do not exist in the Browns Creek watershed.

The pattern of the different soil parent material found in the two watersheds is illustrated in the maps entitled "Soils: Parent Material" and "GW Traces: Soil Parent Material."

The variability in soil formation within the watershed produced differences in soil properties that are largely attributable to whether the soil formed in a wetland, outwash or till condition.

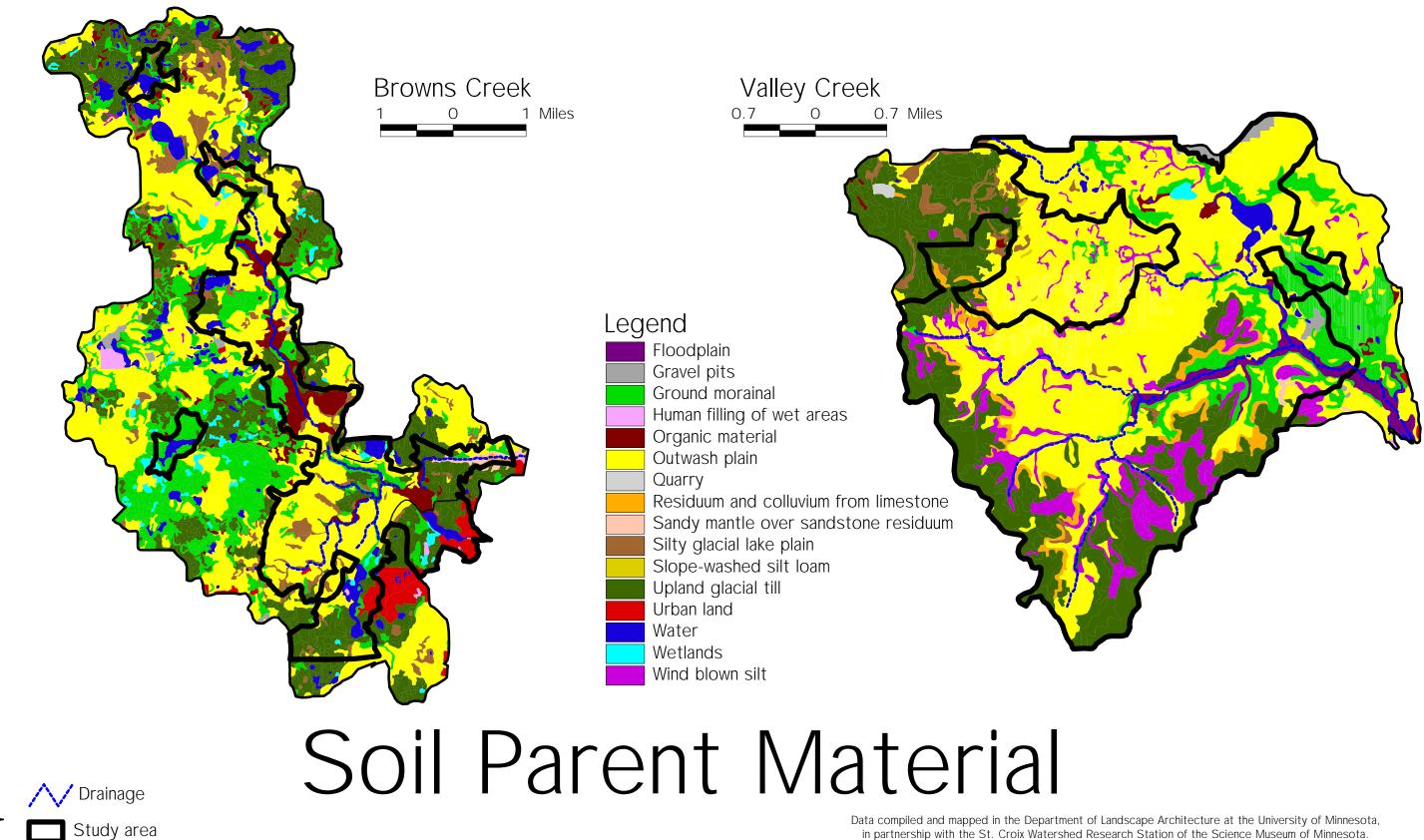
### **Hydric Soils**

The map entitled "Soils: Hydric" identifies the location of soils that formed in a wetland condition. For the most part, these soils contain peat and muck, and they are flooded for major portions of the year. Hydric soils typically have poor internal drainage, and they exist in a saturated condition.

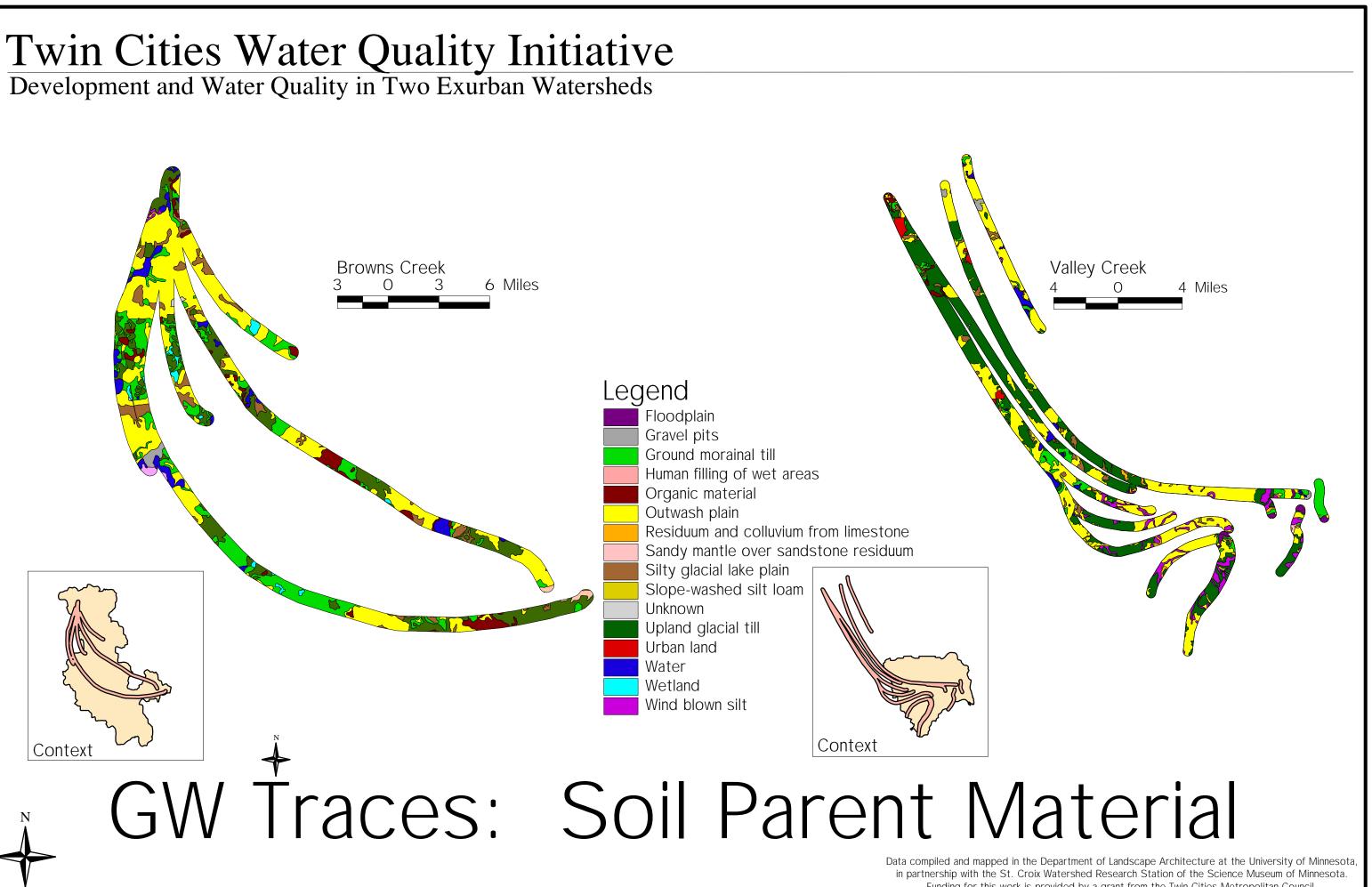
The pattern of hydric soils in the Browns Creek watershed parallels that found in the northern portion of the Valley Creek watershed but contrasts with the pattern found in the southern portion of Valley Creek. This is attributable to the fact that the Browns Creek watershed and the northern portion of the Valley Creek watershed are of similar age, and they evolved under similar conditions during the Wisconsinan glaciation. Within the Browns Creek watershed and northern one-third of the Valley Creek watershed, hydric soils are dispersed in a patchy pattern. Soil formation in these areas occurred in topographic depressions over prolonged periods of saturation created by highwater table conditions

## **Effects on Soil Properties**

Development and Water Quality in Two Exurban Watersheds

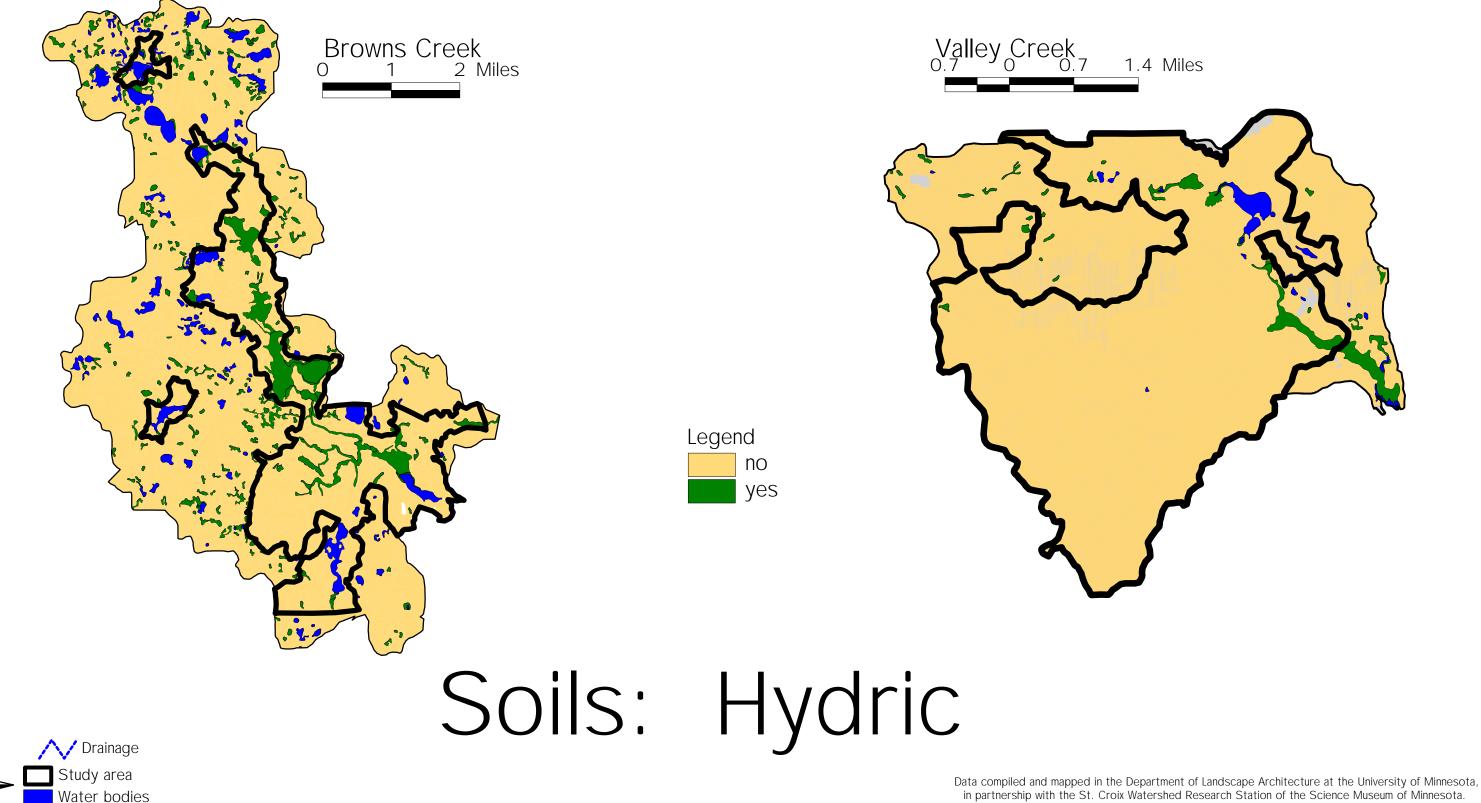


Funding for this work is provided by a grant from the Twin Cities Metropolitan Council.



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Development and Water Quality in Two Exurban Watersheds



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and poor surface drainage. Both locales also contain significant expanses of hydric soils located along the channel of their north branch. Finally, Valley Creek also contains extensive hydric soils associated with the mainstem of the creek between the confluence of the north and south branches and with the confluence of the mainstem and the St. Croix River.

The southern two-thirds of the Valley Creek watershed contains no hydric soils. This phenomenon is associated with the increased age of this landscape. Because this portion of the watershed was not glaciated during the Wisconsinan phase, it is over 100,000 years older than the northern one-third of the watershed or any portion of the Browns Creek watershed. The increased age of this landscape has produced a more mature drainage system leaving no surface water or wetland impoundments.

### Soil Drainage

Two soil drainage characteristics are particularly important to urban development.

Soil Infiltration Capacity. Soil infiltration capacity affects the rate at which surface water will move into the soil horizon. Soils having a high infiltration capacity absorb water while soils having a low infiltration capacity shed water. As less surface water is absorbed into the soil, more becomes available to join surface runoff. Infiltration capacity is measured in terms of the number of inches of water a soil will absorb in one hour. The USDA-Natural Resource Conservation Service has established a rating system known as hydrologic soil groups which classifies soils into four categories based on their infiltration capacity. Nearly all of the soils in the Browns Creek and Valley Creek watersheds are rated as having high or moderate to high infiltration capacity. Nearly all of the soils in the Browns Creek and Valley Creek watersheds are rated as having high or moderate to high infiltration capacity. Nearly all of the soils in the Browns Creek and Valley Creek watershed are rated as having high or moderate to high infiltration capacity. Nearly all of the soils in the Browns Creek and Valley Creek watershed are rated as having high or moderate to high infiltration capacity. Areas containing soils with low infiltration capacity are a result principally of shallow depth to bedrock or shallow depth to the zone of saturation. The spatial variability of infiltration capacity among soils in the watershed is illustrated in the maps entitled "Soils: Infiltration Capacity" and GW Traces: Infiltration Capacity."

**Soil Permeability**. Soil permeability measures the rate at which water will move through the soil horizon once it has entered the soil. Soil permeability is measured as the number of inches of water that will drain vertically in the soil horizon in one hour when the soil is at field

capacity. The outwash soils in the watershed generally have higher permeability rates than do the soils formed in glacial till. Thus, the central, northern and eastern portions of Valley Creek, and the western portion of Browns Creek, have higher rates of permeability than do the other parts of the watersheds. The spatial variability of permeability among soils in the watersheds is illustrated in the maps entitled "Soils: Permeability" and "GW Traces: Permeability."

**Depth to Zone of Saturation**. In digging below the surface of the land into the underling soil profile, a zone if often reached where all of the pores between the granular mineral and organic constituents of the soil are filled with water. The depth at which all pores are filled with water is known as the depth to the zone of saturation. This depth is often referred to as the water table in the soil. Depths to zone of saturation will vary in different landscape conditions. Where regional water tables are close to the surface of the land, the depth of the zone of saturation will be relatively shallow. These conditions often exist in expansive wetland complexes or in areas where ground water is discharging into the base flow of streams. Shallow depths to the zone of saturation can also be produced when the zone of saturation is "perched" on top of an impermeable layer of unconsolidated geologic material (e.g. clay). In these conditions, the saturation is attributable to the inability of the water to penetrate through the impermeable underlying material.

The map entitled "Soils: Depth to Zone of Saturation" illustrates the distribution of the varying depths to saturation that exist within soils in the two watersheds. The majority of both watersheds is characterized by soils that have depths to saturation that exceed six feet. Within the Valley Creek watershed, there are three principal location s of soils having depths to the zone of saturation that are less than six feet. The bottomland floodplain areas along the mainstem, the South Branch and the North Branch of Valley Creek all contain soils with less than six feet of depth to the zone of saturation. In addition, there are wetlands located west of Lake Edith that also have shallow depths to saturation. The extensive wetland complexes located in the northwest corner of the watershed also have shallow depths to saturation.

The pattern of soils containing shallow depth to saturation is more complex in the Browns Creek watershed. A central spine of shallow saturation parallels the extensive wetland areas through which the North Branch of Browns Creek passes. There are also extensive areas of soils containing shallow depth to saturation located in the southeast corner of May Township. Throughout the remainder of the watershed, the pattern of soils containing shallow depths to saturation is fragmented. Lowlying areas in the "kettle and knob" landscape of the St. Croix moraine often contain soils that have shallow depths to saturation. Similar conditions are also found in depressional features of the outwash landscape.

### Soil Erodibility

The propensity of soil to erode as a result of surface hydrological processes is affected by several soil properties, including the size and shape of the soil particle, the mixing of soil particle sizes present in the soil matrix and the slope upon which the soil resides. Soils having uniform particle sizes that are relatively small and granular in shape and residing on steep slopes tend to have the greatest propensity for erosion generated by surface runoff. Within the Valley Creek watershed, these conditions are especially prevalent in the upland conditions on the north and south side of the south branch of Valley Creek. The areas adjacent to Lake Edith, in the eastern part of the watershed and the Falstrom Lakes area, and along the more steeply sloping areas where the landscape transitions from the Prairie de Chien dolomite to the Platteville-Glenwood Formation also contain highly erodible soils. Within the Browns Creek watershed, soils found on steeper slopes in the eastern, central and northern portions of the watershed tend to be more erodible.

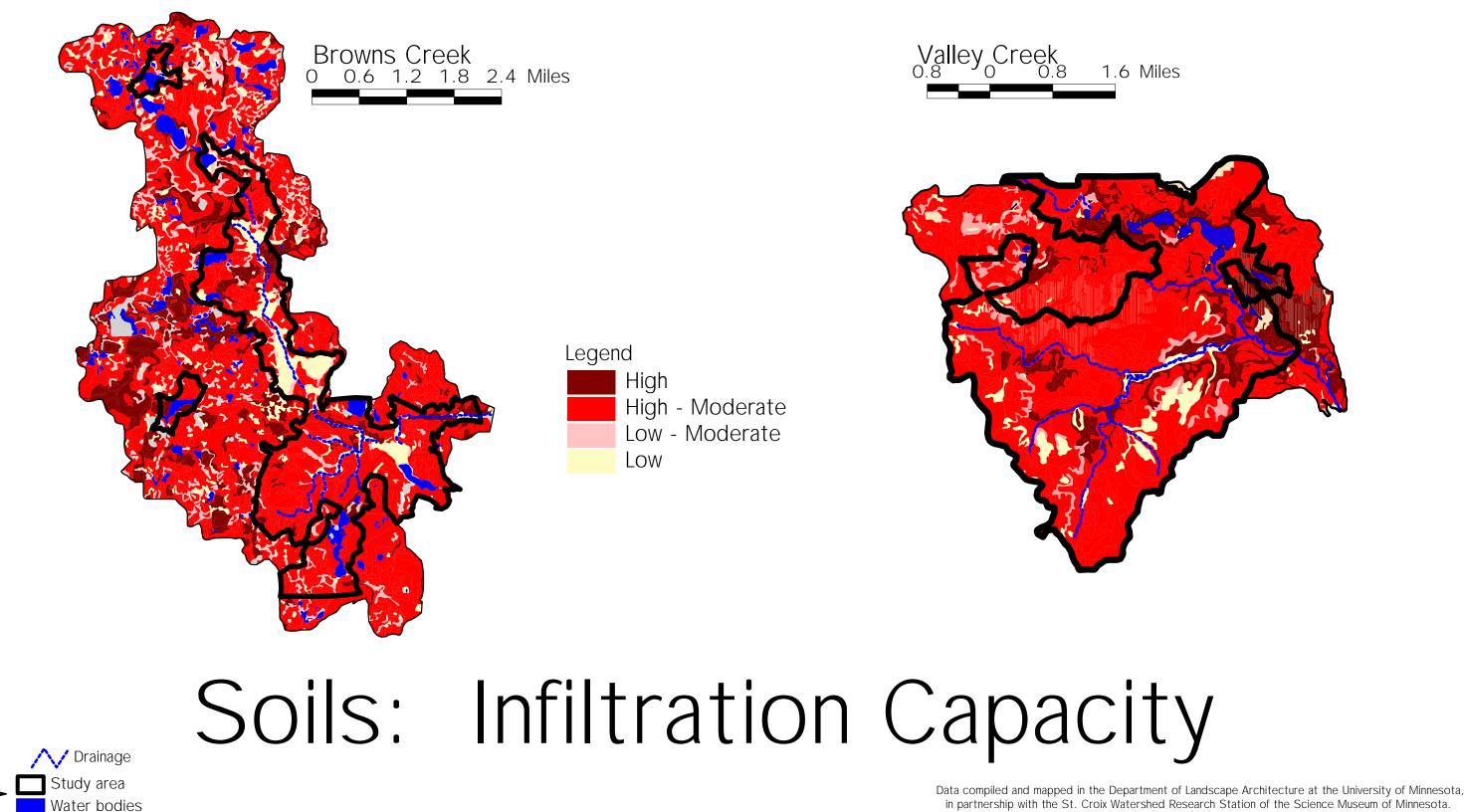
The spatial variability of erodibility among soils in the watershed is illustrated in the map entitled "Soils: Highly Erodible Soils."

### **Soil Flooding**

Soils in low-lying areas and in wetland areas tend to experience periodic flooding primarily because they possess a relatively shallow depth to saturation. Within the Valley Creek watershed, these conditions tend to be most prevalent along the mainstem and south branch of the creek and in the wetland areas located in the northwest portion of the watershed. The pattern of soils flooding in the Browns Creek watershed tends to be more dispersed than that for the Valley Creek watershed. Soil flooding tends to be more predominent along the north and south branches of the creek and in the wetland area immmediately north of Lake Mckusick.

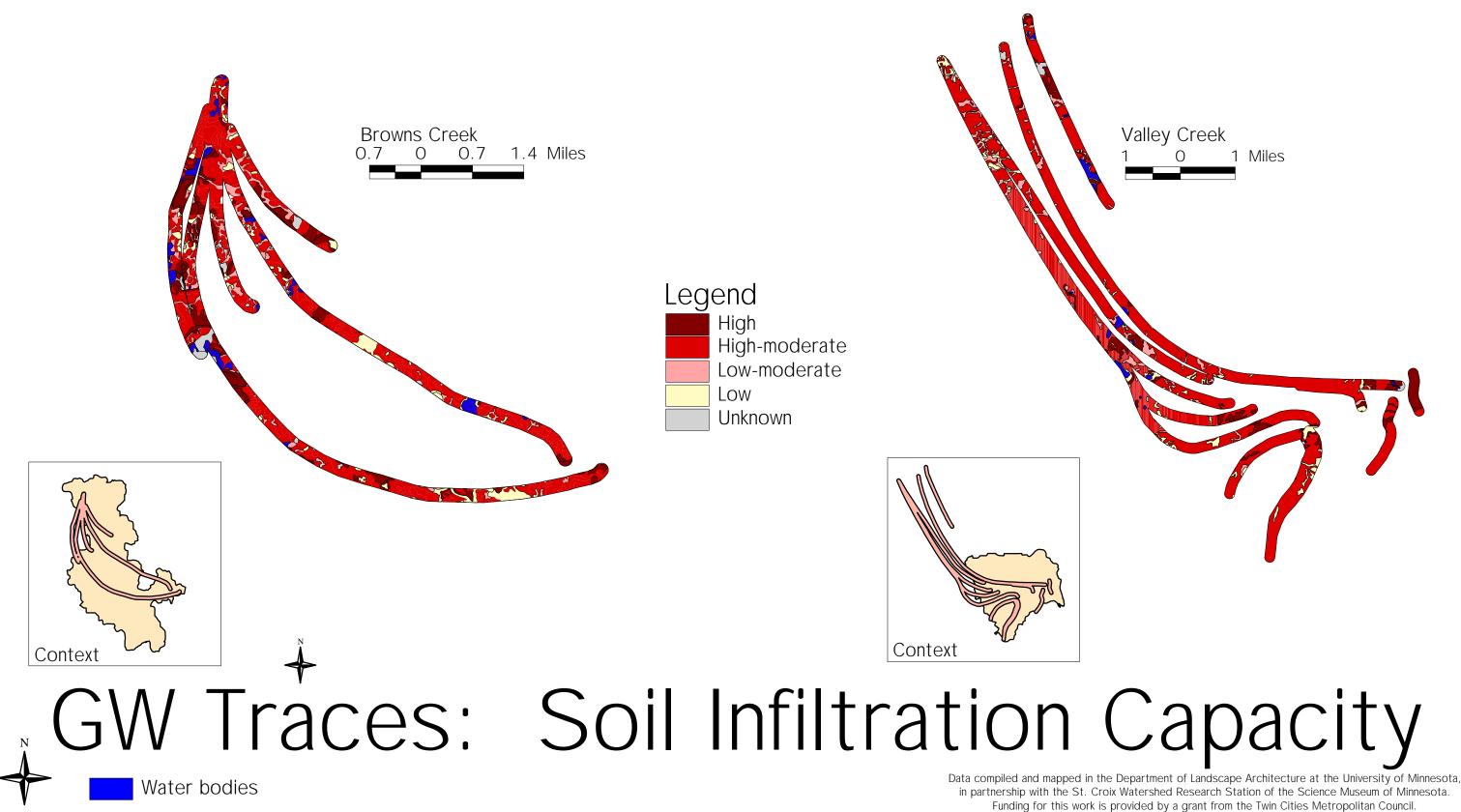
The spatial variability of flooding among soils in the watershed is illustrated in the map entitled "Soils: Flood Frequency."

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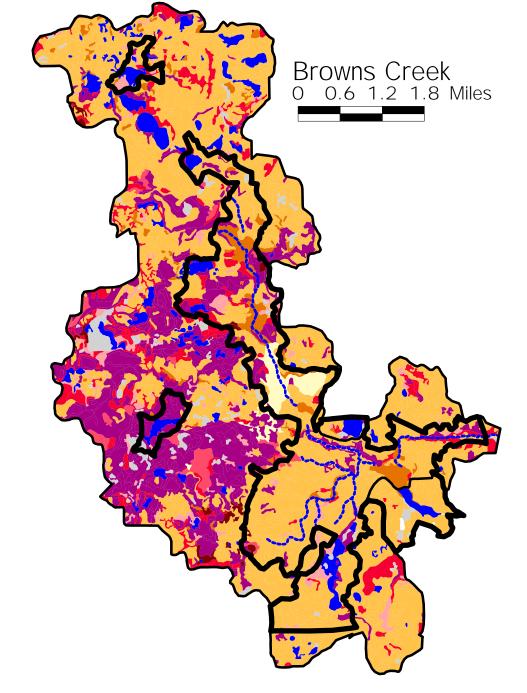


Funding for this work is provided by a grant from the Twin Cities Metropolitan Council

Development and Water Quality in Two Exurban Watersheds



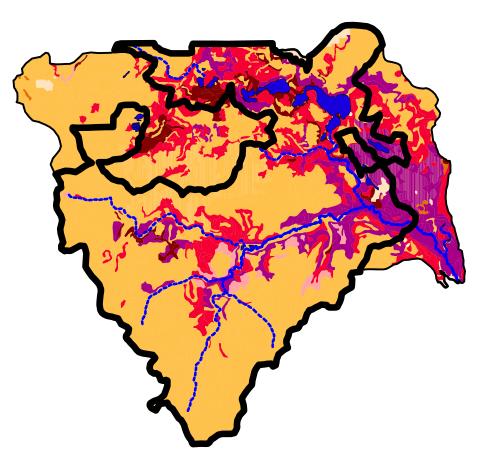
Development and Water Quality in Two Exurban Watersheds





#### Legend

>0.2 inches per hour 0.2-6.0 inches per hour 0.6-2.0 inches per hour 0.6-6.0 inches per hour 2.0-20 inches per hour 2.0-6.0 inches per hour 6.0-20 inches per hour >20 inches per hour

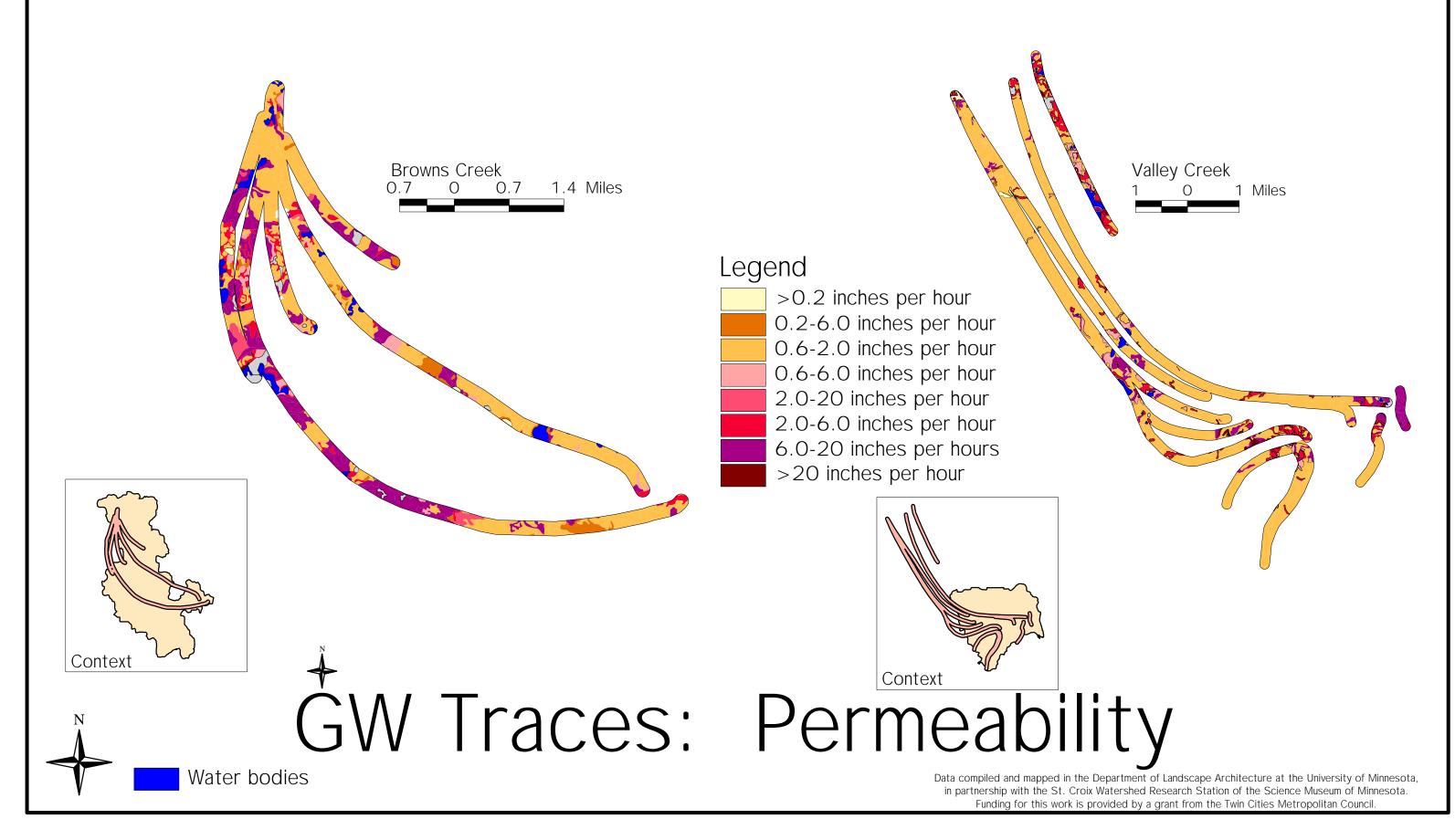


# Soils: Permeability

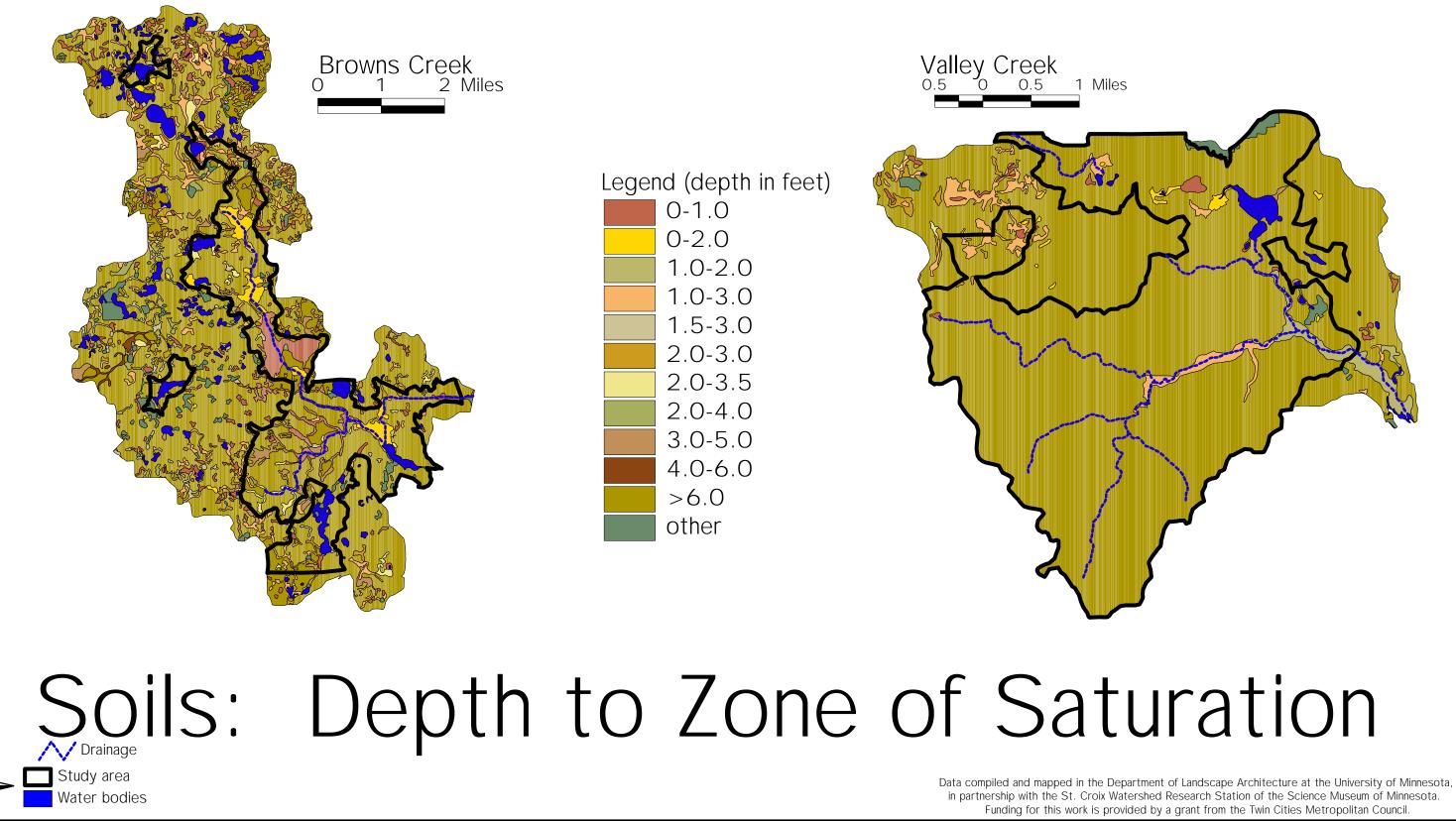


Data compiled and mapped in the Department of Landscape Architecture at the University of Minnesota, in partnership with the St. Croix Watershed Research Station of the Science Museum of Minnesota. Funding for this work is provided by a grant from the Twin Cities Metropolitan Council

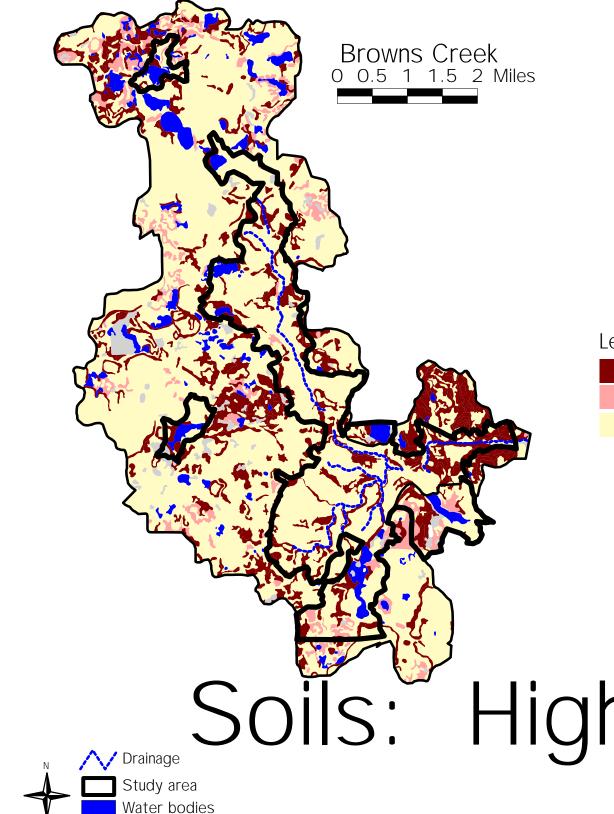
Development and Water Quality in Two Exurban Watersheds



Development and Water Quality in Two Exurban Watersheds



Development and Water Quality in Two Exurban Watersheds





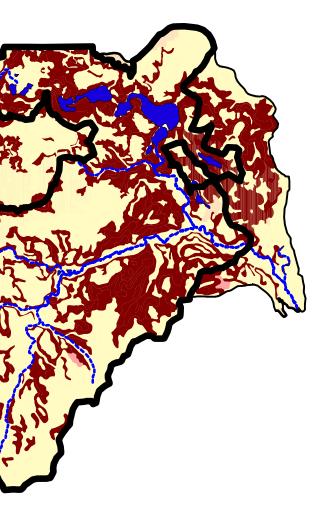
#### Legend



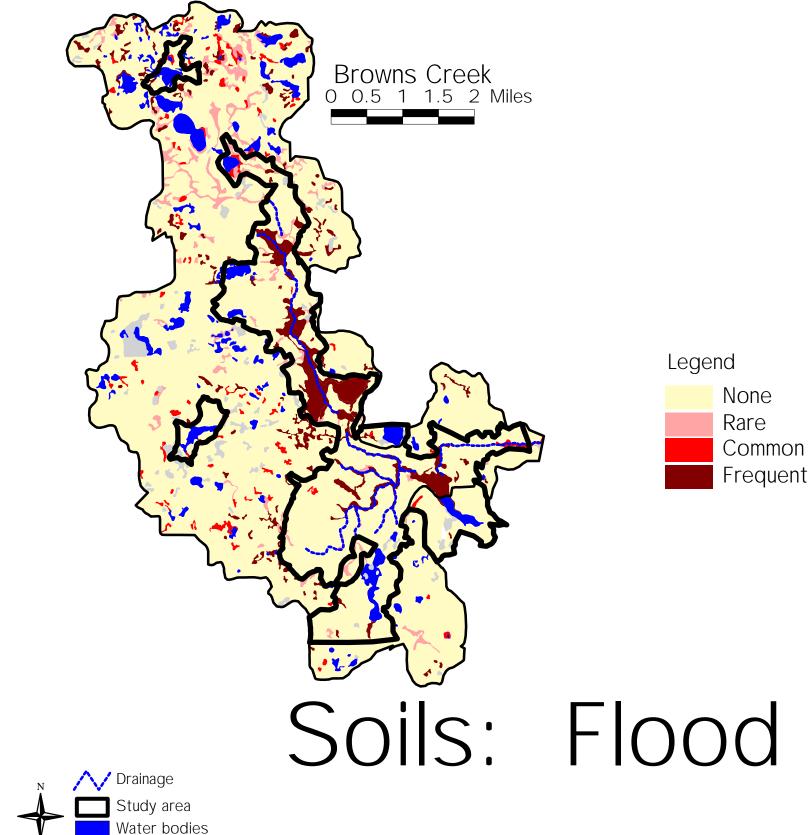
Highly erodible soil Possibly highly erodible soil Not highly erodible soil

# Soils: Highly Erodible Soils

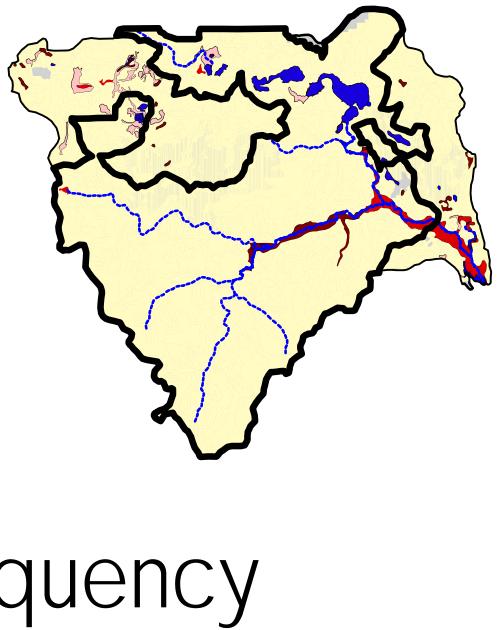
Data compiled and mapped in the Department of Landscape Architecture at the University of Minnesota, in partnership with the St. Croix Watershed Research Station of the Science Museum of Minnesota. Funding for this work is provided by a grant from the Twin Cities Metropolitan Council.



Development and Water Quality in Two Exurban Watersheds



Valley Creek 1.6 Miles



# Soils: Flood Frequency

Data compiled and mapped in the Department of Landscape Architecture at the University of Minnesota, in partnership with the St. Croix Watershed Research Station of the Science Museum of Minnesota. Funding for this work is provided by a grant from the Twin Cities Metropolitan Council

# **CULTURAL HISTORY OF THE ST. CROIX RIVER VALLEY**

The cultural history of Browns Creek and Valley Creek watersheds dates back 12,000 years to the period immediately following recession of Grantsburg Sublobe. Evidence of cultural development prior to the period of Early Contact between Native American inhabitants of the St. Croix River valley and European explorers has been investigated using anthropological and archeological methods. Recordation of the valley's history since the Early Contact Period has relied on more traditional methods of historiography.

#### **History of Native American Occupation of the St. Croix** Valley

#### **Pre-historic Inhabitants**

As early as 12,000 years BP, Paleo-indians hunting mammoths were probably active in the St. Croix valley. During the period 9000 to 2500 years BP, native Americans of the Archaic Period occupied the valley and/or its surrounding landscape. They used copper to make axes, knives, fishhooks, harpoons, spear points, bracelets, and beads. This culture was making complicated metal tools several thousand years before their counterparts in Egypt and the Tigris Valley (Curtis 1971). The Archaic indians were nomadic hunters.

Between 3500 and 1500 years BP, the Early Woodland Period of Native American occupation emerged. Native communities during this period became more sedentary, and the inhabitants began extensive use of clay pottery.

The Hopewell and Effigy Mound cultures flourished between 1500 and 1000 years BP. The Hopewellians were highly skilled in arts and crafts, making objects in chalcedony, obsidian, and jasper. They raised corn, beans, tobacco, and squash; they understood the art of textile weaving; and they made beads of hammered silver and copper, pearls, and shells. Such a cultural development undoubtedly was based on a highly organized division of labor and could have occurred only under rather high population levels with strong political and religious controls.

The Effigy Mound Builders existed contemporaneously with the Hopewellians. The Mound Builders constructed ceremonial or totem mounds in life-like effigies of birds, turtles, snakes, bison and other animals. This culture attained its acme in Wisconsin. Effigies constructed during this period are apparent on hillcrests overlooking lakes, streams, or springs in southern Wisconsin. The mounds were built from hand-carried basket-loads of earth. The size and internal structure of these mounds indicate that they were probably built in treeless prairie landscapes. The culture combined hunting and agriculture, and it likely migrated with the seasons according to the availability of game and plant foods. The early mound builders abandoned their earthworks at Lac Court Orielles and abandoned the area in approximately 1225 BC (Curtis 1971).

Between 1000 and 1600 AD, the Mississippi period or the last prehistoric period of Native American cultural development emerged. Three cultures occupied this period, the Middle Mississippi, the Upper Mississippi, and the Late Woodland. The Upper Mississippi people were most abundant along the Mississippi and Lake Winnebago. They are thought to have lived in large permanent villages, and they supported themselves by agriculture, hunting, and fishing. They made garden beds of raised mounds of earth, often in intricate curving patterns of parallel rows. Their use of metal was less than that of the Hopewellians and their artistic abilities were also less well developed.

A single village, Aztalan, in Jefferson County reflects the culture of the Middle Mississippi people. This was a large stockaded village, 20 acres in size with numerous homes. Villages of very similar type were seen in the southern portions of the continent by DeSoto in 1541, but they had completely disappeared when Joliet explored the Mississippi, a century later. Some archaeologists are of the opinion that the Spaniards introduced measles and smallpox, which completely wiped out the susceptible Indians in their compact village units. The Woodland Indians, in smaller, isolated bands, escaped.(Curtis 1977)

The Late Woodland culture people made pottery and dug burial mounds. Some mounds along the St. Croix are dated at 1225 AD. A Late Woodland fishing camp site under about 18 inches of accumulated soils in Minnesota 's Interstate Park camping/picnic area has been dated at between 1000 and 1300 AD (Crawford undated).

#### **Impact of Pre-historic Native Americans on** Landscape Pattern

Occupation of the St. Croix valley by pre-historic Native American cultures had at least five impacts on the pattern of the landscape (Curtis 1971).

**Fire.** The continued existence of oak openings, prairies, and shrub communities in the St. Croix valley depended on regular pattern fire disturbance. Fire suppressed establishment of woody vegetation that would ordinarily have occupied this landscape, and it allowed the herbaceous grassland and scattered patches of bur oak to predominate. The frequency of lightening strikes does not explain the maintenance of these landscapes. The presence of nomadic hunting tribes throughout the valley in the entire post-glacial period meant that human-made fires were an important if not the sole cause of the fires. A few widely scattered tribes of natives could start enough intentional and accidental fires to keep all but the most protected sites in a fire seral climax condition where prairie and oak openings predominated over woody vegetation.

Hunting. Native American communities affected the diversity, richness and distribution of animal populations through their fire-starting activity and through their influence on the populations of large mammals.

Agriculture. Many of the early sedentary cultures favored floodplain forests sites for food protection. Native woodland vegetation was removed by girdling the trees. However, the total land area affected by agricultural practices was small.

Native Plants as Food Sources. Berries and nuts (e.g. hackberry, walnut, hickory, acorns, and hazelnut) were favorite food sources for many Native American communities. The act of gathering these food stores did not affect the abundance of these species with the possible exception of the Pomme de Prairie (Psoralea esculenta), a legume prized by the Indians. This plant may have been gathered to the point of reducing population levels.

**Intentional and Accidental Plant Introduction.** Circumstantial evidence suggests that introduction of some plant species not normally found in the valley may have occurred as a result of Native American occupation. Species that were possible introduced during this period include Canada plum, white gentian, wild leek, sweetflag, and groundnut and Kentucky coffee tree (Curtis 1971).

#### More Recent Native American Communities

Ojibwe Indians, displaced from the St. Lawrence River valley by westward movement of Iroquois tribes farther east, begin to move into the Western Lake Superior region in the 1500's. Their movement down into the St. Croix valley during the mid 1600's established a period of conflict with the woodland Dakota that was to last for two centuries (Crawford undated).

In 1745, a major Dakota-Ojibwe battle near Lake Mille Lacs forced the Dakota people out of area around the St. Croix valley. However, war parties continued to enter the valley from villages in the St. Anthony Falls area and along the Mississippi River (Crawford undated). In the 1770's, an Ojibwe war party from Madeleine Island, Wisconsin, encountered Dakota and Fox Indians near today 's NSP hydroelectric dam at St. Croix Falls, Wisconsin. Ojibwe victory in the battle drove the Dakota from the valley. This was the last full-scale Indian battle in the valley (Crawford undated), although skirmishes continued into the mid-nineteenth century. A treaty signed by the Ojibwe and the Dakota at Prairie du Chien, Wisconsin in 1825 established a line of demarcation between the two tribes extending from the present-day location of Eau Claire, Wisconsin through Cedar Bend on the St. Croix River to the present-day location of St. Cloud (Dunn 1979).

The military contests between the Dakota and the Ojibwe caused significant change in the vegetative pattern of the St. Croix Valley landscape. Since political control of the valley remained contested for a period approximately 200 years, neither tribe established permanent settlements. The absence of permanent human occupation resulted in the cessation of human-generated fire. The absence of fire in the landscape transformed many areas that had been described by early European explorers as grassland and oak openings into brush or young forests. The vegetation records provided by the government land survey in the years from 1830 to 1860 reflect changes that had occurred in the preceding 200 years under the influence of unstable and varied Indian populations, but they do not properly indicate the prehistoric conditions (Curtis 1971).

# **European Exploration of the St. Croix Valley**

In 1654, French explorers Radisson and Grosseillers explored southern Minnesota, becoming the first recorded white men in the state. Radisson and Grosseillers explored Lake Superior by canoe between 1658 and 1660. They later explored the Mississippi River, and they may have reached the mouth of the St. Croix (Crawford undated).

Daniel Greysolon, Sieur Dulhut (Daniel Duluth) entered the St. Croix valley in 1680 by way of the Brule River. He traveled the length of the St. Croix, the first European to make this trip. He attempted to make peace among the Indians in anticipation of opening fur trade in this area. Dulhut claimed the St. Croix valley for France.

#### **Expansion of the Fur Trade**

During Dulhut's second trip to the St. Croix in 1683, he built a trading post somewhere in the St. Croix area. A fur-trading post was also established near Danbury, Wisconsin in the late 1680's (Crawford undated).

In 1693, Pierre LeSeur established a post near the mouth of the river to keep the St. Croix/Brule River route open for French fur trade. Fort St. Croix, a French fort and fur trade post, was reportedly built and operated near the St. Croix Dalles in 1770 (Crawford undated). French fur traders found themselves in increasing competition with English newcomers in eastern North America. During the late 1700's, two English fur companies, the Northwest Company and the XY Company, were established. The Northwest Fur Company established operations in Minnesota in 1789. The holdings of these two companies were acquired later by John Aster's American Fur Company. Lawrence Booth opened a fur post in the Taylors Falls area in 1793. In 1825, the Indian agent at Fort Snelling licensed the Columbia Fur Company to operate the Fort Barbour fur trading post at St. Croix Falls. In his travels to the St. Croix valley in the mid-1830's, Joseph Nicollet reported finding many fur posts still in operation. Such a post was operating in the Taylors Falls area in 1837. Toward the end of the 1830's the fur industry declined and essentially disappeared from the St. Croix valley (Crawford undated).

#### Cession of the St. Croix Valley to the United States

In 1763, France was defeated in the French and Indian War. The Treaty of Versailles ceded control of the St. Croix valley to England (Crawford undated). After the American Revolution provided independence for the United States in 1783, the claims of the original 13 colonies to land west

of the Appalachian Mountains were ceded to the newly formed republic. The St. Croix valley was described by the Land Ordinance Survey Act of 1787 as part of the Northwest Territory that extended westward to the Mississippi River. In the early nineteenth century, the valley became part of the Indiana Territory and subsequently part of the Illinois Territory and the Wisconsin Territory (Crawford undated). When the Wisconsin Territory was authorized to begin movement toward statehood in 1846, the federal government used the St. Coix River rather than the Mississippi River to define the potential state's western boundary (Dunn 1979). Despite much debate over the appropriateness of this boundary definition, the St. Croix River remained the western boundary of Wisconsin when it became a state in 1848. Formation of the Minnesota Territory west of the St. Croix River followed, and the territory became a state in 1858.

#### **Development of the Timber Industry**

The first reported harvesting of timber by white settlers occurred in 1836 when pine logs were harvested in the Taylor's Falls area with Ojibwe permission but against the wishes of the US government. Most of the 200,000 board feet of pine burned subsequently in a forest fire (Crawford undated). In 1837, Franklin Steele built a cabin on the Wisconsin side of the St. Croix Falls to establish a claim to the water rights for lumber milling. Steele established the St. Louis Lumber Company, and he completed a dam in 1840. The mill was completed in 1842, but it ceased operation in 1845. Jesse Taylor and Benjamin Baker also built a dam and sawmill near the site of the present highway bridge and the upper boat landing in Taylor's Falls. They constructed a log house, the first building within what is now Taylor's Falls. In 1837-38, the logs cut and floated on the St. Croix and its tributaries amounted to 300,000 board feet (Crawford undated).

The first commercial sawmill in Minnesota began operation at Marine Mills, now Marine-on-the-St. Croix, in 1839. Some of the trees being cut at this time were 6 feet in diameter. A commercial mill was established in Stillwater in 1844. Arcola was established and platted in 1846. Early plans reveal never-to-be-realized intentions for a community of sawmills. A second dam was built in the Dalles in 1847, and Caleb Cushing's Boston Lumber Company began operation in St. Croix Falls. The mill burned the subsequent year.

The establishment of government land offices in 1848 and 1849 provided a means for the first legal sale of timberland. The average price for much of this land was \$1.25 per acre, although some sold for as little as 10 cents an acre. Logs cut in St. Croix River watershed between 1847 and 1848 produced 26,000,000 board-feet of lumber. However, a nationwide financial crisis and the depletion of the timber resource brought a significant downturn to the timber industry on the St. Croix River.

#### Abbreviated Timeline of Settlement in the St. Croix Valley

#### Date Event

- 1803 This part of Minnesota was part of Indiana Territory.
- 1809 This part of Minnesota became part of Illinois Territory.
- 1838 Franklin Steele built cabin near what is now St. Croix Falls. Jesse Taylor and Benjamin Baker built cabin near what is now Taylor's Falls.
- 1839 St. Croix County, Wisconsin was established.
- 1840 Arcola was platted.Population of St. Croix Falls was 20.
- 1849 Point Douglas was platted on the western side of the mouth of Lake St. Croix. Named after Stephen D. Douglas.
- 1849 Lakeland Village was platted.
- 1850 Scandia was established.
- 1851 Taylors Falls was platted.
- 1852 South Stillwater was platted. Built on part of the former Oak Park site.
- 1853 Marine Mills was platted.
- 1855 Afton township was first settled and platted. It was named after the Robert Burns' poem, 'Afton Water' that gives a fine description of the 'neighboring hills, and clear winding rills.'
- 1857 Oak Park village site platted. Currently in location of Bayport.

1858 Afton Village was incorporated. Taylor's Falls was incorporated, Baytown was founded and later became known as Bayport. It was named after the bay created by Mulvey's Point. Marine Township founded. Lakeland Township is settled and organized Franconia township was organized and platted. Ansel Smith, who came from Franconia, N.H, named the township.

1884 Franconia Village was incorporated.

#### Growth and Development of the Valley Creek and Browns Creek Watersheds

In 1838, following cession of the St. Croix Valley by the Dakota and Ojibwe native Americans to the United States, white settlers began to enter the valley. The progression of this settlement in both time and space is evidenced by the abreviated timeline of settlement.

Settlements occurred earliest along the river and many of these communities evolved as centers of timber milling. Early examples of these communities established in the late 1830's through the 1840's include Taylors Falls, the present-day Marine-on-St. Croix and Stillwater. Several river communities, such as Arcola and Franconia Village, existed for short periods of time. These communities hoped to become centers of milling and river activity, but eventually their economic functions were overtaken by larger, more prosperous communities. Remnants of these settlements can be found in the contemporary landscape at places like Franconia landing.

Agricultural service centers began to evolve in the 1850's to serve the needs of the growing numbers of farmers who had moved into the valley. Afton, for example, was settled in 1855 and incorporated in 1858. Marine Township, Franconia Township and Lakeland Township, which was subsequently divided into West Lakeland and Baytown Townships, were settled in 1858.

Many of these communities experienced cyclical patterns of growth. The 1860 Census of Population, for example, enumerated the number of people residing in Afton Township at 360. This nimber grew steadily during the last half of the 19th century, reaching a zenith of 1130 in 1900. The first four decades of the twentieth century saw Afton's population decline to 889 in 1940. Following World War II, the Township's population grew dramatically. In 1960, 1181 people called the township their home. by 1970, the population of the twonship had increased by 69% to 1963. During the 1970's, a 28% increase in population growth occurred, and the number of township residents surged to 2550. The leveling-off of population growth continued during the 1980's as the township reached a 1990 poppulation of 2850.

In the 1970's, the Village of Afton and the Afton Township incorporated into the City of Afton. This enabled the community to deal more effectively with the benefits and costs of growth and development. A City Building Code was adopted in 1978, and a Zoning Ordinance and Sanitary Sewer Disposal Code were adopted in 1982. A Bluffland and Shoreland Ordinance was passed in 1985, and the city revised its Subdivision Ordinance in 1989. Afton revised its Shoreland Ordinance in 1991, and adopted an indovidual Sewage Treatment System Ordinance in 1993 to replace the Sanitary Sewer Disposal Code. A Heritage Preservation Ordinance and revised Floodplain Zoning regulations were adopted in 1994. Finally, in 1998, the City of Afton revised its Comprehensive Plan, reaffirming a desire to retain its status designated by the Metropolitan Council as a Rural Preserve.

#### Current Land Use in the Valley Creek and Browns Creek Watersheds

The prehistoric pattern of land cover has changed dramatically in the last 300 years. Prior to the immigration of the Ojibwe into the St. Croix Valley, the upland areas of both the Illinoian and the Wisconsinan landscapes were likely covered with oak savanna and oak openings. The low-lying areas were apparently part of the big woods community consisting of maple, basswood, elm and other lowland species. The grassland and bur oak communities of the savanna were apparently maintained largely through the fire management efforts of early prehistoric native peoples and subsequently by the Dakota. As the St. Croix became a zone of contention between the Ojibwe and the Dakota, the upland oak savanna began to fill in with brush land, as permanent occupants of the land were no longer present to steward the process of fire succession of the grassland community. Oak forests evolved, similar to the remnant forests found in the contemporary landscape.

Following establishment of Afton in 1855, most of the Valley Creek and Browns Creek watersheds were in cultivation by 1890. The pattern of cultivation encroached upon the oak savanna community as well as the emerging oak forest. The floodplain bottomlands in the two watersheds and associated hillsides were also brought into cultivation. Rougher, wetter and less fertile portions of the watersheds were reserved for woodlots. These forests undoubtedly contained substantial quantities of oak.

During the first 100 years of white settlement in the Valley Creek and Browns Creek watersheds, most inhabitants of the watersheds farmed the land. Except for Stillwater, the county seat of Washington County, most of the settlements existed as agricultural service centers.

Following World War II, and especially in the 1960's, the two watersheds began to experience new pressures for land use change. Enhancement of Highways 10 and 36 and construction of Interstate 94 made it now possible for watershed residents to work in St. Paul or Minneapolis. As the political jurisdictions within the two watersheds organized in the 1970's to manage this growth pressure, zoning and subdivision ordinances were passed that mandated minimum lot sizes of between one acre and ten acres. The advent of suburban development in the watersheds was accompanied by the abandonment of agricultural activity on the steeper, wetter and less fertile soils. Agricultural activity within the watersheds became more concentrated with fewer people owning and/or operating larger tracts of land. The concentrated agriculture has produced a decline in the number of working farmsteads, and some have been abandoned entirely.

The land use pattens that exist today in the two watersheds, (see maps entitled "Landcover" and "GW Traces: Land Cover") reflects yet another transitional point in time. From an original cover of oak savanna uplands and big woods bottomlands, land cover in the watersheds first transitioned into an agricultural matrix in both the bottomlands and the uplands. More recently, the bottomlands have become reforested, and an agricultural matrix containing interspersed patches of suburban development characterizes the uplands.

The following table illustrates that a considerably higher proportion of land area in the Browns Creek watershed is appropriated to development than is true for the Valley Creek watershed. The Valley Creek watershed contains over twice the percentage of crop land as does Browns Creek. Over two-thirds of the Valley Creek watershed is divided into parcels exceeding ten acres in size, whereas less than 50% of Browns Creek watershed area contains parcels larger than ten acres. The proportion of the Browns Creek watershed area containing lawn cover and residential subdivisions is almost twice as large as is true for Valley Creek. Similarly, the proportion of the Browns Creek watershed containing parcels less than one acre in size is over 16 times that of the Valley Creek watershed (see map entitled "Parcel Size").

	Watershed		
Land Cover Characteristic	Valley Creek	Browns Creek	
	-		
% watershed in crop land	25%	10%	
-			
% watershed in lawn cover	8%	14%	
% watershed in residential subdivision	on 7%	12%	
% watershed having parcel size:			
* less than one acre	0.3%	8%	
* one to ten acres	30%	44%	
* greater than ten acres	68%	48%	

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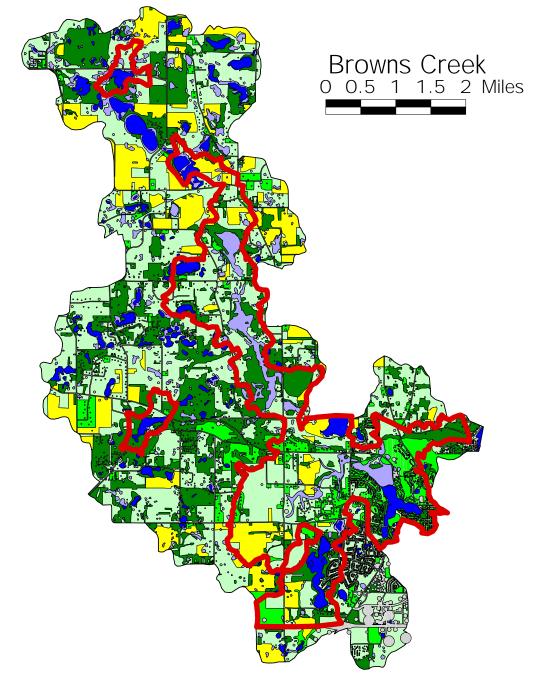
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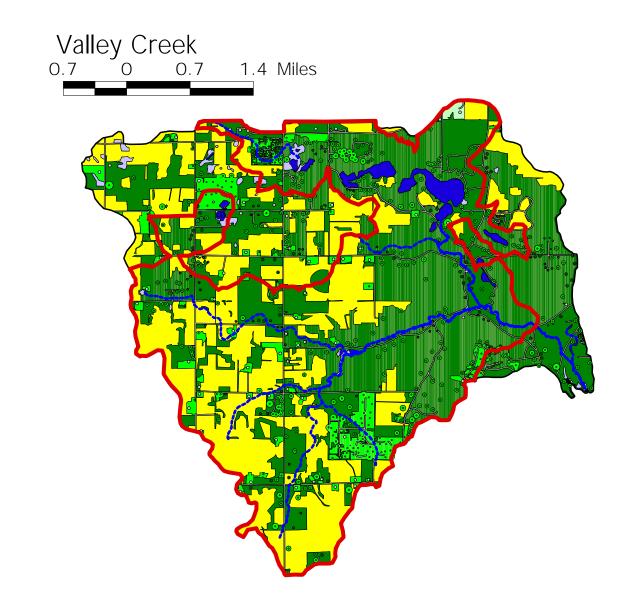
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Development and Water Quality in Two Exurban Watersheds





# Land Cover

Legend

// Drainage

Crops Forest

Lawn Other

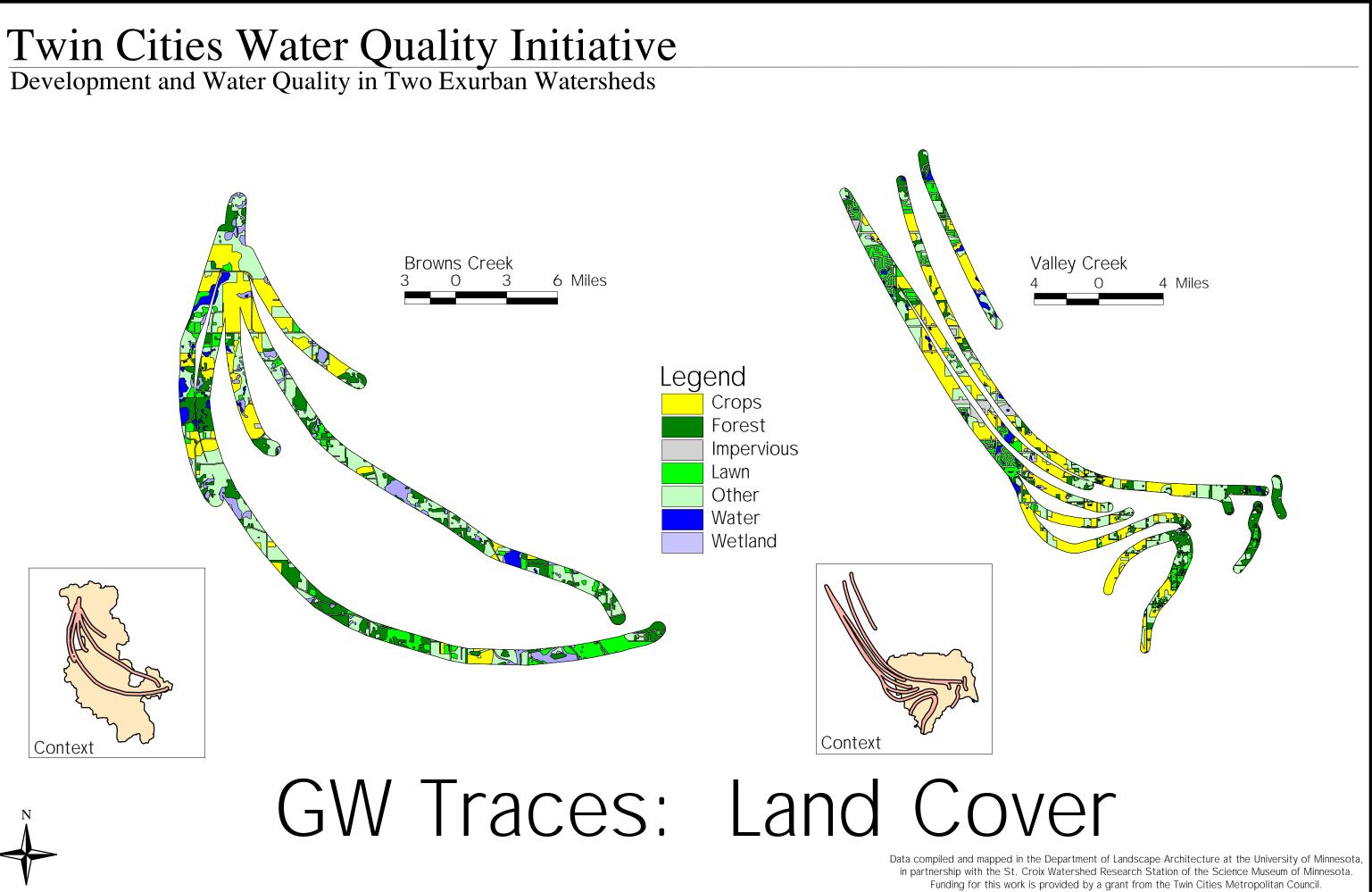
Impervious

Water body

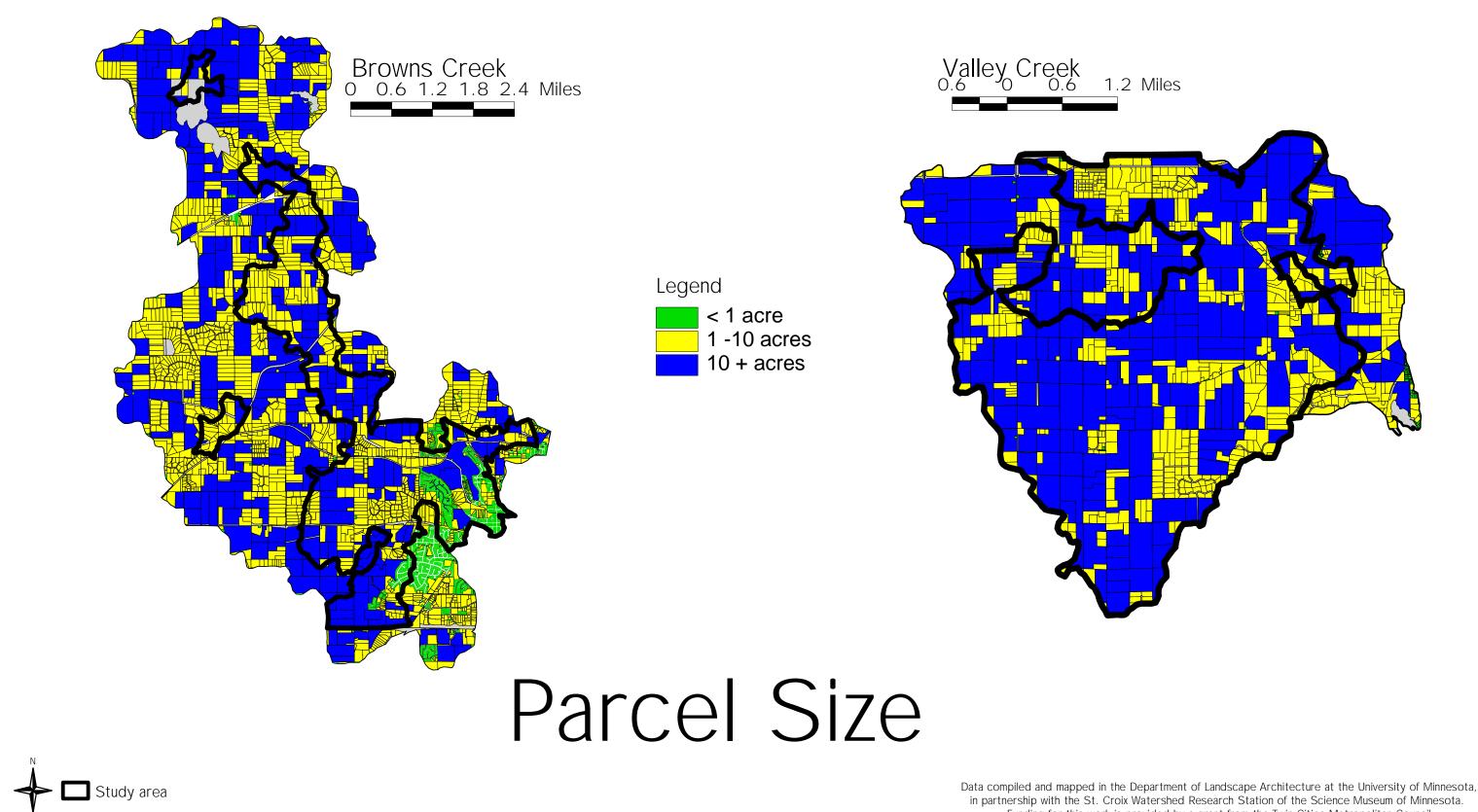
Wetland



Data compiled and mapped in the Department of Landscape Architecture at the University of Minnesota, in partnership with the St. Croix Watershed Research Station of the Science Museum of Minnesota. Funding for this work is provided by a grant from the Twin Cities Metropolitan Council.



Development and Water Quality in Two Exurban Watersheds



Funding for this work is provided by a grant from the Twin Cities Metropolitan Council.

# **Geographic Information Data Dictionary**

Geographic Theme	Type of Information	Source	Scale	Method of compilation	Con
Geographic extent of watersheds	polygon	Valley Branch Watershed District and Browns Creek Watershed District. Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute Quadrangles.	1:24,000	Legal boundaries of watershed districts were plotted on USGS 7-1/2 minute Quadrangles and digitized. Valley Branch District was truncated at Interstate 94, as described in text.	Geog
Bedrock geology	polygon	Mossler, J. H. and B. A. Bloomgren. 1990. Bedrock Geology. Plate 2. In L. Swanson and G. N. Myer. Geologic Atlas of Washington County, Minnesota. County Atlas Series C-5. St. Paul, MN, MinnesotaGeological Survey.	1:100,000	Polygons from Mossler and Bloomgren 1990 were imported from Minnesota Geological Survey data files.	Name bedro
Soils: Depth to Bedrock	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Depth 1 = 2 = 3 = 4 =
Surficial Geology	polygon	Meyer, G. N., R. W. Baker and C. J. Patterson. 1990. Surficial Geology. Plate 3. In L. Swanson and G. N. Myer. Geologic Atlas of Washington County, Minnesota. County Atlas Series C-5. St. Paul, MN, Minnesota Geological Survey.	1:100,000	Polygons from Myer et al. 1990 were imported from Minnesota Geological Survey data files.	Name surfic forma
Perennial and intermittent sreams.	line	Perennial and intermittent stream data were obtained in digital form from the Minnesota Department of Natural Resources. Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute . Quadrangles	1:24,000	Perennial and intermittent streams were imported from http://deli.dnr.state.mn.us. Data were verified from investigation of topographic quadrangles and field inspection.	Peren Intern
Drainage network	line	Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute Quadrangles.	1:24,000	Drainage network presented in perennial and intermittent drainage map was extended to include all first order streams as indicated by crenulations in topographic contour lines.	Identii 1 = 2 = 3 = 4 = 5 =
Surface water bodies	polygon	Surface water body data were obtained in digital form from the Minnesota Department of Natural Resources. Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute Quadrangles.	1:24,000	Data were imported from http://deli.dnr.state.mn.us. Data were verified from investigation of topographic quadrangles and field inspection.	Surfa
Wetlands	polygon	Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute Quadrangles. Digital orthophoto quadrangles obtained from the Metropolitan Council.	1:24,000	Wetlands were delinated by aerial photographic interpretation from orthophotographic quadrangles. Interpretations were corrorborated with Topographic Quadrangle and field investigations.	Wetla
National Wetlands Inventory Sites	polygon	National Wetland Inventory Survey conducted by the USDI-Fish and Wildlife Service	1:24,000	Data were imported from http://deli.dnr.state.mn.us.	Natio any tv 1. T 2. T a 3. T
Floodplain soils	polygon	Federal Emergency Management Agency	1:24,000	Data were imported from http://deli.dnr.state.mn.us.	100-у
10 foot topographic contours	line	Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute Quadrangles.	1:24,000	Topographic contours provided by USGS on mylar were scanned and attributed.	Eleva conto
50 foot topographic contours	polygon	Hudson, Lake Elmo, White Bear Lake East, Stillwater and Hugo USGS 7-1/2 minute Quadrangles.	1:24,000	Topographic contours provided by USGS on mylar were scanned and attributed.	Eleva conto



#### ontents ographic extent of the two watersheds. me of uppermost drock formation. pth of soil to bedrock is recorded in four classes: l = < 20 inches. 2 = 20 - 40 inches. 3 = 40 - 60 inches. = > 60 inches. me of uppermost rficial geologic rmation. rennial streams termittent streams entifies order of drainage within watershed: l = No tributaries enter the channel 2 =Two first order channels join together 3 = Two second order channels join together 4 = Two third order channels join toger ther = Two fourth order channels join together rface water bodies etlands as of 1998 tional wetlands inventory sites include landscapes that meet two of the following three criteria: . They contain hydric soils . They have a hydrologic regime such that their soil spends a portion of the year in a saturated condition . They support wetland vegetation 0-year floodways evation of land surface above mean sea level in 10 foot ntour intervals. evation of land surface above mean sea level in 50 foot ntour intervals.

Topographic slope	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identifies six classes of topographic slope associated with soil mapping units: 1 = 0 to 3% slope 2 = 3 to 6% slope 3 = 6 to 12% slope 4 = 12 to 18% slope 5 = 18 to 25% slope 6 = >25% slope
Soil Parent Material	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS). Soils data were reclassified based on processes of soil formation as described in Vinar 1980.	Identifies the geomorphic material from which each soil mapping unit evolved. Soil mapping units having common soil parent material were grouped together.
Soils: Hydric	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identifies hydric soils (i.e. soils formed in wetland conditions)
Soils: Infiltration Capacity	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identifies four soil hydrologic groups that describe soil infiltration capacity: 1 = Group A (high infiltration) 2 = Group B (moderate to high infiltration) 3 = Group C (moderate to low infiltration) 4 = Group D (low infiltration)
Soils: Permeability	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identifies seven categories that describe soil permeability: 1 = less than 0.2 inches per hour 2 = 0.6-2.0 inches per hour 3 = 0.2-6.0 inches per hour 4 = 0.6-6.0 inches per hour 5 = 2.0-20.0 inches per hour 6 = 6.0-20.0 inches per hour 7 = >20.0 inches per hour
Soils: Depth to Zone of Saturation	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identifies 11 categories that describe depth to zone of saturation 1 = less than 12 inches 2 = 12-24 inches 3 = > 24 inches 4 = 12-36 inches 5 = 18-36 inches 6 = 24-36 inches 7 = 24-42 inches 9 = 36-60 inches 10 = 48-72 inches 11 = > 72 inches

Soils: Flood Frequency	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identi 1 = 2 = 3 = 4=1
Soils: Highly Erodible Soils	polygon	Vinar, K. R. 1980. Soil Survey of Washington and Ramsey Counties, Minnesota. St. Paul, MN, University of Minnesota Agricultural Experiment Station; Washington County Surveyors Office; Map Unit Interpretation Database of the USDA-Natural Resources Conservation Service.	1:15,840	Topology was obtained from Washington County Surveyor's Office. Attribute information was linked to each soil mapping unit from the Map Unit Interpretation Database (MUIR) maintained by the USDA- Natural Resources Conservation Service (NRCS).	Identi 1 = 2 = 3 =
Land cover in 1998	polygon	1997 digital orthophotography and 1998 field reconnaissance. Minnesota Department of Transportation (MNDOT) Base Data CD. Surface water body data were obtained in digital form from the Minnesota Department of Natural Resources.	1:24,000	1997 digital orthophotography was interpreted to identify areas, containing crops, forest, lawn, grassland and shrubland complex and wetland. Photo interpreations were field checked for accuracy. Water was identified from surface water body data imported from http://deli.dnr.state.mn.us. Structures were digitized as point symbols from digital orthophotographs, and roads were imported from MNDOT Base Map data. Structure data were buffered by 30 meters to approximate impermeable surface area of rooves, driveways, decks, etc. Roads were buffered by 5 meters.	Identi crop fore imp law othe wat
Property parcel boundaries	polygon	Washington County Surveyors Office	1:24,000	Digital data were imported from Washington County Surveyors Office.	Descr

dentifies 4 categories that describe frequency of soil flooding 1 = none 2 = rare 3 = common 4= frequent dentifies 3 categories that describe soil erodibility 1 = not highly erosive 2 = possibly highly erosive 3 = highly erosive dentifies 7 categories that describe land cover: crops forest impervious lawn other (grassland and shrubland complex) water body wetland Describes property parcel boundaries