Prepared in cooperation with the
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION,
OFFICE OF SCIENCE AND RESEARCH

WATER-RESOURCES INVESTIGATIONS
REPORT 87-4181

CORROSIVE GROUND WATER IN THE KIRKWOOD-COHANSEY AQUIFER SYSTEM IN THE VICINITY OF OCEAN COUNTY, EAST-CENTRAL NEW JERSEY

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INTRODUCTION

Studies conducted in several areas of the United States and Europe have correlated the occurrence of corrosive water and the leaching of trace metals from commonly used water-supply materials (Karalekas and others, 1976; O'Brien, 1976; Hoyt and others, 1978; Lovell and others, 1978; Matthew, 1981; Lassovsky, 1984; de Mora and Harrison, 1984; Maessan and others, 1985; Murrell, 1985; Kish and others, 1987). In general, corrosion is the deterioration of a material by electrochemical or chemical reactions with the material's environment (Singley and others, 1985). In water-supply systems, the environment is water. Materials used in most public water-supply systems, such as copper, lead, steel, cast iron, galvanized iron, brass, and asbestos-cement, may be susceptible to corrosion. Metallic structures in contact with ground water, such as underground storage tanks, also may be subject to corrosion.

Corrosive waters generally have an acidic pH, low calcium hardness[1] and low alkalinity[2]. The relative corrosiveness of a water can be measured indirectly by one or more corrosion indexes. A corrosion index is a mathematical representation of the corrosion potential of a water based on certain physical and chemical characteristics of the water. Some of the characteristics include pH, temperature, and concentrations of alkalinity, calcium, dissolved oxygen, chloride, sulfate, and total dissolved solids.

One commonly applied corrosion index is the Aggressive Index, which requires only alkalinity, calcium hardness, and pH for its calculation. The Aggressive Index was originally formulated to determine aggressiveness (corrosiveness) of water with respect to asbestos-cement pipe used in water-distribution systems (American Water Works Association, 1977). However, the effectiveness of the Aggressive Index in this regard has been questioned by Schock and Buelow (1981). The Aggressive Index has been used in a nationwide survey of the corrosion potential of drinking-water supplies and was found to estimate adequately the aggressiveness of the water tested (Millette and others, 1980).

The Aggressive Index is a simplification of the widely used Langelier Saturation Index. The Langelier Index (and, therefore, the Aggressive Index) is based on the solubility of calcium carbonate and the ability of a water to precipitate a protective film of calcium carbonate on water-distribution pipes. When a water is supersaturated with calcium carbonate, a calcium-carbonate film precipitates on pipe interiors, sealing the pipe surface from corrosive reactions with the water. Undersaturation indicates that the water is free to react corrosively with the pipe surface. Water supersaturated with calcium carbonate is considered noncorrosive, whereas water undersaturated with calcium carbonate is considered corrosive.

Ground-water-quality data for the Coastal Plain were found to be incomplete in a number of instances. Thus, the Aggressive Index, which requires few parameters for its calculation, was used as a first approximation of the distribution of corrosive ground water in the Kirkwood-Cohansey aquifer system. Laboratory leaching experiments, using Kirkwood-Cohansey water, and tap-water analyses have confirmed the high corrosion potential indicated by the Aggressive Index values (Barringer and others, 1987; Kish and others, 1987).

The purpose of this report is to show the areal extent of corrosive ground water in the Kirkwood-Cohansey aquifer system in the vicinity of Ocean County, New Jersey, as estimated by the Aggressive Index.

DESCRIPTION OF THE STUDY AREA

Geographic Setting

The study area includes Ocean County and small parts of Monmouth and Burlington Counties (fig. 1). The study area, which is situated in the Atlantic Coastal Plain physiographic province, has predominantly sandy soils, low topographic relief, and gently sloping hills.

Geohydrology

The New Jersey Coastal Plain consists of a seaward-thickening wedge of unconsolidated sand and gravel with interbedded clay units. Within the study area, this wedge ranges in thickness from about 1,100 feet in the western part of Ocean County to more than 4,800 feet near the coast (Zapecza, 1984, pl. 1). The seaward thickening of the strata and the sequence of the aquifers and confining units are illustrated in figure 2. Only the unconfined Kirkwood-Cohansey aquifer system (fig. 2) is considered in this report.

In the vicinity of Ocean County, the Kirkwood-Cohansey aquifer system is composed of the Kirkwood Formation and the overlying Cohansey Sand, both of Miocene age; locally it includes overlying deposits of the Miocene Beacon Hill Gravel. In the study area, the Kirkwood Formation contains thick clay beds interbedded with thinner lenses of sand and gravel. The Cohansey Sand, which is coarser grained than the underlying Kirkwood Formation (Zapecza, 1984, p. 32), is predominantly a yellow (limonitic) quartz sand with variable amounts of fine- to coarse-grained sand, clayey sand, and interbedded clay (Rhodehamel, 1973, p. 24).

Geochemistry of Ground Water

Ground water in the Kirkwood-Cohansey aquifer system generally is acidic. Alkalinity and calcium hardness concentrations are low, typically less than 10 mg/L (milligrams per liter). Along the coast and in areas where the Kirkwood Formation crops out, some pH values exceed 7.0. Also, calcium hardness and alkalinity concentrations are higher in coastal regions, and tend to be higher in the areas where the overlying Cohansey Sand is absent. Some wells on barrier islands and near the coast contain more saline water (Harriman and Sargent, 1985, p. 59), and thus have elevated pH, alkalinity and calcium hardness. Table 1 gives median values and ranges for pH, alkalinity, and calcium hardness of ground water in the interior of the Coastal Plain and along the coast. An anomalous value from the northern part of the map area is included with the coastal values.

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[1] The term "hardness typically is defined as the sum of the divalent cation concentrations (calcium, magnesium, strontium, etc.) expressed as equivalent calcium carbonate ($CaCO_3$). In this report, the term "calcium hardness" refers to calcium concentrations only, expressed as equivalent calcium carbonate.

[2] Alkalinity is the acid-neutralizing capacity of water. Chemical species that contribute to alkalinity are bicarbonate ion (HCO_3^-), carbonate ion (CO_3^{2-} and hydroxyl ion (OH^-). Alkalinity concentrations frequently are expressed in milligrams per liter of calcium carbonate ($CaCO_3$).

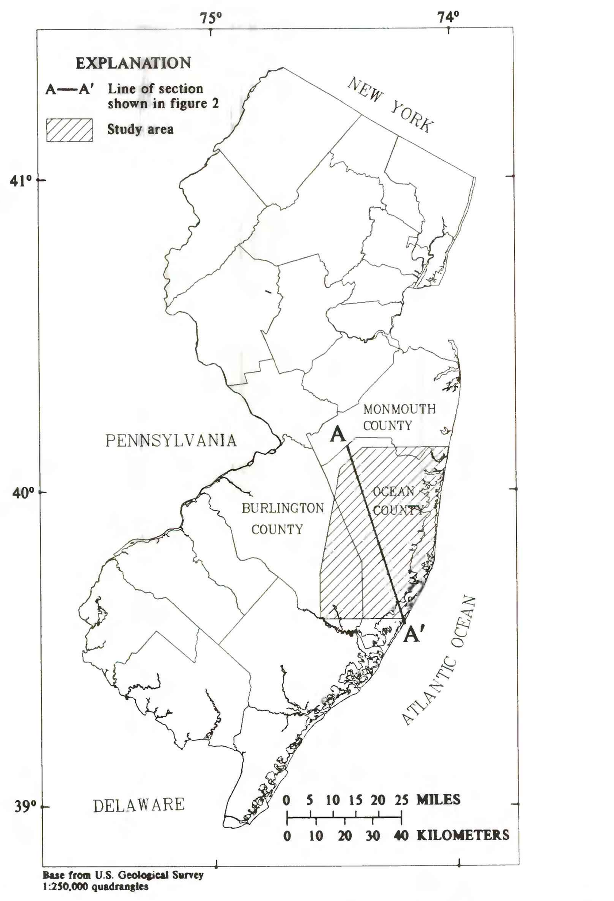

Figure 1.--Location of study area and line of geohydrologic section.

METHODS AND DATA SOURCES

Chemical analyses of water from 181 wells in the unconfined Kirkwood-Cohansey aquifer system were included in this study. The chemical data were retrieved from the WATSTORE data base maintained by the U.S. Geological Survey. The data set included domestic wells, observation wells, and municipal supply wells. Water samples from municipal wells were taken before the water was treated and distributed. Data from landfill-monitoring wells and contaminated wells were excluded. In order to represent the current water quality of the aquifer system, only the most recent chemical analysis of water from each well was used. All data were checked for ion balances (D. A. Harriman and J. L. Barringer, U.S. Geological Survey, oral commun., 1987) by using the criteria established by Friedman and Erdmann (1982).

Aggressive Index (AI) values were calculated for the ground-water-quality data by using the formula:

$$AI = pH + \log[(\text{total alkalinity}) \times (\text{calcium hardness})]$$

where pH is the negative logarithm of the hydrogen-ion concentration; total alkalinity and calcium hardness are expressed in mg/L as $CaCO_3$.

The values for the AI are divided into the following categories: (1) AI less than 10, very corrosive; (2) AI from 10 to 11.9, moderately corrosive; and (3) AI equal to or greater than 12, noncorrosive (American Water Works Association, 1977).

Field pH measurements were used to calculate the AI. In the few instances where field pH measurements did not exist, laboratory pH values were used in the calculations. For samples with alkalinity reported as less than 1 mg/L (the minimum detection limit for alkalinity), the value of 1 mg/L was used for index calculations. Therefore, indexes calculated for these samples indicate less corrosive water than is actually present.

A geographic information system (GIS) software package was used to display graphically the well information from the U.S. Geological Survey's Ground Water Site Inventory (GWSI) data base. A map of the well locations and the corresponding AI value was constructed by using the GIS. Lines of equal "aggressiveness" were drawn using the triangulated irregular network (TIN) option of the GIS software. The contour lines were modified in areas where the TIN could not accomodate all the data points. Geographic features have been added from a number of base maps of different scales.

The map shown in this report is a generalized representation of AI values that is based on the available data. The depths of the wells used in the study ranged from 12 to 331 feet. AI values, calculated for three pairs of wells screened at different depths, indicated little change with depth of well screen. Rank correlation indicated no significant relation between depth and AI value for the wells in the data set. Therefore, it is assumed that the AI values adequately represent the corrosive potential of ground water in both shallow and deep parts of the aquifer system.

RESULTS

A frequency distribution of the AI values of ground water (fig. 3) shows that 95.5 percent (173 observations) of the analyses fall into the very corrosive range. None of the 181 analyses is in the noncorrosive range, and only 4.5 percent of the analyses (8 observations) fall within the moderately corrosive range.

Lines of equal AI values for the Kirkwood-Cohansey aquifer system (fig. 4) show that corrosiveness generally decreases from west to east. The least corrosive water generally is found along the coastal areas and in the northern part of the study area where the Cohansey Sand is thin or absent. The most extensive zones of highly corrosive ground water in Ocean County, based on AI values, are found in four areas: (1) Beachwood Borough, Berkeley and Dover Townships; (2) the eastern parts of Lacey, Ocean, and Barnegat Townships; (3) Manchester Township; and (4) Plumstead and Jackson Townships, in the northwest part of the study area. Areas of extremely corrosive ground water in Burlington County, near the western border of the map, underlie State Forest lands in Woodland and Washington Townships.

CONCLUSION

On the basis of these data, the water in the Kirkwood-Cohansey aquifer system in the Ocean County area is, in general, very corrosive. These results complement previous and ongoing studies that document the leaching of trace metals exposed to water from the Kirkwood-Cohansey aquifer system in Beachwood Borough and Berkeley Township, Ocean County (Kish and others, 1987; J. Preczewski and T. Hayes, N.J. Department of Environmental Protection, Trenton, N.J., written commun., 1983; R. T. Mueller, N.J. Department of Environmental Protection, Trenton, N.J., oral commun., 1987).

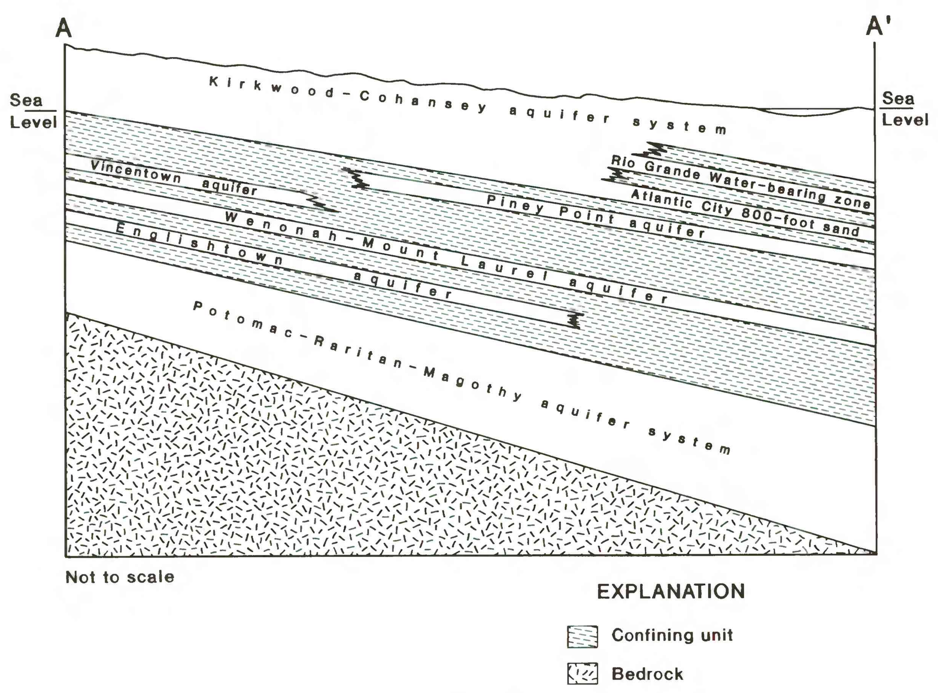

Figure 2.--Generalized geohydrologic section of the study area.

Table 1.--Median values and ranges for pH, alkalinity, and calcium hardness for ground water from the Kirkwood-Cohansey aquifer system

[Alkalinity and calcium hardness given in milligrams per liter as calcium carbonate; <, less than; ≥, greater than or equal to; n = number of samples]

AGGRESSIVE INDEX < 10 (Interior ground water)

	pH	Alkalinity	Calcium Hardness
median	5.3	4.0	2.3
minimum	4.0	< 0.5	<0.1
maximum	7.0	54	38

n = 173

AGGRESSIVE INDEX ≥ 10 (Coastal ground water and anomaly)

	pH	Alkalinity	Calcium Hardness
median	7.2	45	52
minimum	6.4	28	18
maximum	7.6	64	182

n = 8

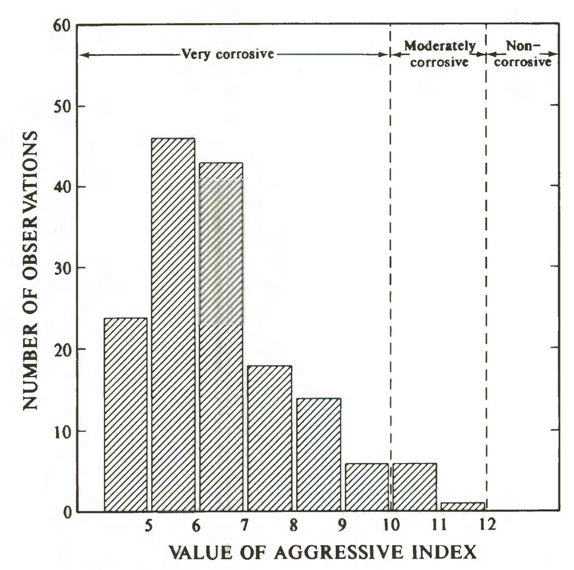

Figure 3.--Frequency distribution of Aggressive Index.

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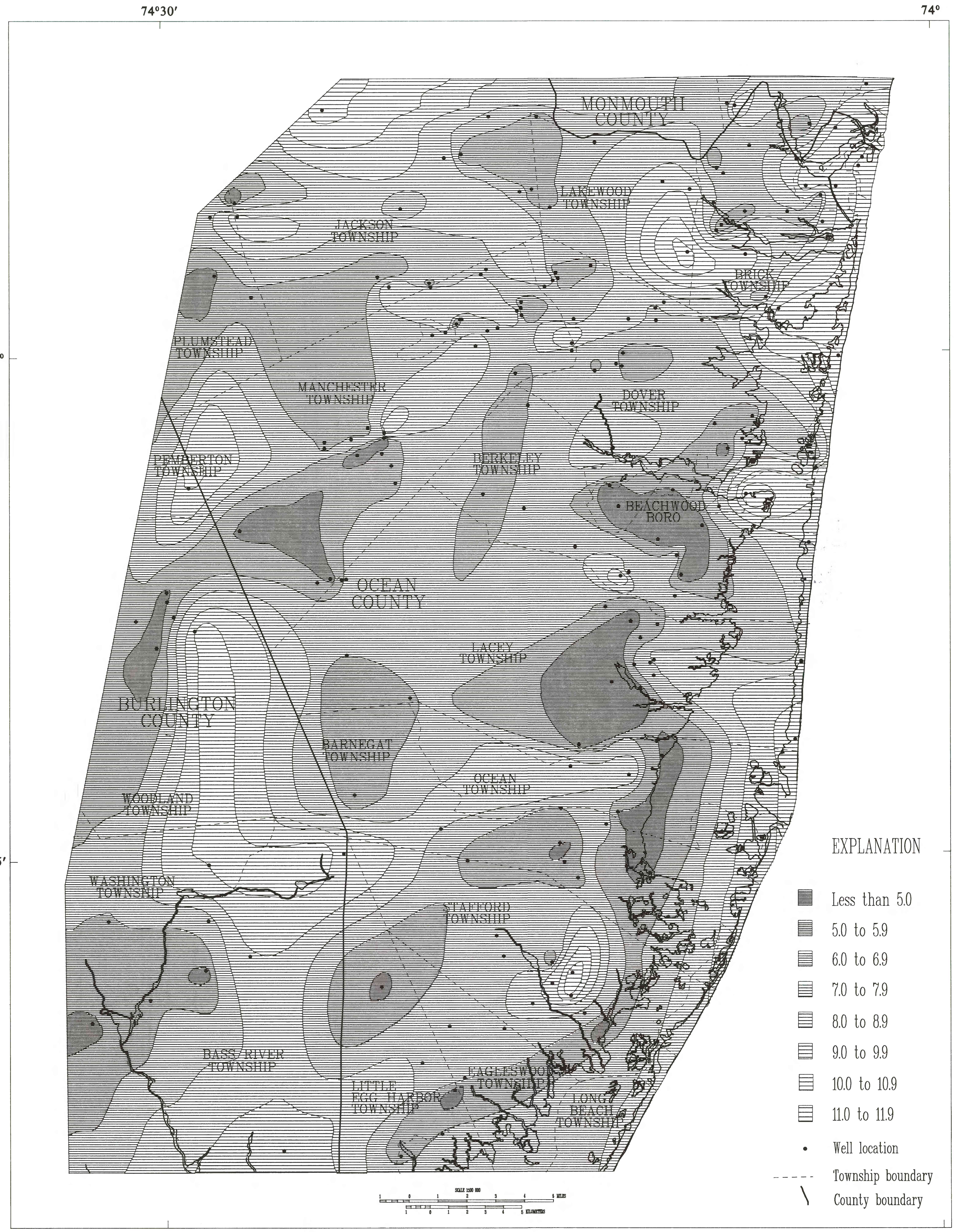

Figure 4.--Aggressive Index for water samples from the Kirkwood-Cohansey aquifer system in the vicinity of Ocean County, New Jersey.