4. HYDROLOGIC SYSTEM

4.1 GENERAL

The City's current and proposed surface water system is shown on Maps 1 and 2. Expansion of the system according to this CSWMP will control surface water runoff and erosion, incorporate water quality treatment, and protect downstream priority water-bodies.

A comprehensive HydroCAD computer model of the City system has been developed. The following section provides details on the HydroCAD modeling. A general description of the surface water system is provided, along with identifying special issues for each basin area during the course of the CSWMP preparation.

4.2 HYDROLOGIC MODELING

4.2.1 Runoff and Land Use

Stormwater runoff is defined as that portion of precipitation that flows over the ground surface during, and for a short time after, a storm. The quantity of runoff is dependent on the intensity of the storm, the amount of preceding rainfall, the length of the storm, and the type and slope of surface the rain falls onto.

For the Comprehensive Surface Water Management Plan, a 10-year, 24-hour frequency rainfall event was used for the storm sewer design, while a 100-year, 24-hour frequency rainfall event was used for overland drainage and pond storage design. A 10-year, 24-hour frequency rainfall event (4.0 inches in 24 hours) has a 10% chance of occurring or being exceeded in any given year whereas a 100-year, 24-hour frequency storm (5.7 inches in 24 hours) has a 1% chance of occurring or being exceeded in any given year. These design rainfall periods are commonly used by the Minnesota Department of Transportation throughout the state and have been used for the design of the most recent existing stormwater facilities in Cold Spring.

A number of methods have been developed to determine the expected maximum rate of runoff from a known area with a specific land use under a certain design storm and assumed soil moisture conditions. The preliminary trunk storm sewer design presented in this CSWMP is based on the Rational Method and the pond design on the HydroCAD computer program, which is an enhanced version of NRCS TR-20 methodology.

The Rational Method involves the selection and/or computation of a time of concentration and a runoff coefficient. The time of concentration is the time required for the runoff from a storm to become established and for the flow from the most remote point (in time, not distance) of the drainage area to reach the design point. The time of concentration will vary with the type and slope of the surface.

The percentage of rainfall in area that must be collected by a storm sewer facility is dependent on watershed variables such as soil imperviousness, ground slope, vegetation, surface depressions, type of development, and preceding rainfall. These factors are taken into consideration when selecting a runoff coefficient C in the Rational Method or a runoff curve number (CN) for use in NRCS TR-20 Methodology.

The runoff coefficient for urban areas varies from 0.2 for parks to 1.0 for ponds and other water surfaces. The runoff curve number varies from 58 for parks to 99 for ponds and other water surfaces. CN values depend on the type of soil; cover type, and hydrologic condition. Under ultimate (fully developed) conditions, the values of the coefficient will increase with increases in the amount of impervious surfaces caused by street surfacing, building construction, and grading. (See Table 2 for corresponding runoff coefficients for various land uses.)

The results of the modeling are contained in Appendix C.

Table 2. Runoff Coefficients and Curve Numbers

Land Use Type	Runoff Coefficient C		CN Value
	10 Year	100 Year	
Parks and Public Land	0.25	0.3	58
Rural and Estate Residential	0.35	0.4	66
Low Density & Single Family Residential	0.45	0.5	72
Medium Density Resident	0.55	0.6	78
High Density Residential	0.67	0.7	84
Commercial, Industrial	0.67	0.7	84
Ponds	1	1	99
Special	As Required		

4.2.2 Storm Sewers

Storm sewers are the conduits used to transport stormwater runoff. The capacity of the storm sewer is dependent on the pipe slope, pipe diameter, and the roughness of the inner surface of the pipe. Computations for the storm sewer conduit capacity were based on the following Manning's formula:

$$Q = \frac{1.49}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2} A$$

Where:

Q = Storm sewer conduit capacity in cubic feet per second (cfs)

n = Roughness coefficient

A = Area of conduit (sq. ft.)

P = Wetted perimeter of conduit (ft.)

S = Slope of conduit

A roughness coefficient (n) of 0.013 was used for concrete storm sewer pipe, and 0.024 for corrugated metal pipe. These roughness coefficients take into account losses due to bends and manholes in the system as well as the roughness of the inner pipe surface.

A complete working system consists of trunk storm sewers, manholes, lateral lines, overland drainageways, catch basin leads, catch basins, pond inlets and outlets, and all related items.

Proper design of a storm sewer system requires that all storm sewer lines be provided with access for maintenance and repair operations. Spacing of manholes should be no greater than 400 feet for lines 15 inches or less in diameter and 500 feet for lines 18 to 30 inches in diameter. Intervals on larger diameter lines can be increased since the pipes are sufficiently large for a person to physically enter the storm sewer pipe for maintenance operations. Regardless of storm sewer size, manholes are normally provided at all junction points of abrupt alignment or grade changes.

Although lateral systems are designed for 10-year storm events, their performance is analyzed for storms exceeding the design storm. It is anticipated that surcharging of the system will occur when the design storm is exceeded. During surcharging, the system works as a closed conduit, and the pipe network becomes pressurized with different pressure heads throughout the system. Low areas that are commonly provided with catch basins become small detention ponds, often performing like pressure relief valves (water gushing out in some locations). For this reason, it is extremely important to ensure that these low areas have an acceptable overland drainage route that will prevent costly damage to residences and businesses.

For safety reasons, the maximum ponding depth on streets should not exceed two feet at the deepest point, and the lowest exposed building elevation should be a least one foot above the high water level. The high water level for temporary street ponding is defined as the elevation to which water rises before overflowing through adjacent overland routes.

All storm sewer facilities, especially those conveying large quantities of water at high velocities, should be designed with efficient hydraulic characteristics. Manholes and other structures at points of transition are designed and constructed to provide gradual changes in alignment and grade. Pond outlet control structures are designed to allow water movement in natural flow line patterns, minimize turbulence, provide good self-cleaning characteristics, and prevent damage from erosion.

Intake structures are provided at all low points where stormwater collects and at points where overland flow is to be intercepted. Inlet structures are of special importance, since it is a poor investment to have an expensive storm sewer line flowing partially full while property is being flooded due to inadequate inlet capacity. Inlets are normally placed to eliminate overland flow in excess of 1,000 linear feet on local streets or 600 linear feet on collector and arterial streets. Intake grates and openings are designed to be self-cleaning to minimize capacity reduction, which will occur if clogged with twigs, leaves, and other debris.

Energy dissipation devices or stilling basins are provided to prevent erosion at all stormwater outfalls. The following considerations are kept in mind when designing an outlet:

- Inlet and outlet pipes of stormwater ponds are extended to the normal water level whenever possible.
- Outfalls with velocities of less that 4 fps (feet-per-second) that project flows downstream into a channel in a direction at less than 30 degrees from the normal channel axis generally do not require energy dissipaters or stilling basins, but do require riprap protection.
- Where an energy dissipater is used, it is sized to provide an average outlet velocity of less than 6 fps, unless riprap is also used. In the latter case, the average outlet velocity will not exceed 8 fps.
- Where outlet velocities exceed 8 fps, the design is based on the unique site conditions present. Outlet submersion, or installation of a stilling basin is required when excessive outlet velocities are experienced.
- Riprap is provided on all outlets to an adequate depth above and below the outfall. It is placed over a suitably graded filter material and filter fabric to ensure that soil particles do not migrate through the riprap and reduce its stability.

Riprap is placed to a thickness at least 2.5 times the mean rock diameter so as to ensure that it will not be undermined or rendered ineffective by displacement. If riprap is used as protection for overland drainage routes, grouting may be recommended.

In certain areas, stormwater could enter the sanitary sewer system, causing capacity problems and added costs for treatment of the stormwater. For this reason, sanitary sewer manholes that could be subject to temporary inundation should be equipped with watertight castings, and added precautions should be taken in construction of these manholes to prevent the entrance of stormwater. Sanitary manholes located near ponding areas should be raised above the 100-year high water level. All newly constructed sanitary manholes in the vicinity of ponding areas and open channels should be waterproofed.

Pipe capacity and size recommendations are presented in Appendix B and shown on Map 2.

4.2.3 Ponding

Stormwater ponding areas are an essential part of a storm drainage system. The effective use of ponding areas enables the installation of outflow sewers with reduced capacities, since the design storm duration is effectively increased over the total time required to fill and empty the ponding reservoirs.

Storm sewers represent a sizable investment for the community, and this investment can be more efficiently used by ponding stormwater in designated areas and allowing smaller diameter pipes to be used as outfall lines. In effect, storm sewer pipes are being used more efficiently since an equal volume of water is discharged at a lesser rate.

Equally as important as the cost considerations is the use of ponding areas to:

1. Improve water quality.
2. Return stormwater to the groundwater table.
3. Increase water amenities in developments for aesthetic, recreational, and wildlife purposes.

Stormwater quality is improved by allowing nutrients and sediments carried by runoff to settle below the pond's normal water level. Groundwater recharge is increased by restricting the outflow rate from the ponds. Amenity aspects are maximized by careful planning in the initial development of any residential or industrial area.

Most of the ponding areas in the system collect water from large drainage areas. To provide proper protection for adjacent property, the design storm frequency for ponding areas is the Type II, 24-hour, 100-year rainfall event (5.7 inches of rain in 24 hours). To provide an additional safety factor, the lowest exposed floor or opening elevation of a structure in a development should be at least 2 feet above the 100-year high water level or 1 foot above the emergency overflow elevation, whichever is greater.

4.3 System Description

The study was broken down into six major watershed basins as shown in Maps 1 and 2:

- Golf Course
- Brewery Creek
- North Chain of Lakes
- South Knaus Lake
- Byer Lake
- East Sauk River

This was done to identify the major drainage routes and simplify presentation of the basin data within this report. All of the basins are part of the Sauk River Watershed District.

For the purposes of this CSWMP, each basin area was subdivided into smaller drainage districts. A brief description of each basin and some special issues related to the watershed are presented in the following sections.

4.3.1 Golf Course Basin

This basin is located east of County Road 50 and north of the Sauk River in the northeastern portion of the City. The total basin area is approximately 1,500 acres, and elevations range from 1,200′ in the upper basin to the Sauk River at 1,080′. Overland runoff within the basin will flow to the Sauk River. Land use in the watershed is primarily residential but also includes institutional land and a golf course.

Special Issues

- Overland drainage that flows through the golf course: Approximately 900 acres of the basin are upstream of County Road 2 and will contribute overland drainage onto the golf course. It will be extremely important to implement the ponding storage identified in this report within the upper basin areas west of County Road 2 to provide detention and to control the outflow from storm ponds (see Map 1). The existing 48″ storm sewer pipe running through the golf course is the controlling factor for storm sewer flow through this area.

- Increasing the storage volume in the golf course: The storage volume of pond 11P* will need to be increased as development occurs in the upper basin area.

- Overland drainage from the school property: An adequate storm sewer system has been provided for drainage from the school property. The runoff is directed into pond 10P. This pond will need to be expanded when development of the agricultural area to the north of the school property is undertaken. This pond will also provide water quality treatment and rate control for runoff from the entire tributary area.

- Drainage outside the study area boundary: Approximately 350 acres of agricultural land contributes surface water to the area. The golf course basin will be required to maintain the existing flows contributing from the agricultural lands; however it will be financially beneficial to pond the contributing flows in the upper basin, rather than pay for larger storm sewer pipe downstream through the entire system.

* An agreement has already been signed with the landowner to allow for this expansion

4.3.2 Brewery Creek Basin

Tributary to Brewery Creek

This basin is located to the west of County Road 50 and north of Trunk Highway 23. The basin contains a small perennial stream known as Brewery Creek. This creek is a unique resource for the area as it is a designated trout stream and harbors a robust population of brook trout. A large portion of the existing City contributes runoff to Brewery Creek. The total basin area is approximately 2,300 acres, and elevations range from 1,220′ in the upper basin to the Sauk River at 1,080′. Overland runoff within the basin flows into Brewery Creek which discharges into the Sauk River just downstream of the dam. Land use in the watershed includes approximately 1,300 agricultural acres outside the study area boundary. Land use within the study area is primarily residential, but also includes a portion of the existing downtown business district.

The steady increase in urbanization and runoff from the City and upstream agricultural areas continues to threaten the Creek's health and its trout population. Warmer stormwater runoff is detrimental to the trout, and the flashiness of the runoff threatens the stream habitat. The MnDNR has recently conducted an in-depth study of the creek and has taken steps to increase public awareness and enhance streambank and in-stream habitat and stability. The City is committed to being a partner with the MnDNR and a sound land steward to protect this special resource.

Special Issues

Existing Storm Sewer Inlet

- <u>Brewery Creek:</u> Brewery Creek is a DNR protected waterway that is a designated trout stream. It will be extremely important to eliminate further degradation that threatens the integrity of the creek. All development and redevelopment in this area will be required to (1) use stormwater runoff infiltration as the first priority and (2) provide ponding prior to outlet into the creek to reduce runoff flashiness. The City will continue to look for financially viable options to reroute existing stormwater discharges directly into the Sauk River. This will not be easy or even possible in all cases due to elevation and bedrock constraints. The trunk storm sewer that discharges at 2nd Avenue North could be rerouted to the Sauk River, but bedrock and removal of sediment and pollutants prior to its discharge will pose regulatory and construction issues that will need to be addressed.

- Brewery Creek crossings: There are several road crossings over Brewery Creek. A HEC-RAS analysis was completed on the creek as part of this study, and the structures were evaluated on their impact to the 100-year flood elevation. (See section 4.4 for further details on this analysis.) The crossings that failed to handle a 100-year event without overtopping were located at 2nd Avenue North and 2nd Street North. Further detailed design needs to be completed, and the culverts should be replaced.

- Wetland storage: A key component to this watershed basin will be to make use of the wetlands for flood storage. The wetlands are of significant size in the upper basin, as shown by the National Wetland Inventory (NWI). Wetlands are great natural assets for providing flood storage. As development occurs near the wetlands, sedimentation ponds will be required to remove sediment and nutrients prior to discharging into wetlands.

- Existing storm sewer pipe: The City has several existing storm sewer systems within the basin that capture overland runoff and discharge into Brewery Creek. The analysis of the existing system for a 10-year runoff event found that a majority of the trunk storm sewer pipes are undersized. As these areas redevelop or street reconstruction occurs, the City should retrofit the trunk system and address problem areas. Consideration will need to be given to appropriately sizing the storm sewer pipes to meet current standards. Sedimentation structures for water quality treatment should also be considered for various locations. Infiltration trenches and/or basins should be implemented wherever possible for the protection of Brewery Creek. Mechanical sediment structures are an alternative for water quality treatment for existing developments when limited space for sediment ponds is available.

- Flooding near the intersection of 6th Street North and 7th Avenue North: This area is currently experiencing flooding problems due to a significant drainage area (37 acres) and no outlet other than infiltration for the existing low area near the intersection. It is recommended that a storage pond (19P) be implemented near the intersection. A pond in this natural low area will enable a smaller outlet pipe (24 inches) to be used. The pond would provide a significant cost savings over design of a storm sewer pipe to capture the overland flow from the existing development south of 6th Street North and routing the flow to the wetland complex to the west.

4.3.3 North Chain of Lakes Basin

This basin is located in the southwestern portion of the City north of the Chain of Lakes reservoir complex. The total basin area is approximately 1,500 acres, and elevations range from 1,220′ in the upper basin to1,086′ in the lower. Overland runoff within the basin will flow to a series of lakes known more commonly as the Chain of Lakes. Land use in the watershed is a mix of residential, recreational, commercial, and industrial. Trunk Highway 23 runs from east to west and divides the watershed into two distinct areas.

Special Issues

- Development north of Trunk Highway 23: A significant amount of the basin, approximately 950 acres, exists north of TH 23. Further development of the watershed north of TH 23 will require a number of sedimentation ponds. The sedimentation ponds will provide water quality treatment and reduce the rate of flow from development. The wetlands are of significant size in the upper basin as shown by the NWI. As development occurs near the wetlands sedimentation ponds will be required to remove sediment and nutrients prior to discharging into wetlands. Due to the significant amount of topographical relief throughout the watershed, trunk storm sewer piping is generally not required. The natural drainage paths and existing culverts will be used for the overland flow to cross TH 23. This occurs at the existing wetland areas. However, a 48-inch trunk storm sewer is being proposed to cross TH 23 near a future connection with 14th Avenue South.

- Development south of Trunk Highway 23: A large recreational area (golf course) and residential development comprise a majority of the land use south of TH 23. The proximity of these areas to the shorelines of the series of lakes will dictate implementation of water quality treatment. Sedimentation ponds will be required for development of the areas, and we recommend opportunities for infiltration be examined.

4.3.4 South Knaus Lake Basin

This basin is located south of the Sauk River and borders Knaus Lake. County Road 2 runs north-to-south and splits the watershed basin. The basin is characterized by significant topographical relief thus minimizing the need for trunk storm sewer. The total basin area within the study area is approximately 1,200 acres. Overland runoff within the basin will flow to the Chain of Lakes. Land use in the watershed is primarily residential.

Special Issues

- Wetland storage: A key component to this watershed basin will be to make use of the wetlands for flood storage. The wetlands are of significant size (150 acres) in the upper basin as shown by the NWI. Wetlands are great natural assets that function to provide flood storage and groundwater recharge. As development occurs near the wetlands, sedimentation ponds will have to be implemented to remove sediment and nutrients prior to discharging into wetlands.

4.3.5 Byer Lake Basin

This watershed is located in the southeastern portion of the study area. A large portion of the watershed contributes to Byer Lake. The total area of the watershed within the study area is approximately 1,700 acres. Land use in the watershed is a mix of residential, commercial, and industrial. The commercial and industrial areas are near the northern border of the watershed along TH 23 and the Sauk River. Significant topographical relief can be found throughout the watershed basin. Numerous landlocked basins characterize the southeast area of the basin. The vast majority of these basins will continue to be landlocked and will be managed by the goals and policies listed for this type of basin.

Special Issues

- Chapel Street: Residential development has occurred recently in the upper basin areas of Chapel Street. A portion of the CSWMP has already been implemented with the new development. Stormwater ponds have been constructed and the outflows from the ponds have been greatly reduced. This will aid in reducing the size the trunk storm sewer in the lower basin. Ponds 1, 2, and 4 have been constructed and are storing runoff in the upper portions of the basin. A trunk storm sewer pipe will need to be extended as part of the reconstruction of Chapel Street down to TH 23. A sedimentation pond will need to be constructed to provide water quality treatment prior to discharge of this basin area into the wetland area located west of existing Chapel Street and south of TH 23.

- Byer Lake area: The proximity of development near Byer Lake will require implementation of water quality treatment. Sedimentation ponds will be necessary for development of the areas prior to runoff draining from the development site. The soils in this area may also offer an opportunity for infiltration to provide stormwater treatment -. Landlocked basin management strategies are necessary in this area.

- Commercial and industrial areas: Commercial and industrial areas can be found in the lower portion of the basin next to the Sauk River. Further development or expansion of the existing areas will require both water quantity control and water quality treatment for the storm sewer runoff. Ponds in this area will discharge directly into the Sauk River. Special attention should be paid to proper design to ensure removal of nutrients and sediment within the ponds.

4.3.6 East Sauk River Basin

This basin is generally located in the northeastern portion of the study area. The southern boundary of the watershed basin and the outlet area for the basin is directly to the Sauk River. The watershed basin is approximately 1,600 acres in size. Land use within the watershed is currently agricultural and is proposed to be residential in the future. A portion of the upper basin is divided by County Road 2 and near the middle of the basin is divided by Greystone Road. The East Sauk River Watershed has the least amount of relief from the upper reaches to the Sauk River.

Special Issues

- Trunk storm sewer piping: This basin, because of the minimal topographical relief, has considerably more trunk storm sewer than the other basins. The minimal relief will increase the storm sewer pipe sizes due to the minimal gradient at which the pipe will be constructed. Regional ponding will be required in the upper basin to reduce the flow rate downstream, which will help in limiting the size of the trunk storm sewer pipe in the lower basin. A regional ponds are proposed upstream of Greystone Road to help minimize the size of the downstream trunk storm sewer pipe.

- Development near the Sauk River: The proximity of the development south of Greystone Road to the Sauk River will require implementation of water quality treatment and runoff rate control. Sedimentation ponds will be required for development of the areas, and opportunities for infiltration are also recommended for development of the areas due to the soil types present in the basin. Trunk storm sewer pipe will be needed for development of the areas to capture and discharge runoff into ponding areas downstream.

4.4 Hydrologic and Hydraulic Analysis for the 100-Year Flood on Brewery Creek

4.4.1 Hydrologic Analysis

Peak discharges were computed for the 100-year flood at two locations on Brewery Creek and at three additional locations upstream of 8th Avenue at the junction of three tributary streams with Brewery Creek. The two peak discharge locations used for the analysis are located upstream of 8th Avenue North and Red River Avenue.

Floodplain Alterations

Peak 100-year flood discharges were computed using the Natural Resource Conservation Service's (NRCS) methods described in the publications NEH-4 and "Minnesota Hydrology Guide". Discharge computations were derived using the computer program HydroCAD, which uses NRCS TR-20 methodology. The 100-year, 24-hour rainfall depth of 5.7″ was used in the computations. Drainage areas were measured using a 30-meter Digital Elevation Model. (See Map 1 for the drainage areas used.) Runoff curve numbers were selected using knowledge of the area and information gathered from the field.

4.4.2 Hydraulic Analysis

The hydraulic analysis for Brewery Creek was performed using the HEC-RAS computer program developed by the U.S. Army Corps of Engineers. Input data for the program consisted of calculated river discharges, cross section descriptions of the main channel and overbanks, roughness factors, and descriptions of bridges, culverts, and any structures or channel geometry that affect water flow.

2nd Avenue and 2nd Street Crossings

Channel and overbank roughness coefficients ("n" values) were determined by field investigation and in accordance with the Natural Resource Conservation Service guide for selecting roughness coefficients. A roughness coefficient of 0.035 was used for the channel and overbank areas, as the adjacent area consists largely of residential land cover.

Cross sections were obtained by topographical surveys at locations representative of the channel and overbank geometry. Cross sections were generally taken on both sides of culverts, at the roadways over the culverts, and at selected intermediate locations based on field observations. The locations of the cross sections are shown on Figures 5 and 6.

The starting downstream water surface elevation was assumed to be equal to the backwater of the Sauk River for the 100-year flood, assuming a coincidental 100-year flood on Brewery Creek. This elevation is 1083.3' as shown on the Flood Insurance Rate Map of the Flood Insurance Study Report for the Stearns County Unincorporated Areas, November 16, 1994. The Brewery Creek floodplain was established at an unknown time by Wehrman, Chapman Associates, Inc.

5th Avenue Culvert Crossing

Table 3 presents the water surface elevations, 100-year flow, and channel velocity at the cross sections used in the analysis. The 100-year floodplain is shown on Figure 5. The most serious flooding along Brewery Creek occurs at the downstream end due to backwater effects from the Sauk River. Roadways are overtopped at 2nd Avenue North and 2nd Street North. Two structures are within the floodplain; one is located on the south side of the creek upstream of 5th Avenue North, and the other is located in the southwest corner of 2nd Avenue North and 2nd Street North. Figure 6 presents the water surface profile along the creek alongside the old profile for comparison purposes.

Table 3. HEC-RAS Summary

STATION (Tenths of Miles)	WATER SURFACE ELEVATION (Feet)	TOTAL FLOW (cfs)	CHANNEL Velocity (ft/s)
0.801	1108.52	715	1.43
Culvert			
0.791	1102.71	715	10.18
0.771	1102.15	715	4.9
0.646	1099.34	715	1.87
0.556	1099.15	715	1.47
0.532	1099.14	715	1.14
Culvert			
0.522	1096.45	815	7.13
0.478	1096.55	815	2.67
0.458	1096.13	815	5.01
Culvert			
0.441	1093.55	815	9.99
0.422	1092.3	815	6.88
0.310	1090.73	815	3.66
0.298	1090.76	815	2.28
Culvert			
0.282	1088.82	815	2.88
0.273	1088.75	815	3.08
0.263	1088.8	815	1.57
Culvert			
0.249	1086.12	815	5.87
0.236	1085.85	815	5.35

Figure 5 – Brewery Creek 100 year floodplain

11 x 17” color

Figure 6 – Brewery Creek Water Surface Profile

11 x 17 black and white