

Summary of SIR 2008-5015: Hydrochemical Regions of the Glacial Aquifer System, Northern United States, and Their Environmental and Water-Quality Characteristics

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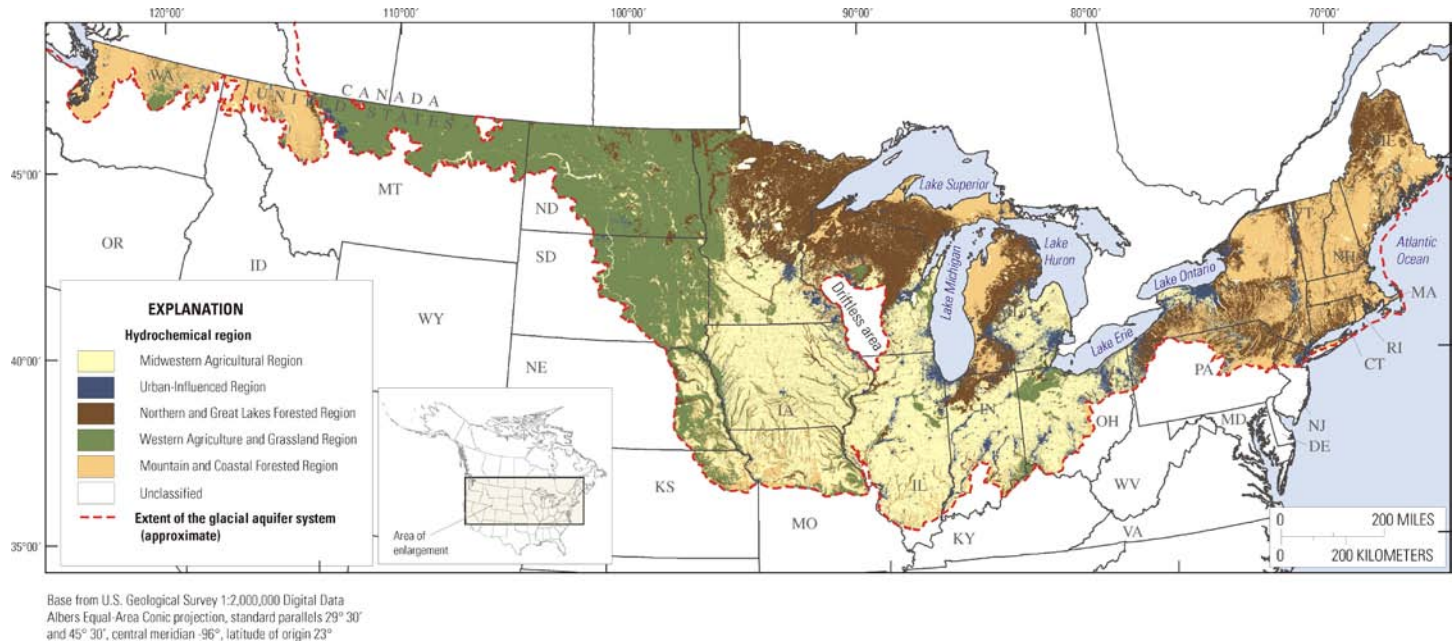


Figure 1. The glacial aquifer system is divided into five hydrochemical regions that have similar environmental settings and basic water chemistry.

The glacial aquifer system in the United States is a large (953,000 square miles) regional aquifer system of heterogeneous composition. As described in this report, the glacial aquifer system includes all unconsolidated geologic material above bedrock that lies on or north of the line of maximum glacial advance within the United States.

Regional variations in the concentrations of major and minor ions and some trace elements are, in large part, controlled by natural variations in the geologic and physical environment. Interaction between water and glacial deposits in different environmental settings can result in differing water chemistry. Land use is the primary anthropogenic environmental characteristic affecting ground-water quality in the aquifer system.

Five hydrochemical regions have been defined for the glacial aquifer system to explain regional patterns in constituent concentrations. The five hydrochemical regions are: Midwestern Agricultural Region (MAR), Urban-Influenced Region (UIR), Northern and Great Lakes Forested Region (NGLFR), Western Agriculture and Grassland Region (WAGR), and Mountain

and Coastal Forested Region (MCFR) (fig. 1). These regions are an extrapolation of what is known about ion concentrations in ground-water from sampled wells to unsampled areas of the aquifer system using a mix of related environmental characteristics that control the movement of ground water through the system, including climate, surficial and soil geology, permeability, recharge, slope, and land use. The delineation of hydrochemical regions of an aquifer system, as defined in this report, is appropriate for use only in large regional-scale studies. The hydrochemical regions were developed to identify and explain regional spatial variations in ground-water quality in the glacial aquifer system.

Data analyzed for this study were collected from 1991 to 2003 at 1,716 wells open to the glacial aquifer system. Cluster analysis was used to group wells with similar ground-water concentrations of calcium, chloride, fluoride, magnesium, potassium, sodium, sulfate, and bicarbonate into five unique groups. Maximum Likelihood Classification was used to make the extrapolation from clustered groups of wells, defined by points, to areas of similar

water quality (hydrochemical regions) defined in a geospatial model (fig. 2). Spatial data that represented average annual precipitation, average annual temperature, land use, land-surface slope, vertical soil permeability, average soil clay content, texture of surficial deposits, type of surficial deposit, and potential for ground-water recharge were used in the Maximum Likelihood Classification to classify the areas so the characteristics of the hydrochemical regions would resemble the characteristics of the clusters. The result of the Maximum Likelihood Classification is a map showing five hydrochemical regions of the glacial aquifer system.

The regions with the highest ion concentrations in ground water (MAR, the UIR, and the WAGR) have environmental characteristics that indicate relatively slow movement of water through the aquifer system (fig. 3): low annual recharge, low permeability, high soil clay content, fine-grained surficial deposits, and dry, warm climate. These regions also have predominantly agricultural or urban land use. In contrast, environmental characteristics of the regions with the lowest ion concentrations (NGLFR and the MCFR) indicate relatively fast movement of ground water through the aquifer system: high annual recharge, high permeability, low soil clay content, mixed- or coarse-grained surficial

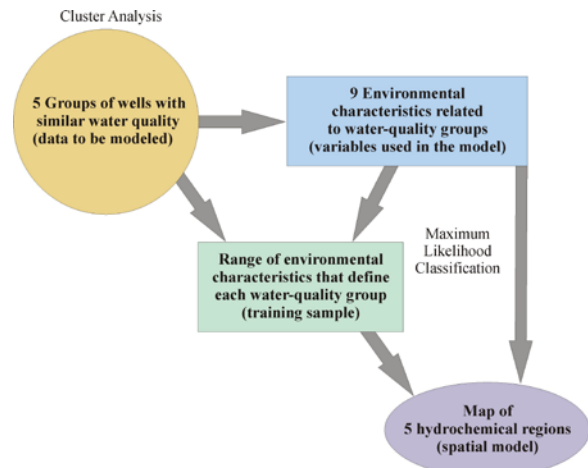


Figure 2. Cluster analysis resulted in five groups of wells with similar water-quality characteristics. The five groups of well combined with the environmental characteristics of each well were used in maximum likelihood classification to map five hydrochemical regions that have similar environmental settings and basic water chemistry.

deposits, and wet, cool climate. These regions are predominantly forested Median concentrations of barium, arsenic, lithium, boron, strontium, and nitrite plus nitrate as nitrogen also are significantly different among the hydrochemical regions and are correlated with environmental factors and major and minor ion concentrations.

Hydrochemical Region	Generalized Environmental Characteristics		Generalized Water-Quality Characteristics	
Urban-Influenced Region	Mostly urban areas with population greater than 70,000; low permeability	Water moves slowly through the system	High in Major and Minor Ions	Highest median Ca, Cl; Second highest median Mg, K, Na, SO ₄ , HCO ₃
Midwestern Agricultural Region	Warm and humid, tile-drained, clayey agricultural areas; low permeability; low recharge			Highest median Mg, HCO ₃ ; Second highest median Ca, Cl, F
Western Agricultural and Grassland Region	Warm and dry, clayey, irrigated agricultural and grassland areas; low permeability; very low recharge			Highest median F, K, Na, SO ₄ ; Second lowest median Cl
Northern and Great Lakes Forested Region	Sandy, cool, forested, areas with high organic content; high permeability	Water moves quickly through the system	Low in Major and Minor Ions	Lowest median Cl, F, Na; Second lowest median Ca, Mg, K, SO ₄ , HCO ₃
Mountain and Coastal Forested Region	Sandy and wet mountainous and coastal forested areas; high permeability; high recharge			Lowest median Ca, F, Mg, K, SO ₄ , HCO ₃ ; Second lowest median Na

Figure 3. The regions with the highest ion concentrations in ground water are predominantly areas of agricultural or urban land use and have environmental characteristics that indicate relatively slow movement of water through the aquifer system. In contrast, environmental characteristics of the regions with the lowest ion concentrations, which are predominantly forested areas, indicate relatively fast movement of ground water through the aquifer system.