TRENDS IN NITRATE CONCENTRATIONS IN PUBLIC WATER-SUPPLY WELLS, SUFFOLK COUNTY, NEW YORK, 1982-2008

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Introduction

Nitrate concentrations in groundwater from public-supply wells of the Suffolk County Water Authority (SCWA) for which suitable and sufficient data exist from 1982 to 2008 were analyzed using the Mann-Kendall and Seasonal Kendall tests for trends in ESTREND (Schertz and others, 1991). The Mann-Kendall test identifies trends without removing variations in nitrate concentrations due to factors other than time; the Seasonal-Kendall test identifies trends after accounting for seasonal variations in nitrate concentrations. In this assessment, two 'seasons' were used that correspond to different pumpage rates (public-water demand) over the course of a calendar year: season one (summer) is April 1 to October 31 and season two (winter) is November 1 to March 31. Separate trends analyses were completed on wells screened in the upper glacial and the Magothy aquifers. Two time periods were identified as having suitable data for analysis with the Mann-Kendall test: 'Long-Term' (1982-2008) and 'Short-Term' (1982-1994). A third time period was identified with data suitable for analysis with the Seasonal-Kendall test: 'Seasonal' (1999-2006). If the Mann-Kendall or Seasonal-Kendall tests identified trends in nitrate concentrations, the Regional-Kendall test for trends was used to assess regional patterns in nitrate concentrations (Helsel and Frans, 2006; Sprague and Lorenz, 2009). The Regional-Kendall test for trend assesses whether a consistent trend occurs at many of the sampling locations within a region (Helsel and Frans, 2006), and is analogous to the Seasonal Kendall test, with 'region' substituting for 'season.' The Regional-Kendall test only allows inclusion of uncensored data for analysis. Five Regions, based on sewerage, land use (including population density), and hydrogeologic factors were identified for the Regional-Kendall test: Northwest (NW), Southwest Unsewered (SW-UN), Southwest Sewered (SW-SE), Central (CE), and Eastern (EA) Regions (figure 1). Previous studies in Suffolk and Nassau Counties have used a similar approach to distinguish regional differences in groundwater quality, including nitrate (Leamond and others, 1992; Stackelberg, 1995; and Pearsall, 1996).

Nitrate data collected from more than 700 public water-supply wells over the last 50 years were assessed for suitability for inclusion in the trends analysis. For each time period, at least one nitrate data result was available in the first and last year. Data were screened to ensure that all wells included met the requirement for the statistical test. The minimum

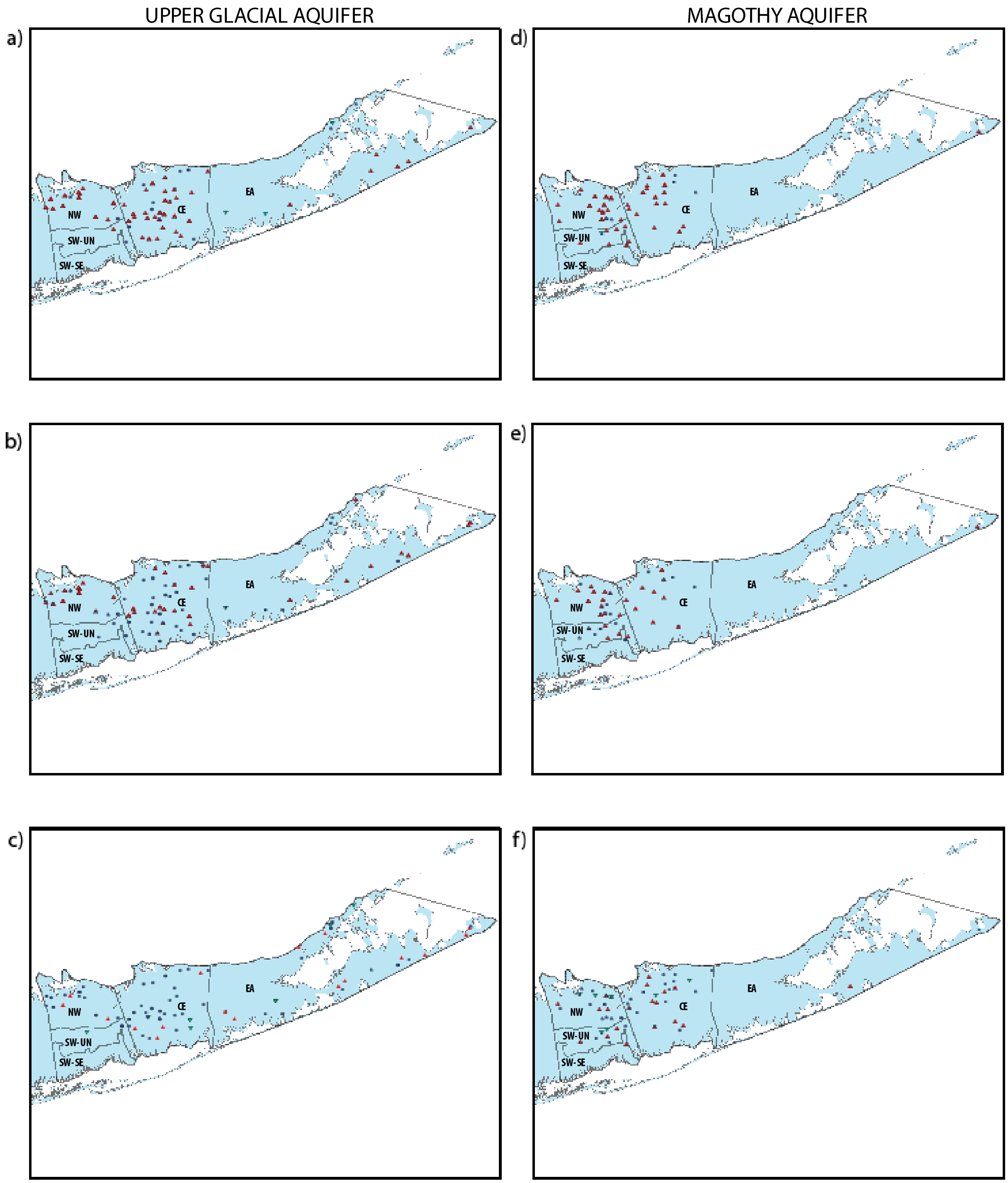


Figure 1: Locations for wells used in a) upper glacial, long term trend analysis (1982-2008), b) upper glacial, short term trend analysis (1982-1994), c) upper glacial, seasonal term trend analysis (1999-2006), d) Magothy long term trend analysis (1982-2008), e) Magothy short term trend analysis (1982-1994), f) Magothy seasonal term trend analysis (1999-2006), Where ▲ is a well with an increasing trend, ▼ is a well with a decreasing trend, ● is a well with no trend.

number of detections required is ten; any wells with less than ten were not included in the analysis. For wells with less than five percent censoring (concentrations reported as less than the method reporting limit [MRL]), the uncensored Mann-Kendall analysis was used, otherwise the censored Mann-Kendall was used. Data were not collected at a sufficient temporal frequency to allow for seasonal trend analysis for the long-term and short-term time periods. For the seasonal trend analysis, each well was required to have a minimum of five years of data for each of the two seasons. Of the 700 wells, 264 wells (95 in the Magothy aquifer, 169 in the upper glacial aquifer) were sufficient to assess one or more of the three time periods.

Statistical trends were evaluated for each well individually for each time period based on the 'representative value' for nitrate concentration. (A trend was considered statistically significant at $p=0.05$.) The 'representative value' is the median of the data used in the trend test. The representative value is assumed to represent a concentration for typical conditions in the middle of the trend test period. Wells were classified by concentration using the representative value. Concentrations were divided into three classes: less than or equal to 1 milligram per liter (mg/L) (low range), greater than 1 mg/ L and less than or equal to 5 mg/L (moderate range), and greater than 5 mg/L (high range).

Results

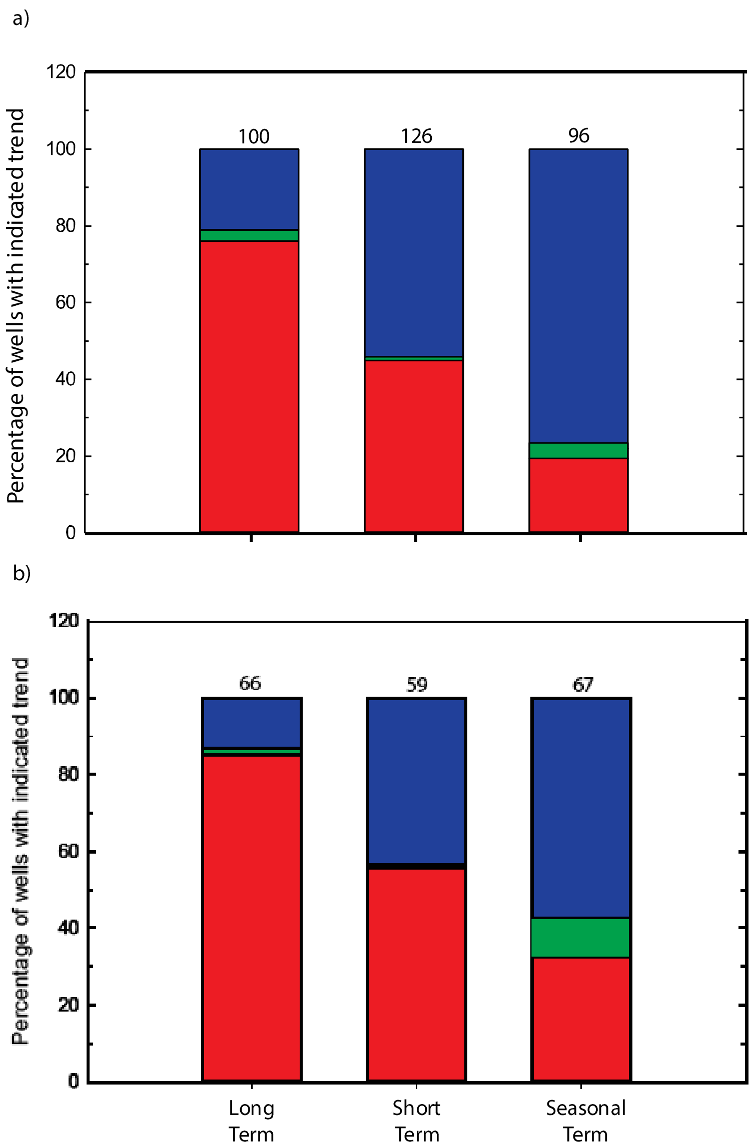
Nitrate concentrations increased in groundwater in many of the wells (40% or greater) over the long- and short-term periods; fewer wells (10-30%) show increasing trends in nitrate when accounting for seasonality (figure 2). Very few (less than 10%) of the wells show decreasing nitrate trends for any of the three periods in either aquifer. Increases in nitrate concentrations were most prevalent in the NW region for both the upper glacial and Magothy aquifers (figures 1 and 3).

Upper Glacial Aquifer

Data were sufficient to assess groundwater nitrate trends in the upper glacial aquifer in 100 wells over the long term (1982-2008) trends analysis, 126 wells over the short-term (1982-1994), and 96 wells for the seasonal assessment (1999-2006) (figure 2a). Trends could not be determined for upper glacial aquifer wells in SW-SE because this region had inadequate data to meet the criteria for trends analysis.

Long Term (1982-2008)

More than 75% of the upper glacial wells had an increasing trend over the long-term, and very few (5%) had a decreasing trend for this period (figure 2a). In all the regions except for EA, the regional trends in nitrate concentrations were increasing (figure 1a and 3a). Because no upper glacial wells were appropriate for analysis in SW-SE, this region was not included in the analysis. More than 70% of the wells in regions NW and CE had a significant increase in nitrate concentrations over this period, whereas 50% of the wells in SW-UN and EA regions had an increasing trend. EA was the only region containing wells (25%) with a decreasing concentration trend (figure 3a). Increasing trends were most prevalent in wells with representative concentrations within the moderate range (82%), followed by wells within the low range (67%), and the high range (64%) (figure 4a).



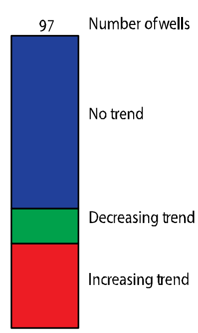
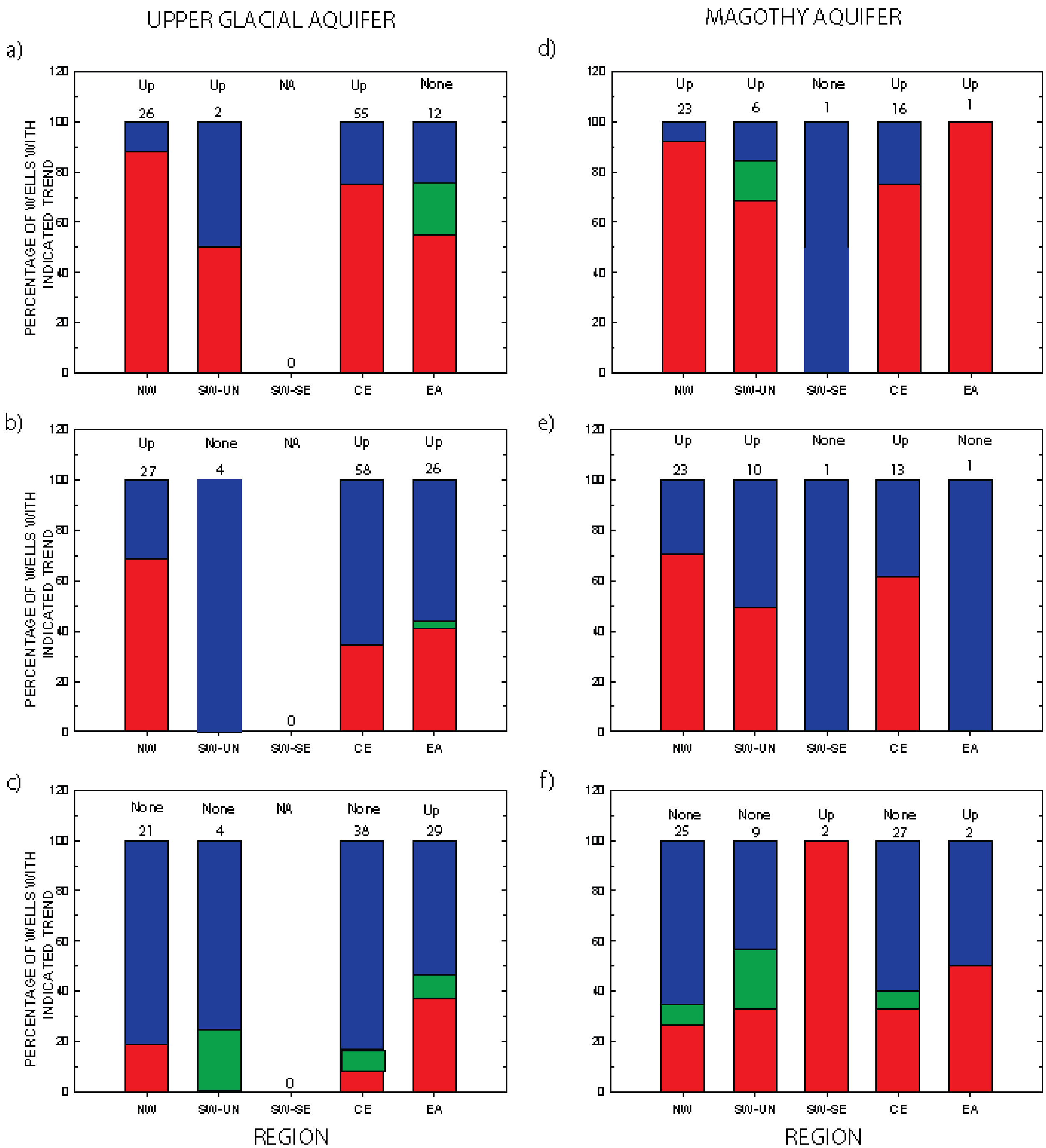


Figure 2: Percentage of well that have increasing, decreasing, or no trend for the long term (1982-2008), short term (1982-1994), and the seasonal term (1999-2006) for a) upper glacial and b) Magothy aquifer. (Analysis includes both censored and uncensored results)

Short Term (1982-1994)

More than 40% of the 126 wells included in the short-term analysis for the upper glacial aquifer had an increasing trend (figure 2a); only one well, located in region EA, had a decreasing



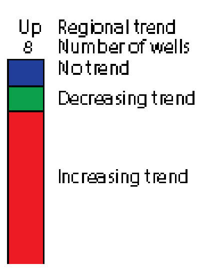


Figure 3: Results of the Regional Kendall analysis for the upper glacial aquifer a) long term (1982-2008), b) short term (1982-1994), c) seasonal term (1999-2006), and the Magothy aquifer d) long term, 3) short term, and f) seasonal term.

trend for this time frame (figure 1b). More than half of the wells (56%) did not have a detectable trend. Three regions, NW, CE, and EA, have an increasing trend in nitrate concentration as reported by the Regional Kendall analysis (figure 3b). Region NW has the greatest number of wells (70%) with increasing trends. The greatest proportion of wells with increasing trends have a representative nitrate concentrations in the moderate range (greater than 1 mg/L to less than or equal to 5 mg/L) (figure 4b).

Seasonal Term (1999-2006)

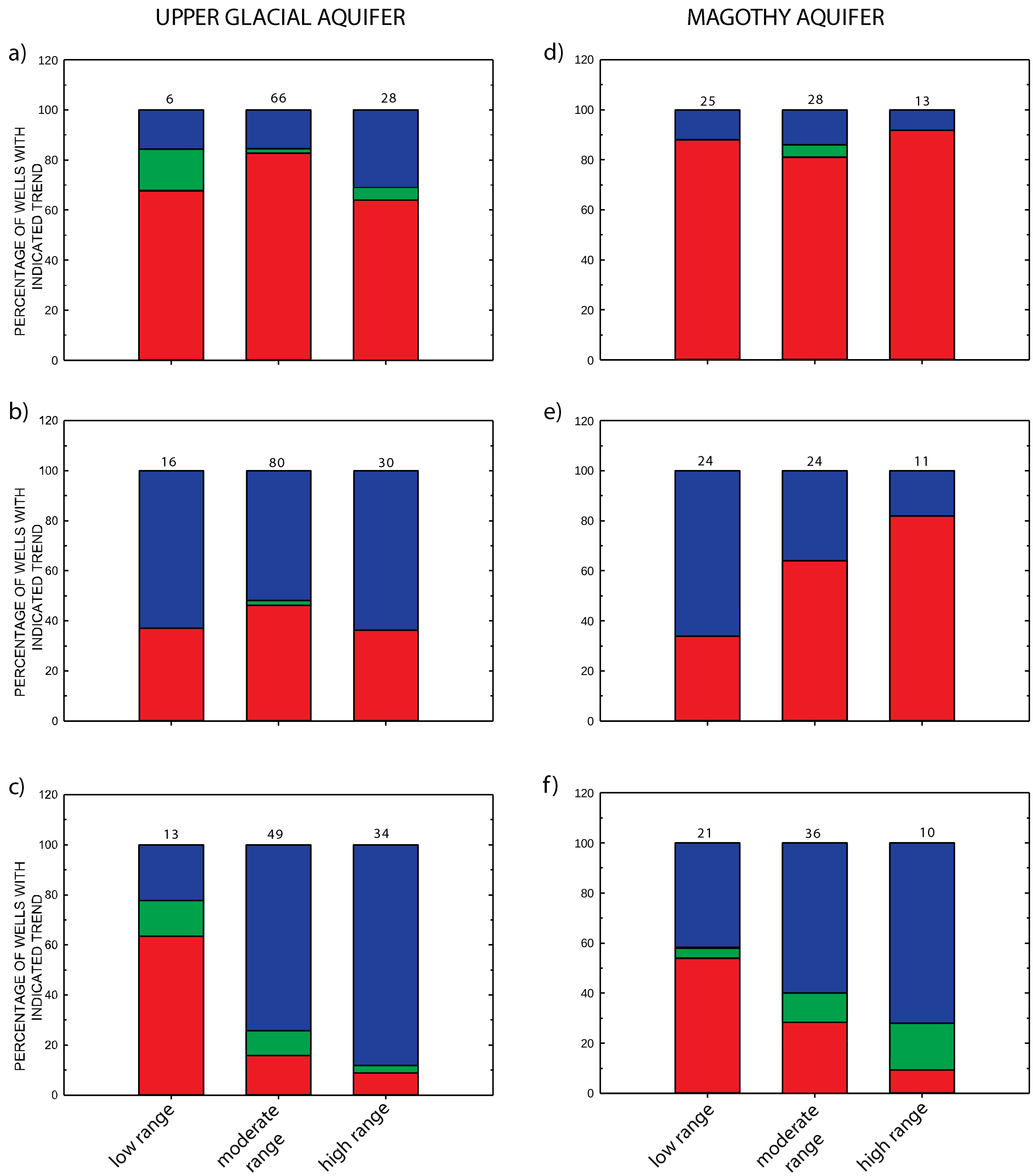
Most (72%) of the 96 wells included in the short term analysis for the upper glacial aquifer did not have a significant trend in nitrate concentration; just 19% of the wells reported an increasing trend and less than 10% of the wells had decreasing trends (figure 2a). The Regional Kendall analysis shows just one region, EA, having an increasing trend; none of the regions have a decreasing trend (figures 1c and 3c). The greatest portion of wells (62%) with an increasing trend are in the low range (less than or equal to 1 mg/L), with less in the moderate (16%) and high (9%) ranges (figure 4c). There are fewer wells that show increasing trends during this term in comparison to the other two terms. This may be a function of water management; however, it is not possible to directly assess this without an analysis of trends in pumpage.

Magothy Aquifer

Sixty-six wells were used for the Magothy aquifer long term (1982-2008) trends analysis, 59 wells for the short-term (1982-1994), and 67 wells for the seasonal analysis (1999-2006). Most of the wells with available data were present in regions NW and CE; very few wells present in regions SW-SE and EA (two or less) had adequate data available to be included in each of the three time periods term trend analysis (figures 1 and 3).

Long Term (1982-2008)

Eighty-five percent (56) of the Magothy wells have a significant increase in nitrate concentrations for the long-term analysis (figure 2b). Only one well (2%), located in region SW-UN, had a decreasing trend; the remaining eight wells (13%) had no trend. Four of the five regions have increasing trends for this period—only one well present in EA met the requirements to be included in the analysis (figures 1d and 3d). Region NW has the greatest portion of wells (91%) with increasing trends. Greater than 65% of the wells in regions CE and SW-UN also have wells with increasing trends (75% and 67%, respectively). Nearly all the wells had an increasing trend, with little difference in proportion of wells with increasing trend



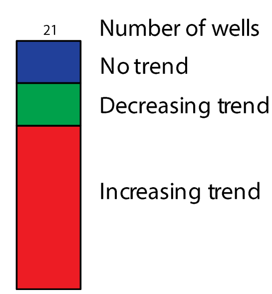


Figure 4: Division of wells based on representative nitrate concentration value for upper glacial aquifer a) long term, b) short term, and c) seasonal term, and Magothy aquifer d) long term, e) short term, and f) seasonal term. Low range = less than or equal to 1 mg/L; moderate range = greater than 1 mg/L to less than or equal to 5 mg/L; high range = greater than 5 mg/L.

among the three different nitrate concentrations range classes (figure 4d). All but one of the wells included within the representative nitrate concentration high range has increasing trends; most of these wells are located in region NW.

Short Term (1982-1994)

Most of the wells included in this analysis (56%) had an increasing trend in nitrate concentration; the remaining 44% of the wells reported no detectable statistical trend (figure 2b). No wells exhibited a decreasing trend for this time period. Three regions, NW, SW-UN, and CE, all have a regional trend increase (figures 1e and 3e). The proportion of wells with increasing trends increased from the low range (33%) to the moderate range (67%) with the maximum in the high range (82%) (figure 4e).

Seasonal Term (1999-2006)

An increasing trend in nitrate concentrations was observed in 33% of the Magothy wells while a few (10%) had decreasing trends and most wells (57%) had no reportable trend (figure 2b). Regional trends for regions SW-SE and EA have an increasing trend in nitrate concentrations and the other three regions did not have a significant trend (figures 1f and 3f). Even though both regions SW-SE and EA have regional increasing trends, this is the result of only two wells that met the requirements for the statistical analysis. Unlike the short term period, the greatest proportion of wells with an increasing trend were found in the low range (52%) with decreasing proportions of wells with significant increasing trends in the moderate range (27%) and the low range (10%). Fewer wells show increasing trends during this time period in comparison to the other two time periods (figure 4f). Similar to the upper glacial trends, the effects of water management on the trends results cannot be assessed without an analysis on the pumpage data.

Summary

Analysis of available nitrate data for public water-supply wells in Suffolk County, New York, over the period 1982-2008 shows statistically significant increases in nitrate concentration during this period. The long-term analysis (1982-2008) for both the Magothy and upper glacial aquifer reports the greatest number of wells with increasing nitrate trends in comparison to the other time periods. In each time period for either aquifer, the majority of wells with significant trends in nitrate show increasing concentrations, while few wells have decreasing nitrate trends. The Magothy aquifer has more wells reporting increasing trends than the upper glacial aquifer. Fewer than 15% of wells have decreasing trends in any term or aquifer; the seasonal term Magothy aquifer analysis had the greatest proportion of wells (10%) with decreasing trends. It is possible that water-use management may contribute to the fewer increasing trends that are present in the seasonal analysis, but this cannot be determined without an analysis of pumpage data. Two regions, NW and CE, had a regional trend increase in nitrate for each aquifer and time period, except for the seasonal term when there was no reportable trend (figure 3). There were no regional trend decreases in nitrate concentrations for any of the analyses (aquifer and time period). Most of the representative concentration values for each of the wells are in the high range (greater than 5 mg/L); the greatest portion of wells with increasing trend in this range was reported for the Magothy long term analysis (92%).

Future analysis of this dataset may include the percent of change in nitrate concentration for the time period. This type of analysis can distinguish which wells (and regions) are experiencing the greatest rate of increase over a time period. This analysis may be useful for determining where future increasing trends in nitrate concentration will occur if water-use management practices continue as they are currently implemented. Additional questions could be addressed by completing a statistical analysis on well pumpage data over the same time frame. The pumpage analysis can be used as a tool to determine the effect water-use management has had on nitrate trends over time periods. The pumpage analysis may also provide insight into how better water-use management can be implemented to control nitrate trends over a long-time period and seasonally.

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