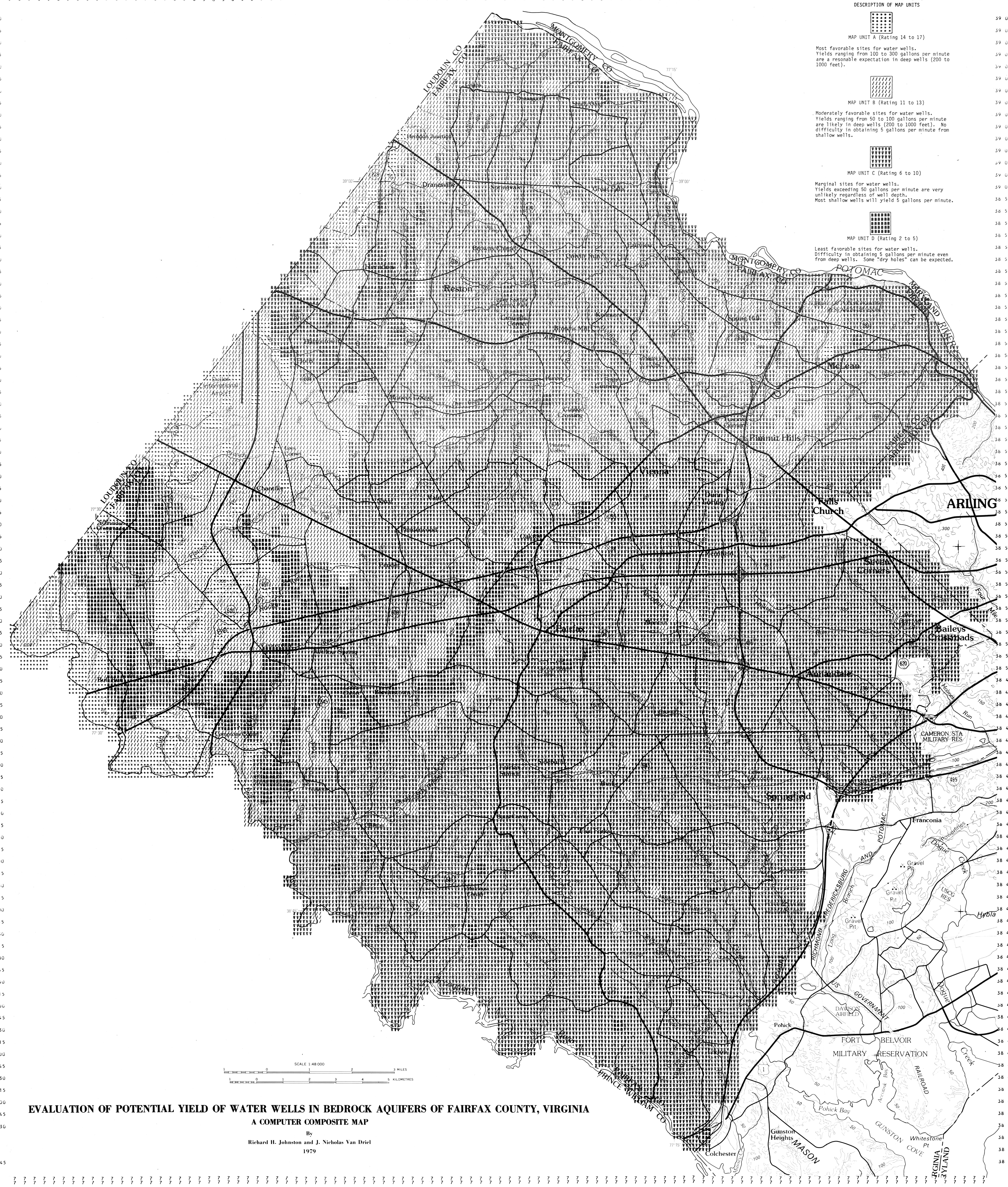


DESCRIPTION OF MAP UNITS

MAP UNIT A (Rating 14 to 17)

Most favorable sites for water wells.
Yields ranging from 100 to 300 gallons per minute are a resonable expectation in deep wells (200 to 1000 feet).

MAP UNIT B (Rating 11 to 13)

Moderately favorable sites for water wells.
Yields ranging from 50 to 100 gallons per minute are likely in deep wells (200 to 1000 feet). No difficulty in obtaining 5 gallons per minute from shallow wells.

MAP UNIT C (Rating 6 to 10)

Marginal sites for water wells.
Yields exceeding 50 gallons per minute are very unlikely regardless of well depth.
Most shallow wells will yield 5 gallons per minute.

MAP UNIT D (Rating 2 to 5)

Least favorable sites for water wells.
Difficulty in obtaining 5 gallons per minute even from deep wells. Some "dry holes" can be expected.

EVALUATION OF POTENTIAL YIELD OF WATER WELLS IN BEDROCK AQUIFERS OF FAIRFAX COUNTY, VIRGINIA

A COMPUTER COMPOSITE MAP

By
Richard H. Johnston and J. Nicholas Van Driel
1979

INTRODUCTION

The yields of water wells tapping bedrock vary widely. A well yielding more than a hundred gallons per minute can be drilled in the western part of Fairfax County within a few hundred feet of another well yielding less than one gallon per minute. These differences in yield are caused by: variations in rock type, differences in the number, spacing, and size of natural openings (termed joints and fractures), and the properties of the overlying soil, alluvium, and saprolite (deeply weathered rock). The highest yielding wells in the county are developed in highly jointed siltstone and sandstone where overlain by sandy alluvium. In contrast, the lowest yielding wells occur in diabase ("trap rock") and greenstone with thin saprolite or soil cover.

To aid the map user in evaluating the potential of a water-well site, the various geologic factors known to affect well yields have been combined in the computer-generated map shown on Sheet 1. An understanding of the interaction of the various hydrogeologic factors is not needed in order to use the map. However, for those interested, a technical discussion follows, and the source map for each factor is shown on Sheet 2.

HOW TO USE THE MAP

The four map units are labeled A, B, C, and D in order of decreasing favorability as water-well sites. Unit A includes the most favorable sites, and yields of more than 100 gallons per minute are probable from deep wells. Unit A comprises 6 percent of the map and is restricted to a small area in the western part of the county underlain by sandstone, shale, and siltstone. Wells in unit A at Dulles Airport yield several hundred gallons per minute.

Unit B (17 percent of the map area) includes moderately favorable sites where chances of obtaining 50 to 100 gallons per minute are good. Unit B is generally restricted to areas underlain by schist (locally termed "mica rock" or "bluestone"), in the north central part of the county, and to the sandstone-shale terrane in the western part of the county. Wells in unit B provide public water supplies at Vienna and Pimmit Hills with yields ranging from 50 to 100 gallons per minute under continuous pumping. Spacing between wells is critical if yields of 50 to 100 gallons per minute or more are desired from many wells. Well spacing involves site specific information on aquifer hydraulic characteristics and economic factors and is beyond the scope of this map-report.

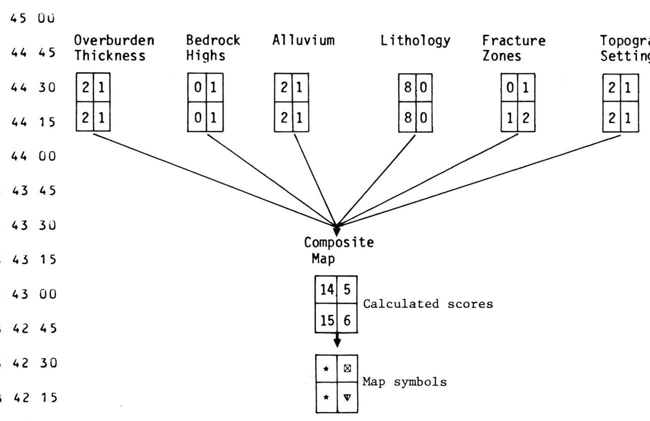
Unit C includes about three quarters of the map area. In general, yields of 5 or more gallons per minute may be obtained from shallow wells or by drilling deeper if necessary. The possibility of obtaining more than 50 gallons per minute from deep wells is very unlikely and probably a third of the wells will yield no more than 5 to 10 gallons per minute regardless of depth.

Unit D has the least potential for constructing successful water wells. Yields will generally be limited to a few gallons per minute and some dry holes (insufficient water to supply a single-family dwelling) may be expected. Unit D is relatively small (6 percent of the map area) and occurs mainly in the western part of the county. Note that Units A and D adjoin one another in some places. The accuracy of the boundary separating the units is restricted by the cell size used on the computer map; thus the map should be used with particular care in those areas. The computer source maps shown on Sheet 2, or the original maps listed in the reference, should be consulted if a more accurate site evaluation is required.

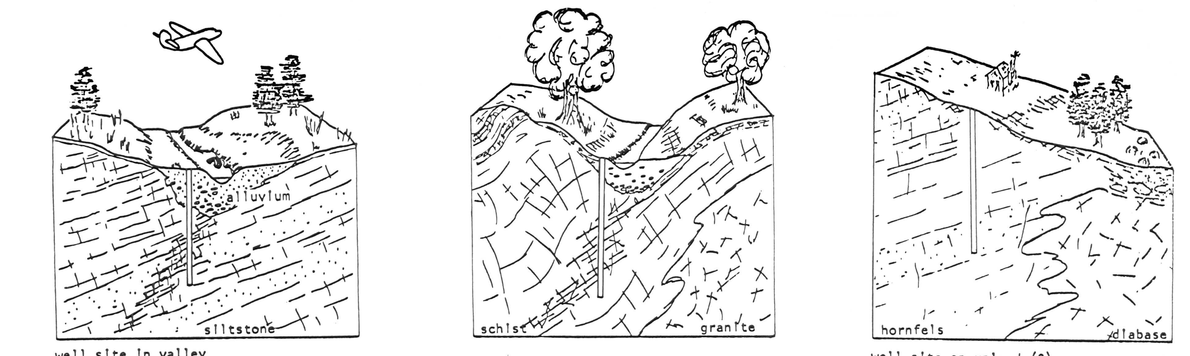
This map will be most useful to those who have a large area or alternate areas in which to select well sites. For example, an industrial plant or small municipality requiring 100 gallons per minute (from one or several wells) can use the map to estimate the probability of obtaining such a yield at alternate sites. the map is not particularly useful for a homeowner selecting a domestic well site because his property is generally much smaller than the cell size (41 acres). However, wells yielding sufficient water for a domestic supply can be constructed almost anywhere in the county -- except that some difficulty may be experienced in unit D.

HOW THE MAP WAS MADE

This computer-generated composite map was made by combining six source maps of the Piedmont and Triassic Provinces of Fairfax County, Virginia. Source maps were stored in the computer by a process called digitizing. This was accomplished by superimposing a grid on each map and recording a latitude-longitude location and numeric identification code for each map unit cell. A cell is one sampling unit, which measures 1200 feet by 1500 feet, and covers about 41 acres. The map contains 5195 cells. Numbers were assigned to the units on each digitized map in the order of increasing favorability for productive water wells. The computer added these numbers for each cell to produce an overall evaluation of potential water yield. Although hydrogeologic conditions within a cell are not uniform, a number representing average conditions is recorded for each cell. An example of computer compositing to obtain ratings for 4 cells is shown below.



EXAMPLES OF HYDROGEOLOGIC CONDITIONS AT ACTUAL WELL SITES IN FAIRFAX COUNTY



well site in valley bottom (2) with alluvium (2) less than 50 ft thick (1)
fracture zone inferred from satellite imagery (2) not on bedrock high (1)
siltstone aquifer (8)
rating = 16
600 GAL/MIN WELL IN SILTSTONE AQUIFER AT DULLES AIRPORT

well site in valley bottom (2) with alluvium (2) less than 50 ft thick (1)
fracture zone inferred from satellite imagery (2) not on bedrock high (1)
schist aquifer near contact with granite (5)
rating = 13
100 GAL/MIN WELL IN SCHIST AT VIENNA

well site on upland (0) with thin overburden (1) not alluvium (1)
no indication of linear features on satellite imagery (1)
not on bedrock high (1)
well in hornfels (0)
rating = 4
1/2 GAL/MIN WELL IN HORNFELS SOUTH OF HERNDON

HYDROGEOLOGIC FACTORS AFFECTING THE YIELD OF BEDROCK WELLS

Under present conditions of light, widely-spaced pumping, the yields of wells tapping the bedrock in Fairfax County are dependent upon:

(1) the transmissivity of the bedrock aquifer

(2) the hydraulic properties of the overlying unconsolidated deposits (which for the most part act as a leaky confining bed)

(3) proximity to boundaries (fracture zones and low permeability rock units).

The major boundary conditions are reasonably well known because of recent detailed geologic mapping (Drake and Froelich, 1977). However, rarely are sufficient data available on the bedrock transmissivity or other hydraulic characteristics of the overburden to assess the potential of a drilling site accurately. An alternative method is to use indirect indications of these properties to obtain clues to the groundwater potential of a locality. For example, it has long been known that wells located in stream valleys generally have higher yields than wells at hilltop sites (Jonhnston, 1964; LeGrand, 1967; Nutter and Otton, 1969). Presumably the stream valley follows permeable fracture zones in the bedrock. Increased overburden thickness generally means higher well yields, as noted by Johnston (1964) and LeGrand (1967).

The accompanying table summarizes the factors which relate to the transmissivity of the bedrock aquifers and the overburden properties, and which therefore influence the yields of wells. To assess the relative importance of each factor, reported yields from about 1100 wells were compared to pertinent hydrogeologic factors using simple statistical methods. These comparisons form the basis for the ratings used to generate the computer-composite map and are listed in the table.

Of all these factors, lithology is by far the most important. All wells yielding more than 100 gallons per minute, and most wells yielding more than 50 gallons per minute, tap either siltstone, sandstone, or sheared zones in schist. No high-yielding wells tap greenstone, diabase or hornfels.

Some linear features observed on LANDSAT satellite imagery are related to zones of more and less transmissive rock. Depressed linear fractures mapped by Iwahashi and Heironimus (1978) correlate closely with the location of high-yielding wells. In making these correlations, the authors defined bands extending 500 feet on either side of these linear traces. Although the areas so defined make up only 33 per cent of the map, they encompass 60 percent of the bedrock wells yielding in excess of 100 gallons per minute. Conversely, narrow bands along positive linear features (which make up only 6 percent) encompass 45 per cent of the "dry holes" (wells yielding less than 2 gallons per minute). In contrast, no relationship between yields of wells and linear traces on aerial photographs was observed. Apparently the aerial photograph traces reflect many cultural features whereas the satellite traces detect differences related to fracturing within the bedrock.

A relationship exists between the yield of wells and bedrock topography. Sixty per cent of the "dry holes" are located on bedrock "highs" and "ridge lines" as mapped by Froelich and Heironimus (1977). However, no corollary relationship is evident between the location of high-yielding wells and bedrock "lows" or "troughs". Thus, elevated bedrock topography simply indicates areas to avoid in selecting a well site.

The character and thickness of overburden directly affect the yields of bedrock wells. The overburden acts as a leaky confining bed characterized by relatively high storage but low permeability as compared to the bedrock aquifers. Pumping from the high-yielding bedrock aquifers (siltstone, sandstone, and fractured schist) produces rapidly generated, widespread cones of depression. Under long-term pumping, substantial amounts of water may be derived by vertical leakage from the overburden. If the overburden is thin or very clayey, well yields may decline with time, a common problem in Virginia according to Cederstrom (1972). A greater-than-average thickness of overburden is a possible indication of high well yields. Seventy per cent of the wells yielding more than 100 gallons per minute penetrate more than 50 feet of overburden; only about 30 percent of the "dry holes" penetrate more than 50 feet.

Alluvium is the only surface material that can be directly related to well yields. Although alluvium underlies a very small part of the map area, about one-third of all high-yielding wells penetrate it. No "dry holes" have been drilled through alluvium.

Topographic setting is an excellent indicator of well yields. About 70 percent of the high-yielding wells are in valley bottoms. On the other hand, only 5 per cent of the "dry holes" occur in stream valleys and 80 per cent are located in uplands.

The assignment of numerical ratings to the 6 factors listed in the table is purely qualitative. Except for lithology, similar weights are given to all factors. Thus a site with a total rating of 9 should not be considered significantly better than one with a 7 rating. On the other hand, a rating of 14 should always indicate a more favorable site than a rating of 3. The hydrogeologic settings and favorability ratings of 3 actual well sites--2 high-yielding wells and 1 "dry hole" are shown in the adjacent sketch. Most wells drilled in the county would be classified between these extremes.

In defining relationships between well yields and hydrogeologic factors, emphasis was placed on the occurrence of very high or very low yields rather than the actual numerical value of the yield. Most domestic wells are not tested for more than small yields. A well reportedly yielding 5 gallons per minute may actually yield 20 or 30 gallons per minute. On the other hand, a reported yield of less than 1 gallon per minute is probably accurate. Likewise, reported yields in excess of 50 gallons per minute (generally for comercial or public supply wells which have been adequately tested) are considered accurate. Accordingly, no significance was placed on reported well yields in the range of 2 to 50 gallons per minute.

The computer-composite map should be used with care as the accuracy in depicting local geologic conditions is limited by the cell size. In particular, the map is intended to differentiate the very favorable water-well sites from the least favorable localities.

SOURCES AND CLASSIFICATION OF MAP UNITS USED TO EVALUATE POTENTIAL YIELDS OF WATER WELLS IN BEDROCK AQUIFERS

HYDROGEOLOGIC FACTORS		DATA SOURCES	MAP CLASSIFICATION	FAVORABILITY RATING
Factors affecting transmissivity of bedrock aquifers	Lithology	Bedrock map of Fairfax County by Drake and Froelich (1977) Probable Well yield map by Johnston (1978). Planar and linear features map by Froelich (1978).	Siltstone Sandstone Schist (in sheared zones near contact with massive rock types) Schist-all other areas Phyllite, Gneiss, Metagraywacke, Conglomerate, Granite Greenstone Diabase and Hornfels	8 7 5 3 2 1 0
	Inferred occurrence of fracture zones based on satellite imagery	Unpublished map of LANDSAT alignments by Iwahishi and Heironimus (1978)	Depressed linear features No linear features Positive linear features	2 1 0
	Inferred occurrence of unfractured ("tight") rock based on bedrock topography.	Base of saprolite map by Froelich and Heironimus (1977)	Bedrock "highs" and "ridge lines" on bedrock surface All other areas	0 1
Factors affecting hydraulic properties of overburden	Overburden character	Surface materials map by Langer (1978)	Alluvium All other unconsolidated deposits	2 1
	Overburden thickness	Thickness of overburden map by Froelich and Heironimus (1977)	Greater than 50 ft. Less than 50 ft.	2 1
Topographic setting (indirectly related to aquifer and overburden characteristics)		Landforms map by Rodgers (1977)	Valley bottoms Sloping valley sides Uplands	2 1 0
			Range of possible ratings	2 - 17

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The Multi-Scale Data Analysis and Mapping Program (MSDAMP) was used to produce this composite map. MSDAMP was written by Glenn H. Beavers and sponsored by the Iowa Agricultural and Home Economics Experiment Station, Iowa State University.