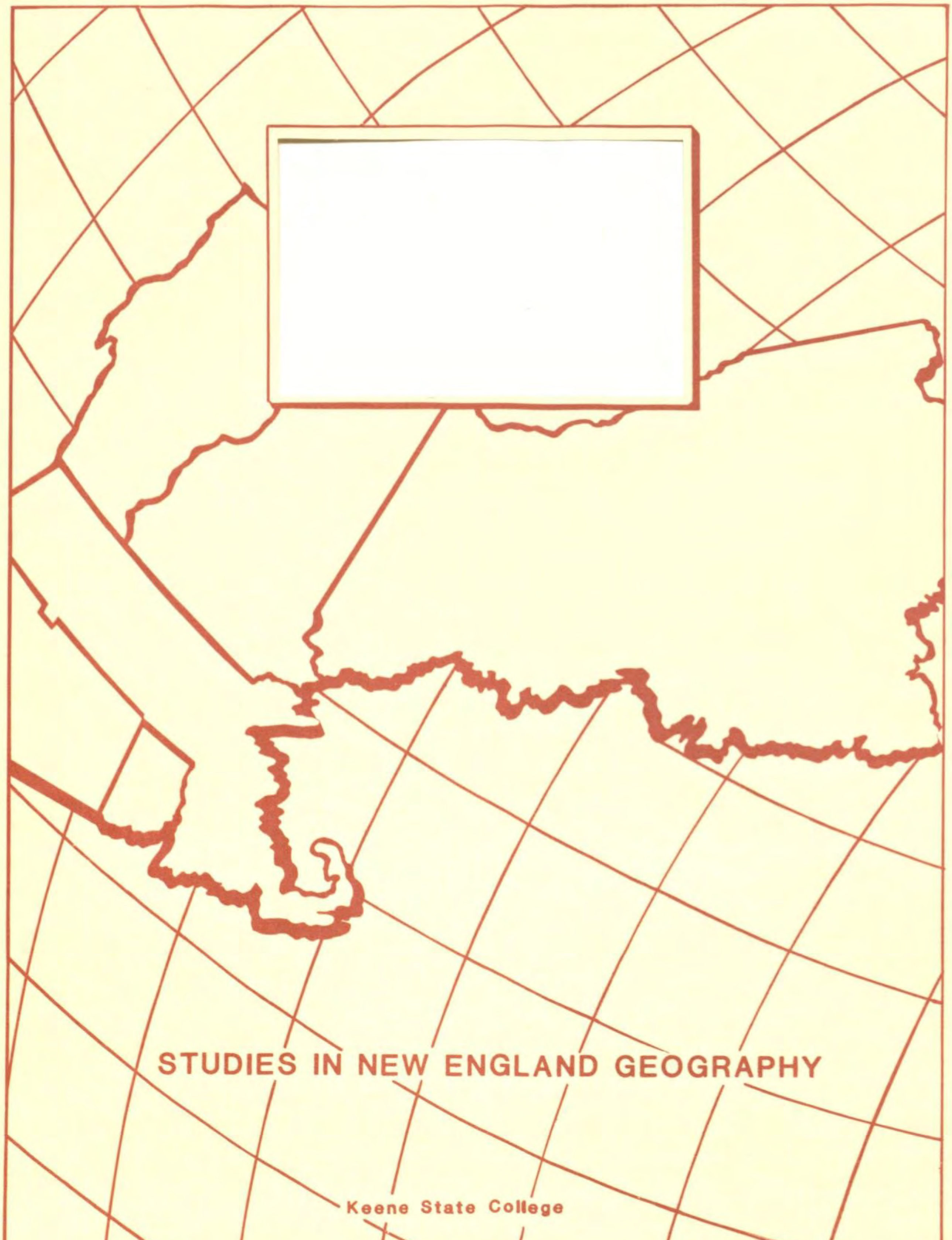

STUDIES IN NEW ENGLAND GEOGRAPHY

Keene State College

MAPPING GROUNDWATER POLLUTION POTENTIAL
FOR THE
LOWER ASHUELOT RIVER WATERSHED

CHESHIRE COUNTY
NEW HAMPSHIRE

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INTRODUCTION

Today more than 90 percent of our nation's public water supplies are obtained from groundwater (Lappenbusch, 1984). In rural zones the figure approaches 97 percent (Solley, et al., 1983). Concomitant with this reliance on groudwater comes the need to protect the resource from contamination, which unfortunately has risen dramatically in recent years. Since 1974 Congress has acted on the national level with legislation to protect aquifers, most notably via the Safe Water Drinking Act, Resource Conservation and Recovery Act, Toxic Substances Control Act, and the Comprehensive Emergency Response Compensation and Liability Act (Superfund).

In order to protect groundwater resources, however, you have to first know where the resource is and how much of it is potentially available - not an easy task for something you cannot see. Consequently a number of methodologies have been developed in recent years to delimit aquifers and their susceptibility to contamination. One of the more innovative programs to come from EPA-sponsored research is known as DRASTIC.* This system was created specifically for use by non-professionals, i.e., for local officials and citizens with only a "basic knowledge of hydrogeology and the processes which govern goundwater contamination" (Aller, et al., 1987:1). The methodology is simple and relies on existing information. Our problem in New Hampshire is that much of the assumed information base may not be readily available or, if it is, may require substantial interpretation to fit the DRASTIC model.

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* D - Depth to water table; R - net Recharge; A - Aquifer media; S - Soils; T - Topography; I - Impact of vadose zone; C - Hydraulic Conductivity

The purpose of this project was to apply the DRASTIC model to produce a map of groundwater contamination susceptibility for the lower Ashuelot River watershed. Our goal was primarily to examine the utility and applicability of the model to New Hampshire and secondarily to provide a planning tool for local officials to use in making decisions relevant to groundwater protection. A significant note of caution is necessary here, however. The DRASTIC model is by its very nature generalized; its spatial resolution level is no less than 100 acres. Additionally, the model was formulated using a "generic pollutant" model, thus the pollutant system was "developed assuming the use of a pollutant having the mobility of water that is introduced at the surface, and carried toward the groundwater by recharge from precipitation" (Aller, et al., 1987:11).

With these limiting assumptions in mind, the model can be best utilized as a screening device for land use decisions.

> "The methodology is neither designed nor intended to replace on-site investigations or to specifically site any type of facility or practice. DRASTIC does not reflect the suitability of a site for waste disposal or land use activities. DRASTIC provides the user with a measure of relative groundwater vulnerability to pollution and therefore may be one of many criteria used in siting decisions, but should not be the sole criteria" (Aller, et al., 1987:11-12).

DRASTIC may be used to prioritize areas for protection, to identify regions for special study or protection measures, to delimit zones more sensitive to pesticide applications, to note areas for monitoring, or to designate special hydrogeologic characteristics which would generally influence clean-up efforts in areas of prior contamination. Thus its role in pollution liability is obvious. Finally, a community may simply use DRASTIC to identify data gaps and justification for further study of a particular area.

METHODOLOGY*

A large technical advisory committee, comprised of the country's leading groundwater specialists, was formed by the National Water Well Association to create a system which evaluates an area's relative sensitivity to groundwater contamination. The system, based on defined hydrogeologic settings, meets the following requirements: (1) it is based upon existing information, (2) it is applicable anywhere in the United States, (3) it can be easily used by persons with nontechnical backgrounds, (4) it is readily displayed in map form, and (5) it is a low cost alternative to more expensive hydrogeological studies.

The advisory committee chose seven parameters that it felt were significant to consider when evaluating an area's groundwater pollution potential. The committee then created a numerical evaluation system by devising a weighting and rating scheme for each of the seven parameters. In this system each parameter is assigned a weight, between 1 and 5, according to its relative significance (the higher the number, the more significant the parameter). Each range of a parameter is assigned a rating between 1 and 10, according to its relative susceptibility to contamination (the higher the number, the more sensitive that given range is to contamination). The weights chosen by the committee remain constant, but the ratings will change according to the nature of the area being mapped. After a numerical value has been chosen for the rating, it is then multiplied by the weight for that parameter, producing a DRASTIC value for that parameter. This process is repeated in each

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* From: Mapping Groundwater Pollution Potential for Shenandoah County, VA. Virginia Water Project, Shenandoah County Planning Commission, June 1988.

location for all seven parameters. Once this is completed, each of the DRASTIC values are added together to generate a DRASTIC Index that is unique for each location (see Appendix A: How to Read the Map).

DRASTIC Parameters

Depth to water:

Depth to water is defined as the distance from the ground's surface to below ground where either the pore spaces in the soil or cracks in the rock are saturated with water. This does not include any saturated zone that will not yield enough water for use. The depth to water is a factor which influences the amount of time it takes a contaminant to reach groundwater. Generally, the deeper the water table the greater the possibility that the contaminant will dissolve or break down before reaching the water table.

Net Recharge:

Net recharge is defined as the amount of water that enters the groundwater system. Annual net recharge is dependent upon precipitation, evapotranspiration, and runoff in a given area. Recharge occurs more readily in areas where there is no natural barrier to inhibit water from reaching the water table, (unconfined aquifers). In areas where a natural barrier is present to inhibit water from reaching the groundwater (confined aquifers), recharge is lower.

Aquifer Media:

Aquifer media is defined as the material which is saturated and yields enough water for use. The aquifer may be consolidated (composed of rock that is compacted and firm) or unconsolidated (composed of rock that is loose and uncompacted). It may have primary porosity, such as space between grains of sand, or secondary porosity like fractures, cracks and solution cavities which are channels created by the rock being dissolved, such as karst limestone. The aquifer will facilitate or inhibit the travel of a contaminant once it is actually present in the aquifer.

Soil:

For purposes of DRASTIC, soil is defined from surface of the ground to six feet below the surface. When rating the soil, one chooses the soil layer which has the greatest ability to influence the movement of water. The soil is important because it influences the amount of attenuation or chemical breakdown a substance will go through when it first enters the ground. It also influences the time a substance takes to move into the water table.

Topography:

Topography is the percent slope and slope variability of the land, (rise/run). Topography influences the rate of runoff that occurs and therefore the potential for a contaminant to enter groundwater. Topography is also useful in estimating the gradient and flow direction of groundwater.

Impact of Vadose Zone:

The vadose zone is the material above the water table and below the soil that is unsaturated. This zone affects the travel time of contaminants and also aids in attenuation processes. It can be the same material as the aquifer media or a different material.

Hydraulic Conductivity:

Hydraulic conductivity is the aquifer media's ability to transmit water. Hydraulic conductivity affects the rate at which a contaminant will be dispersed and the direction it will travel. Hydraulic conductivity is related to the interconnectedness of pore space and the degree of primary and secondary porosity in the aquifer.

GENERAL FEATURES: CHESHIRE COUNTY AND LOWER ASHUELOT RIVER WATERSHED*

Cheshire County is in the southwest part of New Hampshire. It has an area of about 457,856 acres, or 715 square miles. The county is divided into 22 towns and the city of Keene. Keene, which is approximately the geographical center of the county, is the county seat.

The county is characterized by a hilly terrain, a scattering of mountains, and, in small part, river valleys. Most major population centers and many of the larger farms are on terraces and flood plains in the valleys of the Connecticut, Ashuelot, Contoocook, and Cold Rivers.

The soils in the hilly and mountainous areas of the county are loamy and generally gently sloping to very steep. Stones and boulders cover most areas of these soils. Some areas have been cleared for farming. The soils on the tops of high hills and mountains commonly are shallow or moderately deep to bedrock. The soils on lower side slopes of hills are commonly very deep to bedrock.

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* Adapted from: Rosenberg, Gerald L. Soil Survey of Cheshire County New Hampshire. National Cooperative Soil Survey, Soil Conservation Service, U.S. Department of Agriculture, 1989.

These soils range from poorly drained to somewhat excessively drained. The major limitations of these soils for farm and nonfarm use are complex slope patterns, stones and boulders on the surface, shallow depth to bedrock, the seasonal high water table, slow permeability, and the hazard of erosion.

The soils in the major stream valleys are nearly level to very steep and sandy or loamy. They range from excessively drained to very poorly drained. The soils that are nearly level or gently sloping, well-drained or moderately well-drained, and loamy are suited to farming.

Climate

(Prepared by the National Climatic Center, Asheville, North Carolina)

In Cheshire County, winters are cold and summers are moderately warm and have occasional hot spells. Mountains are markedly cooler than the main agricultural areas in the lowlands. Precipitation is well-distributed throughout the year and is nearly always adequate for all crops. Winter snows occur frequently, occasionally as blizzards, and cover the ground much of the time.

In winter the average temperature is 24 degrees F, and the average daily minimum temperature is 13 degrees. The lowest temperature on record, which occurred at Keene on February 18, 1958, is -31 degrees. In summer the average temperature is 68 degrees, and the average daily maximum temperature is 81 degrees. The highest recorded temperature, which occurred at Keene on August 5, 1955 is 102 degrees.

The total annual precipitation is 40.38 inches. Of this, 21 inches, or 50 percent, usually falls in April through September. The growing season for most crops falls within this period. In two years out of ten, the rainfall in April through September is less than 18 inches. The heaviest one-day rainfall during the period of record was 3.56 inches at Keene on October 25, 1959. Thunderstorms occur on about 20 days each year, and most occur in summer.

The average seasonal snowfall is 68 inches. The greatest snow depth at any one time during the period of record was 35 inches. On the average, 58 days have at least one inch of snow on the ground. The number of such days varies greatly from year to year.

The average relative humidity in midafternoon is about 55 percent. Humidity is higher at night, and the average at dawn is about 80 percent. The sun shines 60 percent of the time possible in summer and 50 percent in winter. The prevailing wind is from the northwest. Average wind speed is highest, eight miles per hour, in spring.

Physiography

Cheshire County is in two physiographic regions. The western part is in the Connecticut River Valley section, and the rest is in the New England Upland section.

The New England Upland section consists of hills and mountains underlain by schist, granite, and gneiss bedrock. Many of the county's lakes, ponds, bogs, and marshes are located in this section, particularly on the east side of the county. Common elevations are about 1,000 to 1,500 feet, and the tops of mountains mostly reach about 1,700 to 2,000 feet. The highest elevation in the county, Mount Monadnock, is 3,165 feet. The soils in this section are generally coarser textured than the soils in the Connecticut River Valley section and they generally have more stones and boulders on the surface.

The Connecticut River Valley section consists of terraces and flood plains along the Connecticut River and upland hills adjacent to the river valley. The upland hills are dominantly underlain by phyllite bedrock. Elevations on the flood plains and terraces along the Connecticut River generally range from 200 to 400 feet. The lowest elevation in the county, 180 feet, is at the point where the Connecticut River flows into Massachusetts. The upland hills adjacent to terraces have elevations of 500 to 800 feet. The soils in this section generally are medium textured and have fewer stones on the surface than the soils in the New England Upland section.

Drainage

Most of the county lies within the Connecticut River Valley drainage basin. A small area on the eastern side of the county drains into the Contoocook River, which is part of the Merrimack River drainage basin. The Connecticut River flows south along the entire western boundary of the county. The Ashuelot River is the major tributary of the Connecticut River in the county. It originates in the southeast part of Sullivan County and flows diagonally across Cheshire County, from northeast to southwest, and empties into the Connecticut River near the town of Hinsdale.

DATA ACQUISITION AND DRASTIC PARAMETERS

The process of data acquisition for each DRASTIC parameter was guided by the standardized sources recommended in the program (Table 1). As is evident a variety of sources are necessary to obtain a valid data base. Herein lies the bulk of the work and frustration for such a project, for such data is often not available, poorly kept and scattered in a number of locations, and sometimes contradictory or seemingly inaccurate. Nevertheless, careful scrutiny and cross-checking does allow for the acquisition of apparently reliable data. Primary sources for each parameter in Cheshire County are summarized in the following paragraphs.

D - Depth to Water - generated from information obtained from well-driller logs required by the New Hampshire Department of Environmental Services, Water Resources Division and the U.S. Geological Survey data base for their Lower Connecticut River Basin aquifer delimitation study. As one might expect water depths varied from surface flow to several hundreds of feet, with the 15-30 foot range predominating. Determining depth to water was by far the most difficult task due to the lack of data, the complex geological make-up of the region, and large areas where no wells have been drilled. Depth reported in the setting sheets (Appendix B) enclosed in ( ) are estimates. Topography and aquifer media were primarily used to estimate depth.

R - Net Recharge - was estimated at 1/2 of annual precipitation for the region. This was based upon communications with Rich Moore of the U.S. Geological Survey (NH); the New York State Department of Environmental Conservation Bulletin 75 by MacNish and Randall (1982); a report by Morrissey of the Little Androscoggin River in Maine (1983); and the Hill study of ice-contact deposits in New Hampshire (1979).

TABLE 1. SOURCES OF HYDROGEOLOGIC INFORMATION

Source	Depth to Water	Net Recharge	Aquifer Media	Soil Media	Topography	Impact of the Vadose Media	Hydraulic Conductivity of the Aquifer
U.S. Geological Survey	X	X	X		X	X	X
State Geological Surveys	X	X	X			X	X
State Department of Natural/Water Resources	X	X	X			X	X
U.S. Department of Agriculture-Soil Conservation Service		X		X	X		
State Department of Environmental Protection	X	X	X			X	X
Clean Water Act "208" and other Regional Planning Authorities	X	X	X			X	X
County and Regional Water Supply Agencies and Companies (private water suppliers)	X		X			X	X
Private Consulting Firms (hydrogeologic, engineering)	X		X			X	X
Related Industry Studies (mining, well drilling, quarrying, etc.)	X		X			X	
Professional Associations (Geological Society of America, National Water Well Association, American Geophysical Union)	X	X	X			X	X
Local Colleges and Universities (Departments of Geology, Earth Sciences, Civil Engineering	X	X	X			X	X
Other Federal/State Agencies (Army Corps of Engineers, National Oceanic and Atmospheric Administration)	X	X	X			X	

A - Aquifer Media - was determined using well-driller logs, the U.S. Geological Survey data base noted earlier, and via conversations with state water resource officials and local well drillers. The aquifer media present consisted primarily of bedrock, tills, sand and gravels, and silt and clay. Determining aquifer media was one of the the more difficult parameters to determine, ostensibly due to the paucity of data, largely stemming from the "incompleteness" of well-driller logs.

S - Soil Media - collected from the newly published U.S. Soil Conservation Service survey of the county. The base maps at 1:20,000 formed our base maps for this study. Soils were codified into groupings and lumped together into areas of 100 acres or larger. Final results were reviewed and approved by Gerald Rosenberg, Soil Conservation Service.

T - Topography - generated from the county soil survey maps and the USGS 7.5 minute topo sheets. Soil survey data was converted to the DRASTIC ranges as follows: A = 0-2%; B = 2-6%; C = 6-18%; D & E = 18%+.

I - Impact of the Vadose Zone - was derived using data from well-driller logs, the U.S. Geological Survey Lower Connecticut River data base, and conversations with the geologists at Keene State College. Generally, vadose zone material was of the same type as the aquifer media although some exceptions are apparent in heavily re-worked (glacial ice) areas.

C - Hydraulic Conductivity - was based upon information provided by John Cotton of the U.S. Geological Survey. Categories for DRASTIC are as follows:

silt, bedrock, fine sand, till	1- 100
sand, medium-fine sand	100- 300
sand and gravel, coarse sand	300- 700
well, very well sorted, coarse sand	700-1000

The typical rating provided by DRASTIC was employed. (See also Freeze and Cherry (1979)). Most areas had a rating between 1-100 and 300-700.

MAP PRODUCTION

The maps and overlays shown here represent approximately 90-100 man-days of labor. This includes data collection and interpretation, completing a working copy of an overlay for each DRASTIC parameter, one public presentation session of the preliminary results, and the production of two sets of finished copy overlays. Some 70% of this time was devoted to initial, working copy overlay production. We estimate an additional 160 hours (20 days) will be necessary to prepare a final map for professional printing.

The data collected and maps produced deviated from the DRASTIC model program in that we chose to apply our study to the watershed rather than on a county basis. The reasons are intuitively obvious from a hydrogeologic perspective. Additionally, we limited our study site to the lower Ashuelot Basin south of Keene due ostensibly to temporal and budgetary constraints.

While DRASTIC appears useful from a number of perspectives, there are built-in uncertainties and generalizations which lead us to caution the use of the program and thus the map presented here. DRASTIC is designed to deal with existing data bases and be useful to individuals with a limited or no real hydrogeologic background. Because so little data is available on regional recharge rates and hydraulic conductivity, the very broad values that must be utilized could be somewhat misleading on a local scale.

Similarly, the model parameters, as set out by the program committee, do not appear to fit well in an area such as New England which has been so thoroughly worked and re-worked by glacial action. We experienced consistent problems in classifying aquifer media, vadose zone, and hydraulic conductivity in areas of mixed glacial deposits. This was especially troublesome for the aquifer media classification. While the problem may ultimately be more related to well-driller log reports, we did notice that only very slight modifications in zone or parameter classifications could easily produce a final DRASTIC Index value which varied ±10-15%. Although this did not substantially alter the final map categories and color coding, such levels of error should be borne in mind when utilizing the map.

To compensate for potential errors we adopted a conservative approach when interpreting and classifying parameters. In an area with so little historical data and of fairly rapid population growth, we felt this approach was prudent. We also attempted to be as detailed as possible in "lumping" soil zones together into the necessary 100 acre or larger zones. Again, opting for a higher level of resolution has its obvious advantages.

We found it more useful to construct one overlay for each parameter rather than to combine several similar factors, as suggested in the DRASTIC guide. Moreover, it was useful to plot an additional overlay denoting only specific well locations and depth. This separate sheet formed the basis and made it easier for sketching out depth to water, in conjunction with the topo sheets. Trying to construct depth to water zones from tabular well-log data proved untenable.

Finally, as noted by the Shenandoah County Mapping Program (1988),

> "DRASTIC does not consider all the criteria which may be important in evaluating an area for a ground water protection plan. Some issues not addressed... are the number of people using water from the aquifer; the amount of water a well drilled in the aquifer yields; the consistency of the yields; [and] the natural quality of the ground water" (Mapping Groundwater... 1988:5).

In areas of rapid build-up and especially in valley floors, such as the lower Ashuelot River in southern Cheshire County, such data inputs are necessary and the lack of their representation in the maps produced must be recognized.

MAP INTERPRETATION

The colors used on the DRASTIC map of the lower Ashuelot River basin were chosen to indicate levels of relative vulnerability to pollution. The table below illustrates the DRASTIC index ranges and associated colors used in the development of a National Color Code. DRASTIC Indexes ranged from 86 to 190 using all the colors except violet and red. The areas shaded yellow and orange have the greatest potential for contamination. These are located primarily along the Ashuelot River valley where groundwater is found in sand and gravel aquifers less than 15 feet from the ground surface. These areas have the greatest potential for high-yielding wells and the highest population densities. Blue and indigo areas indicate the lowest potential for contamination. These are mountainous areas composed primarily of granite overlain by thin soils and groundwater occurring greater than 50 feet below the earth's surface. These areas are characterized as having low population densities, the lowest well yields, and the steepest topography. The light and dark green areas have a moderate potential for contamination with the light green areas being more susceptible than the dark green ones.

NATIONAL COLOR CODE FOR DRASTIC INDEX RANGES

DRASTIC Index Range	Color	Printing Specification Color
<79	Violet	Pantone Purple C
80- 99	Indigo	Pantone Reflex Blue
100-119	Blue	Pantone Process Blue C
120-139	Dark Green	Pantone 347C
140-159	Light Green	Pantone 375C
160-179	Yellow	Pantone Yellow C
180-199	Orange	Pantone 151C
>200	Red	Pantone 485C

CONCLUSIONS

DRASTIC, like any model, has its limitations. These revolve around the generalized, "fit the whole nation" nature of the program, its reliance on often scarce or regional-level data sources, and the lack of such inputs as aquifer drawdowns and yields. Despite these limitations, however, we are confident that DRASTIC produces a useful planning tool. It can undoubtedly be a significant screening device delimiting areas of special sensitivity and/or characteristics that warrant enhanced site-specific analysis, either in the face of development or in a pre-development regional planning inventory.

From an educational perspective DRASTIC produces a colorful, comprehensible, and pleasing map which connects human surface developments to the unseen potential for groundwater pollution. If for no other reason, both DRASTIC and this project are and have been worthwhile.

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APPENDIX A

HOW TO READ THE MAP

The DRASTIC* System provides the user with information about the hydrogeologic setting of an area and the pollution potential. The symbols found on the map look like this:

9Da7 defines the hydrogeologic setting

189 defines the relative pollution potential to the groundwater

A. Hydrogeologic Setting:

1. The first number (9) refers to the major ground water region in which the hydrogeologic setting is located, in this case the Northeast and Superior Uplands.
2. The letters (Da) defines the hydrogeologic setting in more detail.
3. The number (7) describes a certain set of DRASTIC parameters which are unique to this setting. When parameters, such as depth to water, change enough to warrant a different DRASTIC Index but not significantly enough to change hydrogeologic settings, a new set of unique characteristics is generated and another number (8) is assigned. See following charts.

B. DRASTIC Index:

This number represents a relative measure of ground water pollution potential. The map has been color-coded using ranges on the map legend. These colors are part of a national color code which has been developed to

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* DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings, Aller et al., EPA-60/2-87-035, April 1987.

assist the user in gaining a general insight into the vulnerability of ground water to pollution. DRASTIC Index values range from 80 to 190 in the Lower Ashuelot watershed in Cheshire county.

What DRASTIC means:

D - Depth to Water (distance from land surface to water table)
R - Net Recharge (amount of precipitation that reaches water table)
A - Aquifer Media (material which contains enough water for use)
S - Soil Media (top 6 feet from surface down)
T - Topography (percent slope of the land)
I - Impact of Vadose Zone (unsaturated layer between soil and water table)
C - Hydraulic Conductivity of the Aquifer (time of travel of water through aquifer)

How to Calculate a DRASTIC Index:

1. Each DRASTIC parameter has been weighted with respect to each other and assigned a number from 1 to 5 (Table 1).
2. Each DRASTIC parameter has been divided into ranges or descriptive terms and assigned associated ratings (Tables 2-8).
3. A DRASTIC Index is calculated by multiplying: Weight x Rating for each parameter.
4. Add the results to obtain the DRASTIC Index.

TABLE 1
ASSIGNED WEIGHTS FOR DRASTIC FEATURES

FEATURE	WEIGHT
Depth to Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	2
Topography	1
Impact of Vadose Zone	5
Hydraulic Conductivity	3

TABLE 2
RANGES AND RATINGS FOR DEPTH TO WATER

DEPTH TO WATER (FEET)	
RANGE	RATING
0- 5	10
5- 15	9
15- 30	7
30- 50	5
50- 75	3
75-100	2
100+	1
Weight: 5	Pesticide Weight: 5

TABLE 3
RANGES AND RATINGS FOR NET RECHARGE

NET RECHARGE (INCHES)	
RANGE	RATING
0- 2	1
2- 4	3
4- 7	6
7-10	8
10+	9
Weight: 4	Pesticide Weight: 4

TABLE 4
RANGES AND RATINGS FOR AQUIFER MEDIA

AQUIFER MEDIA		
RANGE	RATING	TYPICAL RATING
Massive Shale	1- 3	2
Metamorphic/Igneous	2- 5	3
Weathered Metamorphic/Igneous	3- 5	4
Glacial Till	4- 6	5
Bedded Sandstone, Limestone and Shale	5- 9	6
Massive Sandstone	4- 9	6
Massive Limestone	4- 9	6
Sand and Gravel	4- 9	8
Basalt	2-10	9
Karst Limestone	9-10	10
Weight: 3		Pesticide Weight: 3

TABLE 5
RANGES AND RATINGS FOR SOIL MEDIA

SOIL MEDIA	
RANGE	RATING
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking and Nonaggregated Clay	1
Weight: 2	Pesticide Weight: 5

TABLE 6
RANGES AND RATINGS FOR TOPOGRAPHY

TOPOGRAPHY (PERCENT SLOPE)	
RANGE	RATING
0- 2	10
2- 6	9
6-12	5
12-18	3
18+	1
Weight: 1	Pesticide Weight: 3

TABLE 7
RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

HYDRAULIC CONDUCTIVITY (GALLONS PER DAY/FT^2)	
RANGE	RATING
1- 100	1
100- 300	2
300- 700	4
700-1000	6
1000-2000	8
2000+	10
Weight: 3	Pesticide Weight: 2

TABLE 8
RANGES AND RATINGS FOR IMPACT OF VADOSE ZONE MEDIA

IMPACT OF VADOSE ZONE MEDIA		
RANGE	RATING	TYPICAL RATING
Confining Layer	1	1
Silt/Clay	2- 6	3
Shale	2- 5	3
Limestone	2- 7	6
Sandstone	4- 8	6
Bedded Limestone, Sandstone, Shale	4- 8	6
Sand and Gravel with significant Silt and Clay	4- 8	6
Metamorphic/Igneous	2- 8	4
Sand and Gravel	6- 9	8
Basalt	2-10	9
Karst	8-10	10
Weight: 5	Pesticide Weight: 4	

APPENDIX B

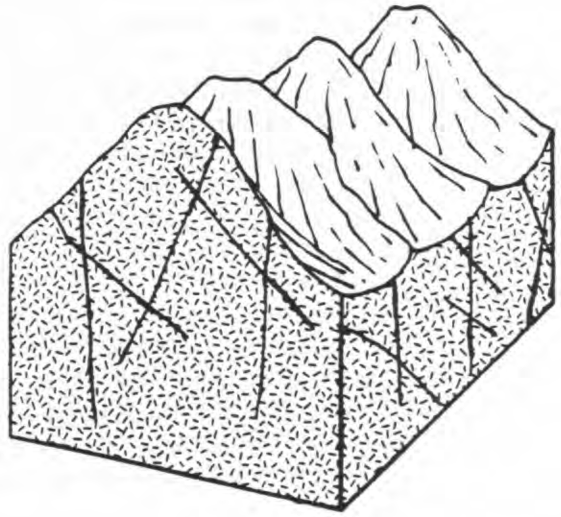
HYDROGEOLOGIC SETTINGS
(NORTHEAST AND SUPERIOR UPLANDS)

9A	Mountain Slopes
9B	Alluvial Mountain Valleys
9C	Mountain Flanks
9Da	Glacial Till over Crystalline Bedrock
9Db	Glacial Till over Outwash
9E	Outwash
9Gb	River Alluvium without Overbank Deposits
9H	Swamp/Marsh

GROUNDWATER REGION AND HYDROGEOLOGIC SETTINGS IN LOWER ASHUELOT WATERSHED
NORTHEAST AND SUPERIOR UPLANDS

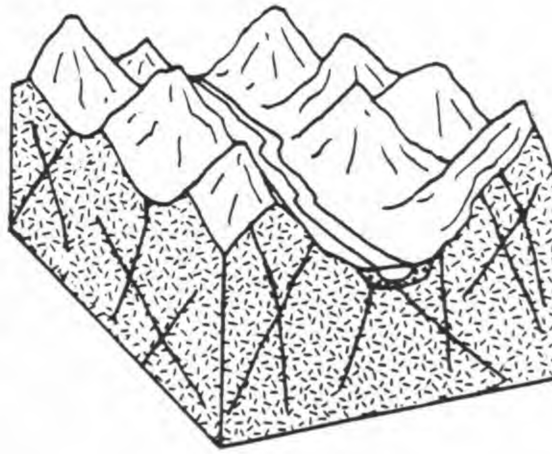
(9A) Mountain Slopes

This hydrogeologic setting is characterized by steep slopes on the side of mountains, a thin soil cover and fractured bedrock. Ground water is obtained primarily from the fractures in the bedrock which may be of sedimentary, metamorphic or igneous origin but which is commonly metamorphic or igneous. The fractures provide localized sources of ground water, and well yields are typically limited. Although precipitation is abundant, due to the steep slopes, thin soil cover and small storage capacity of the fractures, runoff is significant and ground-water recharge is moderate. Water levels are extremely variable but are commonly deep.



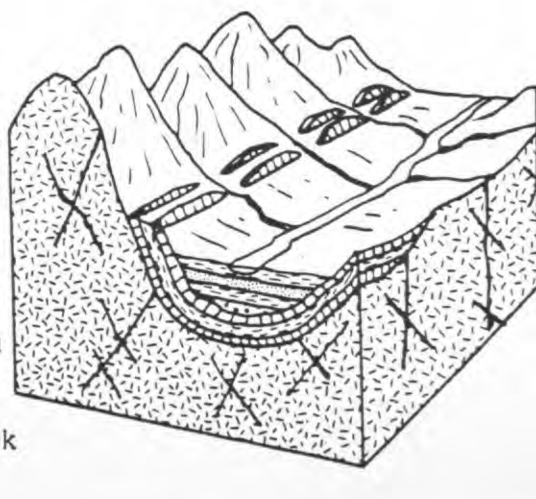
(9B) Alluvial Mountain Valleys

This hydrogeologic setting is characterized by thin, bouldery alluvium which overlies fractured bedrock of sedimentary, metamorphic or igneous origin but which are commonly alternating sedimentary layers. The alluvium, which is derived from the surrounding slopes, serves as a localized source of water. Water is obtained from sand and gravel layers which are interspersed between fine-grained deposits. Surficial deposits have typically weathered to a sandy loam. Water levels are relatively shallow but may be extremely variable. Ground water may also be obtained from the fractures in the underlying bedrock which are usually in direct hydraulic connection with the over-lying alluvium.

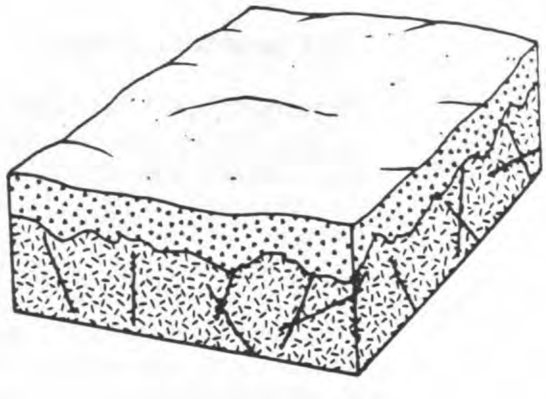


(9C) Mountain Flanks

This hydrogeologic setting is characterized by moderate topographic relief and moderately dipping, fractured, consolidated sedimentary rocks. Soil cover is usually thicker than on the mountain slopes and typically has weathered to a sandy loam. Although precipitation can be significant, ground-water recharge is moderate due to the slope. Water levels are typically moderately deep, although they are extremely variable. The mountain flanks serve as the recharge area for aquifers which are confined in adjacent lowland areas. Ground water is obtained from the permeable sedimentary rocks or from fractures and bedding planes in the sedimentary rocks. The sedimentary rocks may be underlain by fractured bedrock of igneous, metamorphic or sedimentary origin which yield little water.

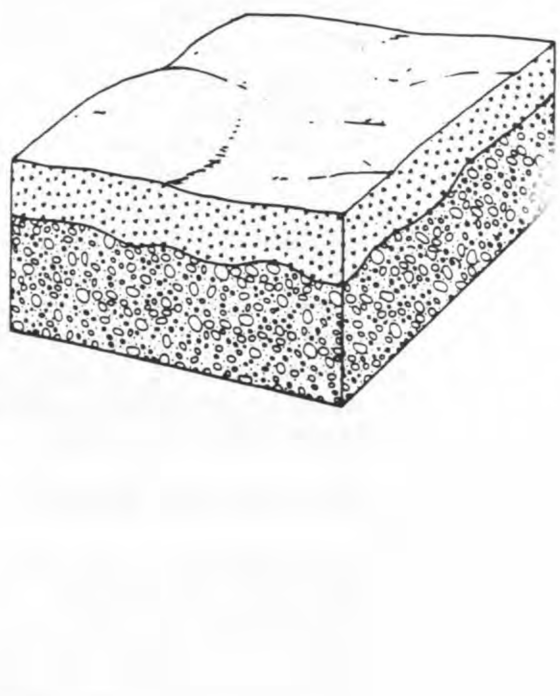


(9Da) Glacial Till Over Crystalline Bedrock



This hydrogeologic setting is characterized by moderately low topographic relief and varying thicknesses of glacial till overlying severely fractured, folded and faulted bedrock of igneous and metamorphic origin with minor occurrences of bedded sedimentary rocks. The till is principally unsorted deposits which may be interbedded with localized deposits of sand and gravel. Although ground water occurs in both the glacial deposits and fractured bedrock, the bedrock is typically the principal aquifer. The glacial till serves as a recharge source. Although precipitation is abundant, recharge is only moderately high because of the low permeability of the glacial till and the surficial deposits which typically weather to loam. Depth to water is extremely variable depending in part on the thickness of the glacial till, but is typically moderately shallow.

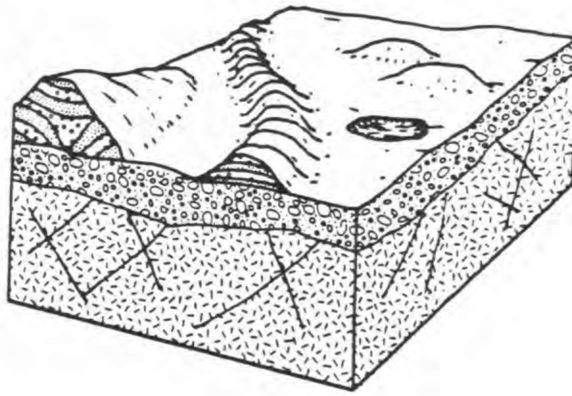
(9Db) Glacial Till Over Outwash



This hydrogeologic setting is characterized by low topography and outwash materials which are covered by varying thicknesses of glacial till. The till is principally unsorted deposits which may be interbedded with localized deposits of sand and gravel. Surficial deposits have usually weathered to a loam. Although ground water occurs in both the glacial till and in the underlying outwash, the outwash typically serves as the principal aquifer because the fine-grained deposits have been removed by glacial meltwater. The outwash is in direct hydraulic connection with the glacial till and the glacial till serves as a source of recharge for the underlying outwash. Precipitation is abundant in the region but recharge is moderate because of the relatively low permeability of the overlying glacial till. Depth to water is extremely variable depending in part on the thickness of the glacial till, but averages around 30 feet.

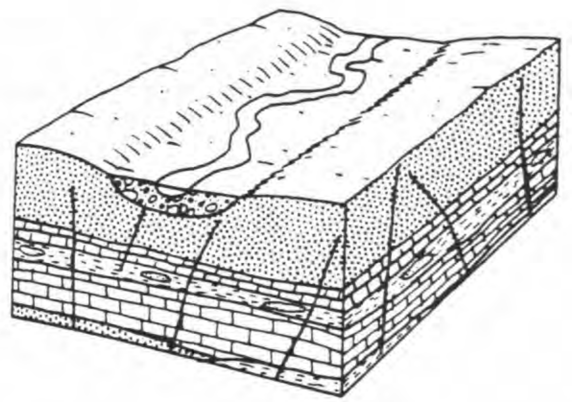
(9E) Outwash

This hydrogeologic setting is characterized by moderate topographic relief and varying thicknesses of outwash which overlie fractured bedrock of sedimentary, metamorphic or igneous origin. The outwash consists of water-washed deposits of sand and gravel which often serve as the principal aquifers in the area, and which typically have a sandy loam surficial layer. The outwash also serves as a source of recharge to the underlying bedrock. Recharge is abundant and ground-water recharge is high. Water levels are extremely variable, but are relatively shallow.



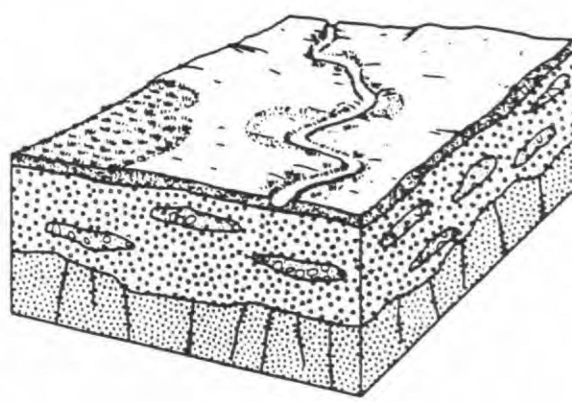
(9Gb) River Alluvium Without Overbank Deposits

This hydrogeologic setting is identical to (9Ga) River Alluvium with Overbank Deposits except that no significant fine-grained floodplain deposits occupy the stream valley. This results in significantly higher recharge where precipitation is adequate and sandy soils occur at the surface. Water levels are moderate to shallow in depth. Hydraulic contact with the surface stream is usually excellent, with alternating recharge/ discharge relationships varying with stream stage. These deposits serve as a good source of recharge to the underlying fractured bedrock.



(9H) Swamp/Marsh

This hydrogeologic setting is characterized by low topographic relief, high water levels and high organic silt and clay deposits. These wetlands occur along the courses of floodplains and in upland areas as a result of vertically restricted drainage. Common features of upland wetlands include those characteristics attributable to glacial activity such as filled-in glacial lakes, potholes and cranberry bogs. Recharge is moderate in most of the region due to restriction by clayey soils. The swamp deposits very rarely serve as significant aquifers but frequently recharge the underlying sand and gravel or bedrock aquifers.



APPENDIX C
PROFESSIONAL ASSISTANCE

The following individuals provided technical assistance and professional advice on various project stages:

1. Dr. Klaus J. Bayr, Geography, Keene State College, Keene, NH
2. Dr. Stephen Bill, Geology, Keene State College, Keene, NH
3. Mr. John Cotton, Hydrologist, U.S. Geological Survey, Bow, NH
4. Mr. Tom Groves, New England Interstate, Boston, MA
5. Mr. Doug Heath, U.S. Environmental Protection Agency, Boston, MA
6. Mr. John Lukin, Senior Water Resources Specialist, Rural Housing Improvement, Inc., Rural Water Resources Division, Winchendon, MA
7. Mr. John McCarthy, Director, Rural Housing Improvement, Inc., Rural Water Resources Division, Winchendon, MA
8. Mr. Richard Moore, U.S. Geological Survey, Bow, NH
9. Dr. Peter Nielsen, Geology, Keene State College, Keene, NH
10. Mr. Robert Panton, Director, Southwest Region Planning Commission, Keene, NH
11. Mr. Gerald L. Rosenberg, U.S. Department of Agriculture, Soil Conservation Service, Keene, NH
12. Mr. Jason Grey, Virginia Water Project, Arlington, VA
13. Mr. Rick Schofield, Hydrogeologist, NH Department of Environmental Services, Water Resources Division, Concord, NH
14. Mr. Ken Stearns, Director, NH Department of Environmental Services, Water Resources Division, Concord, NH
15. Mr. Steven Wallace, Regional Planner, Southwest Regional Planning Commission, Keene, NH
16. Mr. William Yamartino, U.S. Department of Agriculture, Soil Conservation Service, Keene, NH