Developing a GIS for the Spring Creek watershed, Northfield, Minnesota

Miriam Krause
Department of Geology, Pomona College, Claremont, CA 91711
Faculty Sponsor: Eric Grosfils, Pomona College

Joanna Reuter
Department of Geology, Carleton College, Northfield, MN 55057
Faculty sponsor: Mary Savina, Carleton College

INTRODUCTION

Spring Creek drains approximately 27 square kilometers of land in southeastern Minnesota, including farmland, Carleton College, and housing developments in the city of Northfield. (Figures 1 & 2.) During the last century, human activity has greatly changed Spring Creek, both directly and indirectly. A series of holding ponds have been built, the course of the creek itself has been altered, and land use has changed dramatically; these changes affect the amount and quality of runoff, as well as the distribution and deposition of sediment. Today, Northfield has a population of about 15,000 and is growing rapidly. Many of the city's recent housing developments lie within the Spring Creek watershed, and more are in the planning stages. Because of the changes that have taken place, and those that are planned, the Spring Creek watershed provides interesting study possibilities. Furthermore, detailed information is needed to make intelligent decisions concerning land use changes. We developed a GIS of the Spring Creek watershed for use by students, researchers, and city planners interested in studying and managing the Spring Creek area. Our purpose was to compile as much data as possible in the proper format so that analysis can be performed as specific needs or questions arise. The work that we have done in developing a GIS of Spring Creek is the groundwork of much more to come.

Figure 1. Index map of Minnesota.

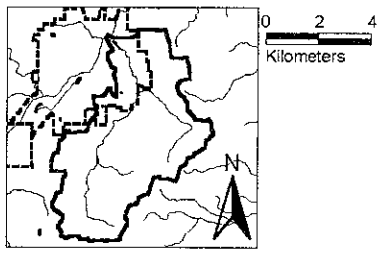

Figure 2. Spring Creek watershed (bold line), the city of Northfield (dashed line), and surface water.

DEVELOPING THE SPRING CREEK GIS

We constructed the Spring Creek GIS in ArcView 3.0a and 3.1 working in UTM coordinates (Zone 15) and the NAD83 datum. Table 1 lists the major layers of the GIS upon completion of our project. The extent

Image	intersections, etc.	streams and rivers[1]*
Digital raster graphic (DRG)[1]*	GPS storm sewer and surface water point features	township and section boundaries[5]*
Digital orthophoto quad (DOQ)[1]*	city wells[3]	**Feature—Polygon**
Landsat (July 1996)[2]	**Feature—Line**	Spring Creek watershed
Grid	city streets of Northfield[5]*	lakes[4]*
Digital elevation model (DEM) and derived grids: hillshade, slope, aspect[1]*	roads[1]*	ponds
	railroads[5]*	bedrock geology[4]*
Feature—Point	bedrock geology[4]*	surficial geology[4]*
storm sewer outlets[3]	surficial geology[4]*	well protection area[3]
GPS ground control points of road	GPS outlines of some lakes and ponds	storm sewer catchments[3]
		outlines of quadrangles*
		land use[6]*

Table 1. List of major layers of the Spring Creek GIS as of fall 1998. Source of data: [1]USGS, [2]Eosat, [3]City of Northfield, [4]Minnesota Geological Survey, [5]Minnesota Dept. of Transportation, [6]Minnesota LMIC. *Indicates layer that was originally obtained, reprojected and/or registered by Kurt Steffen.

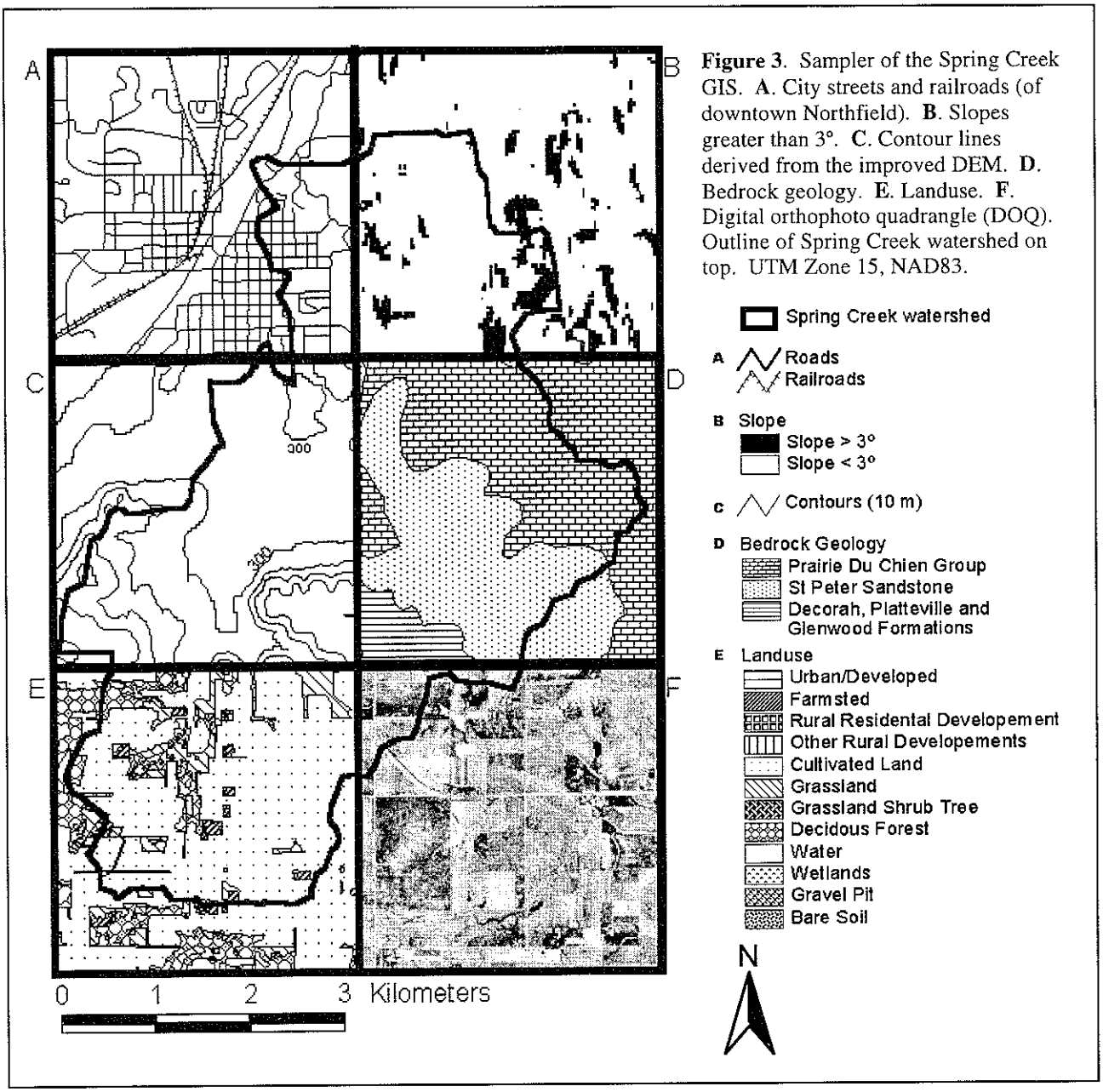

Figure 3. Sampler of the Spring Creek GIS. **A.** City streets and railroads (of downtown Northfield). **B.** Slopes greater than 3°. **C.** Contour lines derived from the improved DEM. **D.** Bedrock geology. **E.** Landuse. **F.** Digital orthophoto quadrangle (DOQ). Outline of Spring Creek watershed on top. UTM Zone 15, NAD83.

of coverage for almost all of the layers includes the entire Spring Creek watershed and the city of Northfield. Figure 3 shows a sampling of parts of several of these layers for the Spring Creek watershed. Compiling all of the listed layers into a single GIS involved a considerable variety of work, including importing layers from ARC/INFO (prepared by Kurt Steffen, '98 Carleton College); digitizing; rectifying and importing a Landsat TM image; working with and improving the DEM; adding attributes to feature themes; mapping with a Trimble GeoExplorer II GPS unit; and last (but not least by any means) working on metadata.

Development of hydrology layers: Much of the work we did related to the hydrology of the watershed (Figure 4). ArcView has a number of hydrology features that make use of the DEM to determine what would happen to runoff during a rain event. Before using those features, however, the DEM needed to be "cleaned up." Errors in DEMs often create internal sinks, which need to be removed because they interfere with simulations of runoff. Having removed all sinks (through the use of an Avenue script), we reintroduced real sinks (such as ponds, lakes, and marshy areas) into the DEM, and subsequently used the improved data to construct an outline of the Spring Creek watershed. The watershed divide is illustrated in the figures. Using Northfield city storm sewer maps, we digitized the catchments of eleven different storm sewer outlets along Spring Creek, whose outlines did not

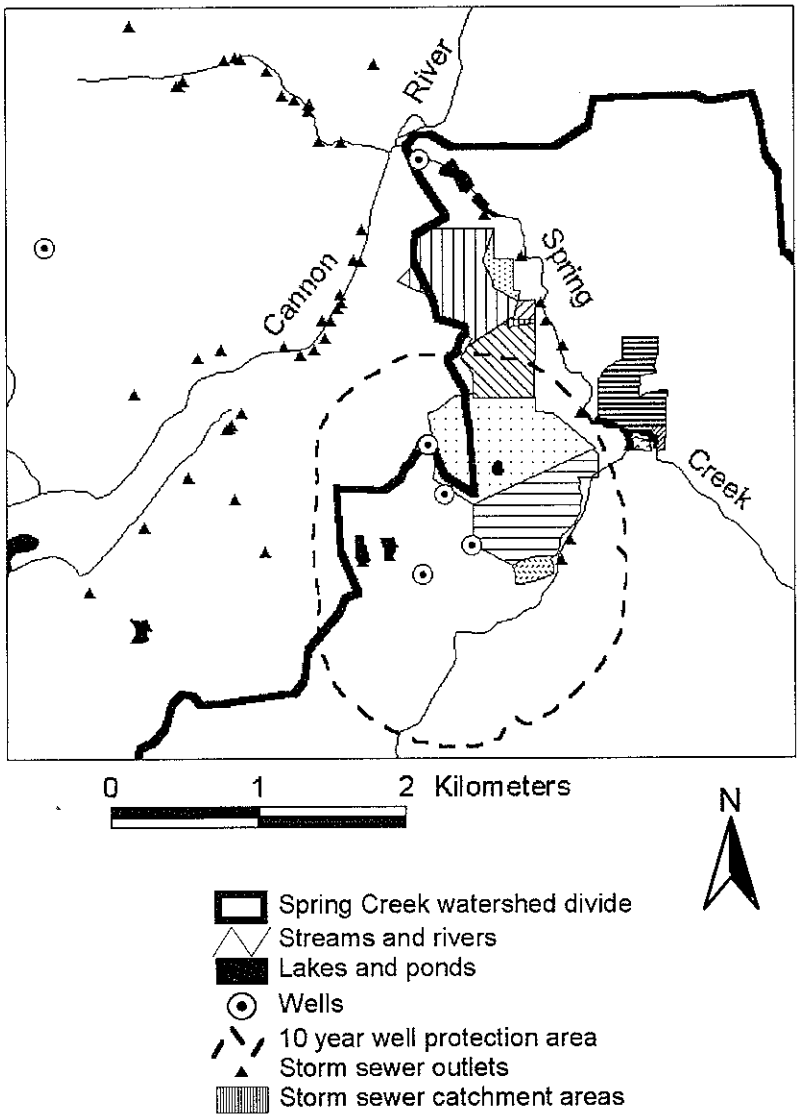

Figure 4. The northern part of the Spring Creek watershed. Incorporated into this figure are several of the hydrologic themes. The Spring Creek watershed divide was derived by ArcView from the DEM (with a slight modification at the mouth of Spring Creek) and represents the approximate natural divide. [The discrepancy between the mouth of Spring Creek as indicated on the "Streams and river" layer and the location that the Spring Creek watershed boundary joins the Cannon River represents an actual change (made by Carleton College) in the course of Spring Creek.] Each of the eleven patterned areas is a developed area of Northfield which drains into Spring Creek through a storm sewer outlet. The outlets are shown for Spring Creek as well as other parts of Northfield. Note that the storm sewer divide differs from the natural divide. Finally, four city wells and two college wells are shown, along with a preliminary 10 year well protection zone for the city wells. UTM Zone 15, NAD83.

always correspond with the natural drainage basin defined by the DEM data. The city and colleges of Northfield use ground water as their water supply. The four city wells and wells of the two colleges are shown, as well as a preliminary10 year well protection area for the city wells.

Other additions to the GIS: We made several general additions to the GIS. For example, we added street names to the Northfield city streets layer, so that a user can click on a street and find out its name, and we also updated the theme to include some streets that had been constructed since the original development of the theme. Using ER Mapper, we registered a Landsat scene of the Northfield area and transformed various three-band combinations into ArcView themes. In Northfield, we interviewed potential users for the GIS. Finally, we used a Trimble GeoExplorer II to gather ground control points and map benchmarks. These activities helped to define possible future uses of the Spring Creek GIS, and to ensure the accuracy of previously created layers.

Metadata: Metadata are the accumulated information that accompany a map and essentially make it useful. For each and every layer, the metadata give source references as well as information about when the map was made, its accuracy, its datum and projection, what changes or additions have been made, and other pertinent information. Compiling the metadata for all of the layers that we worked with exceeded the scope of our project, although in theory, many of the layers should have had accompanying metadata when we received them. We did our best to provide metadata—a record of everything we knew about the theme—for the layers that we worked with. Because this GIS will be used in the future by a wide variety of people, this was a particularly important part of the project—anyone with a problem or question concerning a layer will first look to the metadata.

THE SPRING CREEK GIS: PRESENT USES AND FUTURE DEVELOPMENTS

Even without the significant expansions planned for it, the Spring Creek GIS is already capable of powerful analysis. One simple example of such analysis is a calculation of slope, as in Figure 3b, which shows areas with slopes greater than three degrees. This kind of map could be very useful to developers and city planners for deciding precisely where Northfield should expand its residential, industrial, and recreational areas. For example, a landscape with a steep slope may be better used as parkland than as part of a new subdivision. Northfield has restrictions on the steepness of land that can be developed, and the GIS would allow planners to easily recognize these locations.

Our work only touches upon the issues that the Spring Creek GIS will eventually address. Following are some thoughts about possible additional uses for students, researchers, and city planners who wish to take advantage of the existing data sets or who plan to add new ones.

Spring Creek monitoring: In conjunction with a seminar that Mary Savina of Carleton College will teach in the spring of 1999, several stream monitoring stations will be set up along Spring Creek. These will be used to conduct long-term studies and to assess impacts of urban development, farming, and other factors on the sediment load, discharge, and water quality of Spring Creek. The GIS will be immensely useful in determining the characteristics of the catchment above each monitoring station. ArcView can delineate the area that drains to a particular location, and once that is determined, the amount of farmland or developed area, for example, can be determined from the land use layer. These are important issues in determining pollution sources and answering questions such as whether lawn or farmland fertilizers contribute more to the nutrient load of the creek.

Northfield city planning: The Spring Creek GIS is not only useful for understanding the Spring Creek watershed itself; it has great potential for use in Northfield city planning. Northfield does not yet have a GIS, but most layers of the Spring Creek GIS include the entire city of Northfield. One issue for which this GIS would be useful is determining where parks are needed and identifying land that is suitable for new ones based on characteristics such as slope, distance to other parks, accessibility, and amount of contiguous open land. Similar work could be done for a variety of other land use issues. For example, what areas could be developed for industry (or be targeted for large new retail stores), where should new housing go (and at what density), which areas should be maintained as farmland? Traffic routing is another concern, and (with the addition of attributes such as speed limits and number of lanes to the roads layer), a cost-benefit analysis could be done to determine which of several proposed highways might be the most efficient in moving traffic. Simply having the GIS at city council and city planning board meetings would be immensely useful because it would allow people to ask questions and get immediate answers about characteristics of a site in question.

CONCLUSION

In our work with the Spring Creek GIS, we were able to answer several questions of interest regarding the watershed, such as to what extent the artificially created storm sewer drainage in Northfield overlaps with the natural Spring Creek drainage basin. Answering questions was not, however, the focus of our project. The most substantial task for our Keck work was to bring the themes together into a single datum and projection with necessary accompanying metadata so that it will be useful to city planners, students, and researchers. Anticipating what questions might be of interest influenced our decisions about which layers to add and develop. The development of the Spring Creek GIS is part of an on-going project, and as the work continues, the GIS will be used to answer numerous questions relevant to the city of Northfield and the Carleton College community.

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