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# High-Density Use of Septic Systems, Avon Lake, Iowa[1]

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Avon Lake, a rural-residential subdivision located southeast of Des Moines, has mostly summer cabins around a remnant gravel quarry. Surface material in the area is sand. Each of the homes has a shallow sand-point well for a water supply and a septic system for sewage treatment. Septic systems were examined for evidence of failure, house-to-house surveys were performed, and well water samples were taken. Fifty percent of the septic systems have been operating satisfactorily for more than 20 years. Only one of 68 well water samples contained fecal coliform bacteria. Thirty-six samples exceeded the nitrate standard, the highest being 25.6 mg/l N. Nitrate concentration seemed to change in space but not with well age. Nitrogen loadings from cropland, septic systems, and animals were also estimated; they ranged from 40-120 lb/acre (45-135 kg/ha) for cropland, 35 lb/acre (39 kg/ha) for septic systems, and 13 lb/acre (15 kg/ha) for dogs. All three of these could be important sources of nitrogen to the groundwater.
INDEX DESCRIPTORS: Septic tanks, on-site wastewater treatmenr, well water, nitrate, longevity.

Septic tanks with subsurface absorption of effluent have been the principal method of on-site wastewater treatment in Iowa's rural areas. In the past, many county boards of health have not been actively involved with the construction and operation of septic tank systems on farmsteads. This is because a failure of one of these systems to operate properly would be mainly an individual problem. As septic systems are being used in rural housing developments, however, there is a growing concern that these systems may pose a public health hazard. Two major concerns are the expected lifetime of these septic systems and their effect on the quality of the water resources in the area. In this study, a rural subdivision with high-density housing was examined to determine the longevity and effectiveness of on-site wastewater treatment.

## STUDY AREA

Avon Lake is a rural subdivision located in an agricultural area southeast of Des Moines, Iowa, in Polk County. Presently, the community has about 130 year-round homes in a 58-acre area (23.5 ha). The lot sizes in the subdivision range from 42 by 80 ft. (12.8 by 24.4m) to 100 by 200 ft. (30.5 by 61m). The soils in the area have been classified as Buckner loamy sand and Dickinson sandy loam which occur on the terraces of the Des Moines River. Both these soil profiles consist of more than 50 in. (1.3m) of loamy sand to sandy loam which was laid down by the river (Polk County Soil Survey, 1960).

The water supply for the community is obtained from shallow sandpoint wells located on individual lots. Information on the groundwater table was determined from data on lake elevations compiled by the U.S. Army Corps of Engineers. The elevations and fluctuations in the lake were found to be 20 to 5 ft. (6.1 to 1.5m) below the ground elevations at Avon Lake over the eight year period, 1970 to 1978. Figure 1 shows the extremes in the lake elevation record from 1971 to 1975. During the summer of 1974 many residents had water in their basements and in 1972 wells were running dry (Conklin, 1974a). This illustrates the interconnection between the lake and the water table. The direction of groundwater flow was estimated using 12 auger borings made in 1965 by the U.S. Army Corps of Engineers (1966) just east of the lakes, taken over a 120 by 180 ft. (36.6 by 54.9m) quadrangle. Based on the water level elevations, the groundwater would be moving in an east to south easterly direction as indicated in Fig. 2, 4.

The wastewater in the area is disposed of through on-site wastewater treatment systems. These systems include septic tank-soil absorption systems, cesspools, leaching pits, and even some old oil drums. Many of the homes have more than one system, usually a septic tank to receive toilet wastes and a cesspool to receive graywater.

The history of development of the area explains why a high density of homes would occur in this section of the county. Two lake depressions in the area are remnant gravel quarries (Fig. 2). The quarrying operation was started in the late 1870s by the Chicago, Rock Island, and Pacific railway (Iowa Geological Survey, 1896). Development began in the early 1920s, with the area first being used as a church camp. The first structures were small summer cabins built around the quarry (Conklin, 1974b). Around 1935 the area was purchased by a group of businessmen who formed the Clearwater Lake Corporation (Conklin, 1974c). The area was platted, and the corporation maintained a clubhouse and swimming beach for the residents. As the area developed and the residents were able to commute to work in the surrounding cities, many of the cabins were winterized and converted to year-round homes.

## METHODS OF DATA COLLECTION

Information on the families, homes, wells, and wastewater treatment system in the community was obtained from a house-to-house survey with the use of the form shown in Fig. 3. This information was supplemented by county records available from the health department, planning and zoning office, county engineer's office, and the county offices of the ASCS and SCS. Well water samples were collected at each of the homes surveyed and tested for fecal coliform bacteria and nitrate nitrogen. The survey began August 2, 1979, and by October 21, 1979, 68 homes had been surveyed. Twelve additional well samples were collected April 13, 1980 to spot-check the nitrate results.

## RESULTS AND DISCUSSION

Septic system longevity was estimated for Avon Lake by utilizing the information gathered in the house-to-house survey, supplemented with any available health department records. Many of the septic systems were constructed before the health department started keeping records and making inspections of installations. Information on the type, operation, age, and maintenance record of

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Table 1. Survey results on wastewater treatment systems, Aug. 2 - Oct. 21, 1979

| Survey | Age of House | Additions to House | Homes with Multiple Systems | System Repaired or Replaced |
|---|---|---|---|---|
| 1 | 10 yrs. | — | — | — |
| 2 | 7 | — | — | — |
| 3 | 7 | — | — | — |
| 4 | 7 | — | — | — |
| 5 | 15 | — | — | X |
| 6 | 22 | — | — | — |
| 7 | 1 | — | — | — |
| 8 | 20 | — | — | — |
| 9 | 35 | X | X | — |
| 10 | old cabin[1] | — | — | — |
| 11 | 2 | — | — | — |
| 12 | old cabin | — | — | X |
| 13 | old cabin | — | — | — |
| 14 | old cabin | — | — | X |
| 15 | 45 | X | — | X |
| 17 | old cabin | X | X | — |
| 18 | 50 | — | X | — |
| 19 | 52 | — | X | — |
| 20 | 39 | — | — | — |
| 21 | old cabin | X | — | — |
| 22 | 45 | X | X | — |
| 23 | old cabin | X | X | — |
| 24 | 41 | — | — | — |
| 26 | 27 | — | — | — |
| 27 | 25 | X | — | — |
| 28 | -- | — | — | — |
| 29 | 16 | — | X | — |
| 31 | 20 | — | — | — |
| 32 | 2 | — | — | — |
| 33 | 1 | — | — | — |
| 34 | 12 | — | — | — |
| 35 | 20 | — | — | — |
| 36 | 30 | — | — | — |
| 37 | 25 | X | X | — |
| 39 | old cabin | X | — | — |
| 40 | 42 | X | X | — |
| 41 | old cabin | X | X | — |
| 42 | 13 | — | — | — |
| 43 | -- | — | X | X |
| 44 | 30 | — | — | — |
| 46 | old cabin | — | X | — |
| 47 | 38 | — | X | — |
| 48 | old cabin | — | X | — |
| 49 | 36 | — | — | X |
| 50 | 25 | — | X | — |
| 51 | -- | — | — | — |
| 52 | 30 | — | X | — |
| 53 | old garage | — | — | — |
| 54 | old cabin | X | X | — |
| 55 | 50 | X | — | — |
| 56 | 2 | — | — | — |
| 59 | 21 | — | — | X |
| 60 | 25 | — | — | — |
| 61 | -- | — | — | — |
| 63 | -- | — | — | — |
| 65 | 25 | — | — | — |
| 66 | old cabin | X | — | — |
| 67 | 1 | — | — | — |
| 68 | 35 | X | — | — |
| 69 | 15 | — | — | — |
| 70 | -- | X | X | — |
| 71 | 50 | X | — | — |
| 72 | 1 | — | — | — |
| 73 | 1 | — | — | — |
| 74 | 12 | — | — | — |
| 75 | 1 | — | — | — |
| 76 | 32 | X | — | — |

[1]The exact age of these old cabins are not certain.

these systems was supplied by the homeowner. The responses to this part of the survey are summarized in Table 1. For purposes of this study, a failure of a septic system was defined as the repair or replacement of laterals or the entire system. Problems due to the house sewer freezing or tree roots were not considered failures. Of the 68 households surveyed, 13% of the systems had failed. These failures occurred in homes ranging in age from 15 years old to the old original cabins for which the exact age is not certain. Twenty-two percent of the systems that are still operating satisfactorily are more than 45 years old, and 50% have been operating for more than 20 years without failure.

The results from Avon Lake can be compared with studies on septic system longevity made in other areas of the country. A study of the septic system records in Fairfax County, Virginia (Clayton, 1974), found that 50% of the systems had operated satisfactorily more than 18 years without failure. One system in the area was still operating after 32 years. In another study using health department records, Hill and Frink (1974) found that 50% of the septic systems in Glastonbury, Connecticut operated more than 26.7 years without failure. The results from the literature and Avon Lake show that on-site wastewater treatment systems may operate without failure for many years.

In an attempt to extend the lives of existing septic systems in the area, the possible reasons for the failures need to be examined. From the information obtained from the homeowners, an estimate was made of the size, location, and type of wastewater treatment system on each lot. Because very few of the homeowners knew the size of their septic system, it was not possible to make a direct determination of capacity. Also, many of the older systems were unconventional, consisting of leaching pits, cesspools, or oil drums. Twenty-eight percent of the homes had multiple systems (Table 1), which would be defined as wastewater treatment systems consisting of a septic tank-lateral field for toilet wastes and a cesspool for other household wastewater (graywater). With only 1 exception, all the failures occurred at households with only 1 system that received all the wastewater. Also, about half of the failures occurred in homes where additions had been built (Table 1). This indicates that, in the shift from part-time to full-time residences and the addition of water using appliances (washing machines, dishwashers, etc.), the capacity of the septic system was not increased to handle the increased hydraulic load. By using current county regulations for minimum lateral length and septic tank volume, and with proper operation and maintenance, the new systems should be able to provide adequate wastewater disposal for many years.

Well water samples also were collected from 68 sand-points to determine the impact of high-density housing on groundwater quality. Of all the well samples collected, only one was found to contain any fecal coliform bacteria. The single contaminated sample was most likely limited to that well, the result of some type of cross connection and limited to a single contamination event. Therefore, it is concluded that the septic systems in the area are effectively removing bacteria from the wastewater.

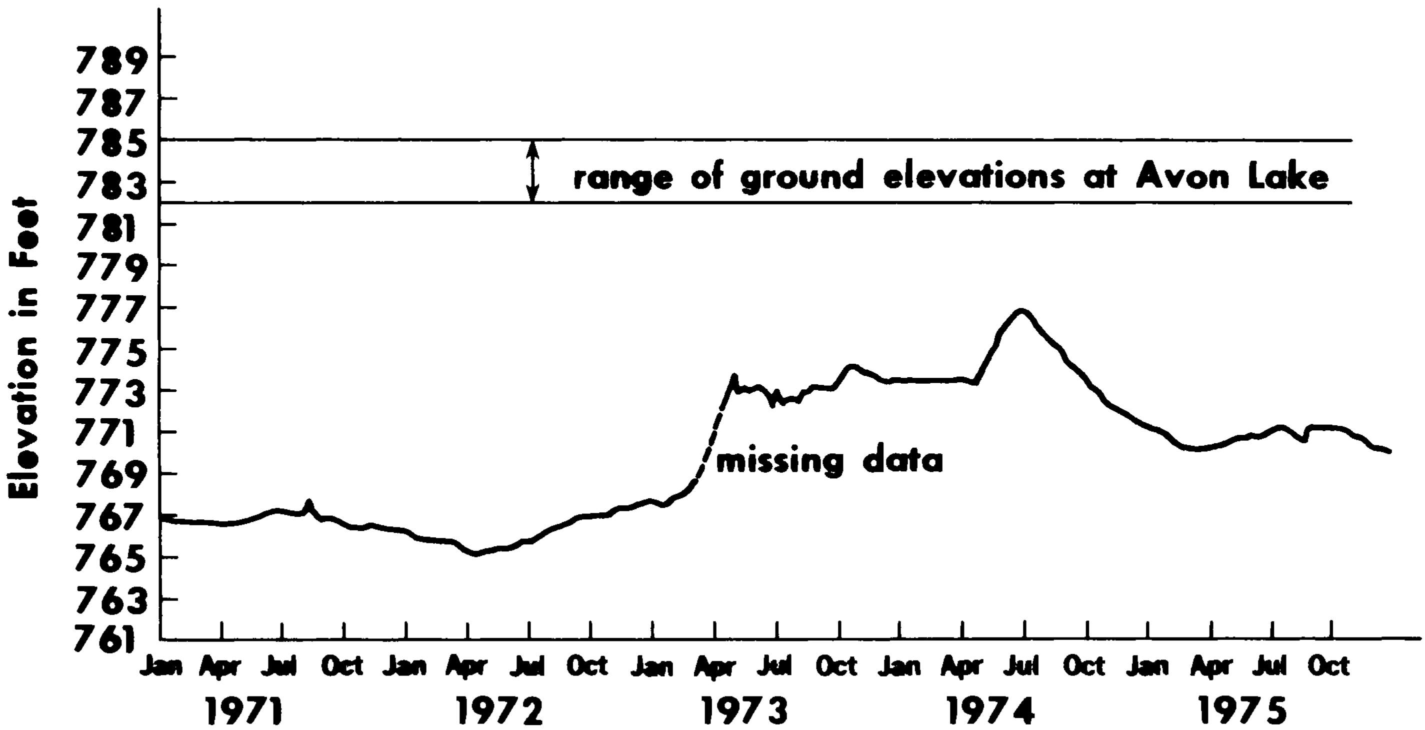


Figure 1. Lake level fluctuations for Avon Lake from 1971-1975.

The well water also was tested for levels of nitrate nitrogen, and the results were compared with the water quality standard. The nitrate standard of 10mg/1N was established to protect public health, primarily infants, who are susceptible to methemoglobinaemia (US EPA, 1976). This survey found that 53% of the well water samples exceeded the 10 mg/1 N standard. The highest nitrate concentration found was 25.6 mg/1 N. When the correlation of nitrate with some characteristic of development was investigated, it was found that nitrate concentration was not correlated with well age or housing density. There was not enough information available to correlate nitrate with well depth. When the nitrate values were plotted on the plat for the area, however, a trend in spatial distribution became evident. Figure 4 illustrates a trend in which nitrate levels that are twice the standard are clustered at the northern part of the subdivision, with decreases in the nitrate levels in the wells located closer to the lake. Nitrate levels for the lake were also recorded. Nitrate concentrations ranged from 1.39 mg/1 N in April 1980 to 0.1 mg/1 N in July and August. These concentrations are much lower than those found in the well samples even though there is a hydraulic link between the groundwater and the lake. The nitrate level in the lake, however, is effected by algal uptake, particularly in late summer when algal production is high. The low nitrate concentrations are comparable to those found in many Iowa lakes (Jones and Bachmann, 1978).

Another point of interest in Fig. 4 is the wells with very low nitrate concentrations. In most instances, these wells are surrounded by wells showing much higher nitrate values, exceeding an order of magnitude difference. When two of these wells were resampled in April 1980, the low nitrate concentration was still present. Because most of these sand points are hand-driven, there is little information available on them in the county records. There was no association with well age, and there was not enough information about well depth to make any conclusions. There is, however, something special about these wells, which will require more detailed study to determine.

In this agricultural area, it is not possible to determine with limited data, the source of the nitrate in the groundwater. To put the nitrogen contribution from the septic systems into perspective, nitrogen loading was calculated. Estimates of nitrogen generation per person per day have been prepared for different fixtures by

Table 2. Total nitrogen contributions from different fixtures. (after: Siegrist, Witt, and Boyle, 1976)

| Fixture | Total N (mg/capita/day) |
|---|---|
| Fecal toilet flush | 1500 |
| Nonfecal toilet flush | 2640 |
| Garbage disposal | 630 |
| Kitchen sink | 420 |
| Dishwasher | 490 |
| Laundry (wash) | 580 |
| Laundry (rinse) | 150 |
| Bath/shower | 310 |

Table 3. Percentage of households surveyed with different fixtures.

| Fixture | Percent |
|---|---|
| Garbage disposal | 28% |
| Dishwasher | 29.6 |
| Laundry | 81.7 |

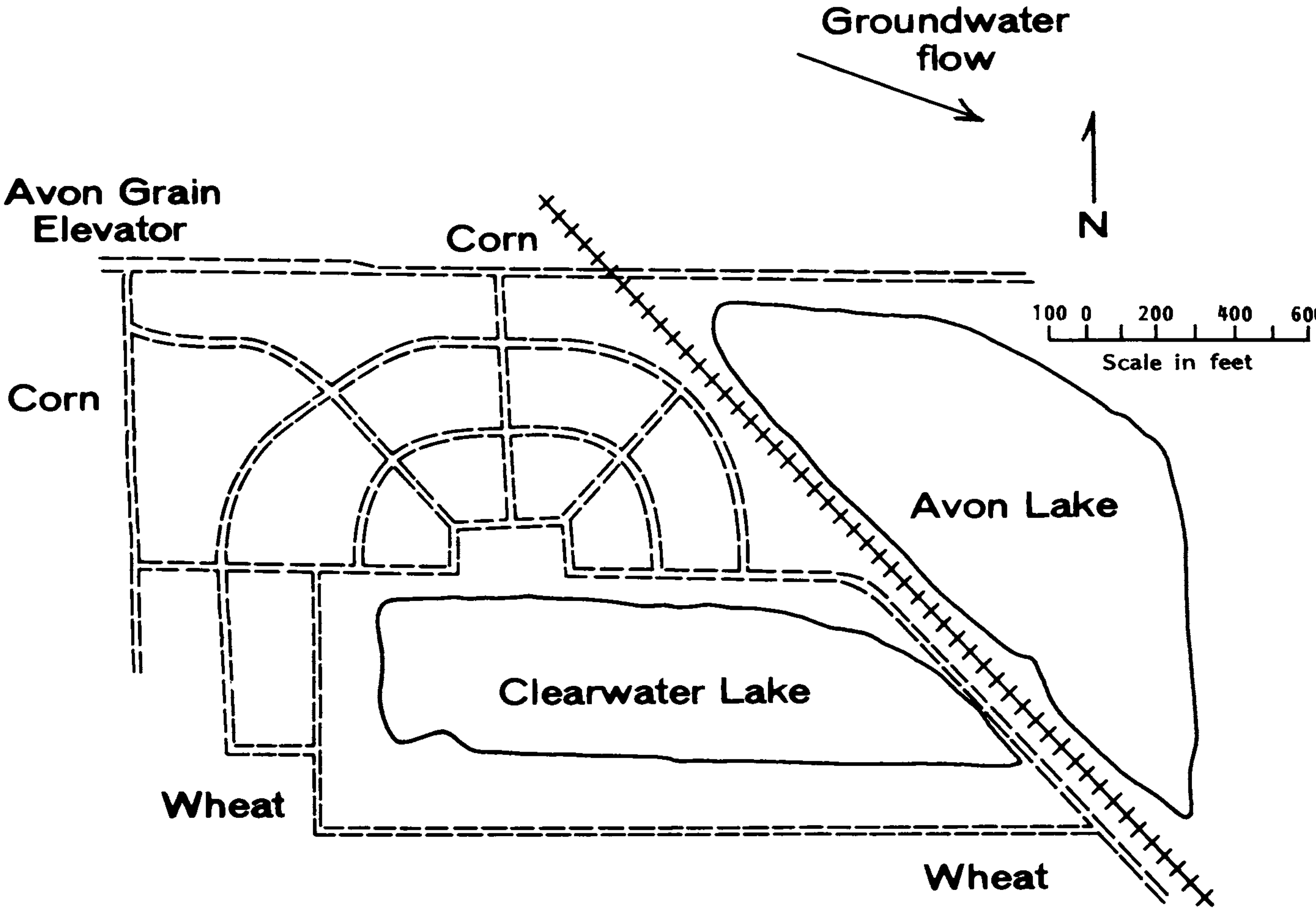


Figure 2. Community of Avon Lake, Iowa.

Siegrist, Witt, and Boyle (1976). These values are presented in Table 2, and the percentages of households surveyed in Avon Lake with garbage disposals, dishwashers, and laundry facilities are listed in Table 3. With these values and an estimated population for the community of 445, a total nitrogen loading can be calculated. Over the development, 35 lb/acre/year (39 kg/ha/year) total nitrogen is estimated to be applied to the soil from septic systems.

The corn and wheat grown in the fields surrounding Avon Lake, which was documented in the ASCS crop certification records for 1979, could have nitrogen applications of from 40 pounds of nitrogen per acre (45 kg/ha) on the wheat to the south and west, to 120 pounds per acre (135 kg/ha) on the corn to the west and north. These application levels were recommended by the local Iowa State Extension Specialist. The large number of dogs in the area also could be a significant source of nitrogen. For dogs, 0.75% of their waste is nitrogen (Loehr, 1974). From the house-to-house survey, an average of 1.8 dogs per household was found. If the average body weight of these dogs is 30 lb. (13.6 kg) and they produce 4% of their body weight in waste each day, the nitrogen application for dogs would be estimated at 13 lb/acre/year (15 kg/ha/year). It is difficult to determine without more detailed nitrogen loading, which nitrogen source is most significant.

To determine the significance of the nitrate problem, the number of infants in the community was estimated. It is children less than 12 months old that the nitrate standard is intended to protect. In the 68 households contacted, there were nine infants. This is 4% of that population, which would require a low nitrate water supply.

This area has several options for providing low-nitrate water. One alternative is to abandon the present water supply and find another that is low in nitrate. This could include drilling a community well or examining the low-nitrate wells noted in Fig. 4 to determine what is different about them. Another alternative is to supply low-nitrate water for just the infants. Many of the mothers indicated that their doctors had advised them to buy bottled water or prepared formula for their babies, rather than use the well water. There also were a few households with water purifiers to distill the impurities from the drinking water. A third alternative would be to locate and try to control the nitrogen that is contaminating the groundwater. To determine if this would be a more cost-effective alternative, more information would be needed.

## CONCLUSIONS

Avon Lake has developed into a year-round rural housing development. Through the use of individual wells and on-site wastewater treatment, much of the rural character has been preserved despite the high density of development. The individuals there, for the most part, seem happy with this arrangement, and the low failure rate of

Address ______________________________

Name ______________________________

Date______________________________

**Family**
How many people live in the house?
Do you live here year-round?
How long have you lived here?
Where do you work?
How many pets do you have?
**Home**
How big is your lot?
What is the age of the building?
How many bedrooms?
Is there a basement?
**Well**
What type of well?
How deep is it?
Has it been tested?
Where is it located?
**Waste Disposal System**
What type of system?
Do you have a cesspool?
How big is the system?
Where is it located?
When was it installed?
**Water Sources**
How many of these fixtures do you have?
  Toilet
  Kitchen sink
  Laundry
  Tub/shower
  Lavatories
  Water softener
  Sump pump
  Dishwasher
  Garbage disposal

**Problems with Septic System**
Have you experienced:
  Slow drains
  Back up
  Odors
  Surfacing effluent
When does this happen?
How often does it happen?
When was your system last repaired or maintained?
What was done?

Figure 3. Survey used at Avon Lake, August 2 - October 21, 1979.

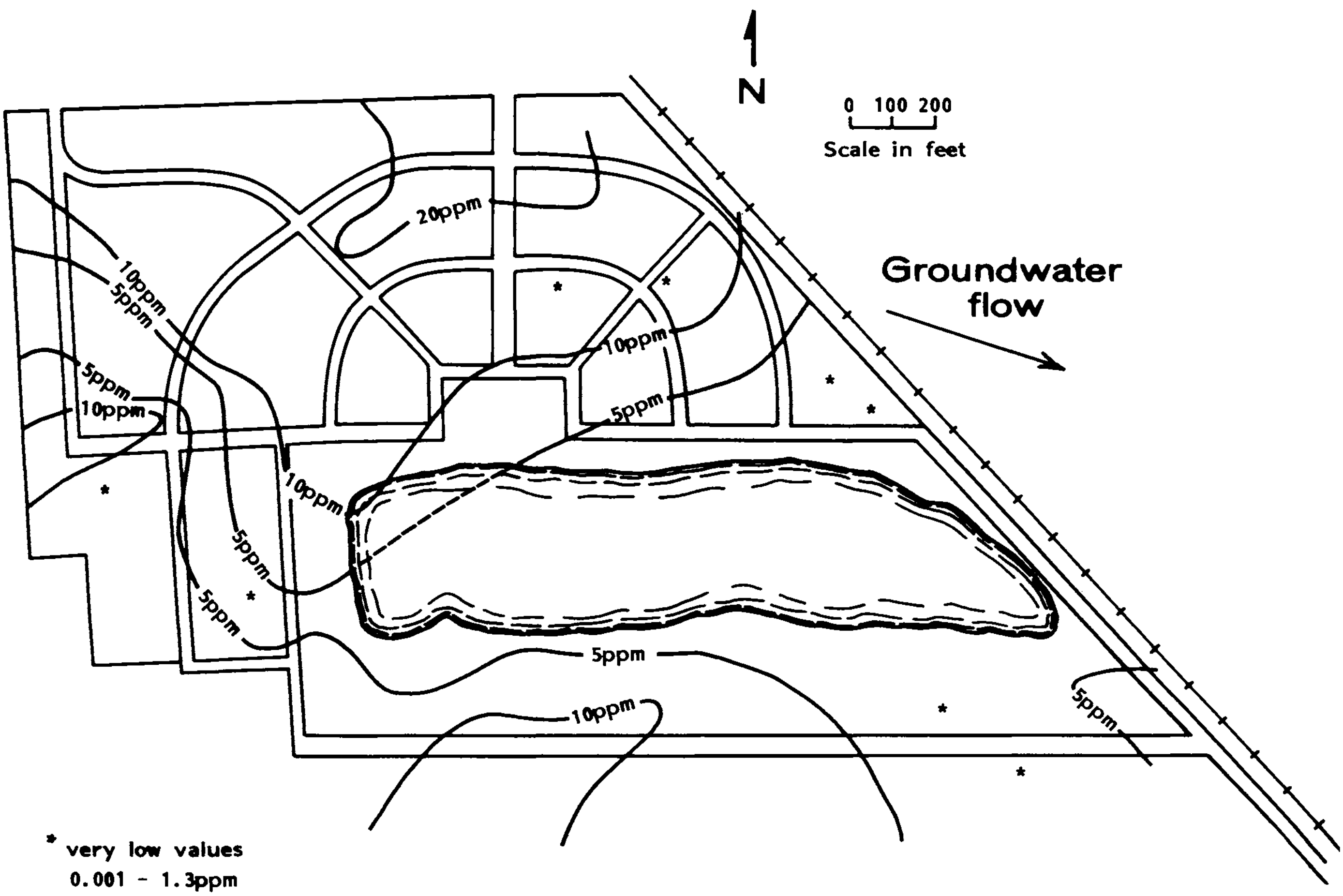


Figure 4. Nitrate isopleths for well water collected between August 2 and October 21, 1979 at Avon Lake, Iowa.

septic systems and adequate water supply help to reinforce this feeling. With the current county requirements for the septic systems to insure adequate capacity, the area should be well served by subsurface wastewater disposal as long as the systems are properly operated and maintained. Because of the very small lot sizes, care must be taken to preserve the existing lateral field. If the only available area on the lot is paved or built over, on-site wastewater disposal may become impossible.

The septic systems in the area are effective in removing bacteria from the wastewater. The source of nitrate contamination, however, is not documented. To better assess the nitrate problem in the area, more information is needed concerning the groundwater supply and movement, nitrogen loading, and losses. It is not a simple problem. What is certain is that infants must not be exposed to high levels of nitrate, and a nitrate-free water supply must be provided for them.

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