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Monitoring Groundwater at Landfills Equipped with Leachate Collection Systems

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Groundwater monitoring wells enable hydrogeologists to confirm and assess aquifer impacts from landfills. Effectively positioned wells can intercept plumes of contaminated groundwater. Moreover, they yield water samples that can be chemically analyzed for contaminants. Identifying contaminants in groundwater before the pollution becomes widespread facilitates efficient aquifer remediation.

Previous investigators devised groundwater-monitoring networks for known contaminant release locations (Meyer and Brill 1988), or for landfill footprints throughout which potential release locations were uniformly distributed (Storck et al. 1997; Hudak 1998). However, modern landfills are more prone to leak beneath pipes in leachate collection systems. Leachate, which forms as liquid percolates through solid waste, collects around perforated pipes under the influence of gravity. Beneath these pipes leachate can escape through holes in liners caused by rips, tears, punctures, subsidence, imperfect seams, or chemical attack. The objective of this study was to test the performance of alternative groundwater monitoring networks devised for a landfill with a leachate collection system.

MATERIALS AND METHODS

Three monitoring networks were designed for a hypothetical rectangular landfill (Figure 1). Sidewalls of the landfill slope to a floor containing leachate collection pipes. Feeder pipes slope toward a header pipe, which discharges to a sump at the end of the landfill. The pipe layout was adapted from Koerner (1994). Oriented 45 degrees to the direction of groundwater flow, the landfill is located 100 m from a buffer zone boundary, which establishes a distance limit of contaminant travel.

A 20-m distance lag between the landfill and monitoring wells was used for each network. The lag was measured parallel to groundwater flow to enhance detection capability (Hudak 1998). Networks 1 and 2 were constructed by drawing five flow tubes across the landfill and placing a monitoring well in the middle of each flow tube. Flow tubes traversed the landfill's entire footprint in Network 1, but only the leachate collection system in Network 2. Network 3 was constructed by shifting wells in Network 2 to the nearest flow path crossing one or more pipe intersections. This was done to target potential leaks within the leachate collection system.

Rectangular buffers were drawn around each pipe in the leachate collection system, and an analytical transport model (Wilson et al. 1993) simulated contaminant releases within each buffer. Buffers measured 6 m by 39 m around feeder pipes and 6 m by 126 m around the header pipe. Contaminant releases were simulated at 2,930 locations distributed throughout the rectangular buffers. This number was selected to fully extend the computer model's capabilities and maximize output accuracy.

Monitoring efficiency determinations were based on the percentage of contaminant releases detected. Four efficiency calculations were made for each network, using groundwater velocities of 0.01 m/d, 0.1 m/d, 1.0 m/d, and 10.0 m/d. A release was detected if its contaminant plume passed through one or more monitoring wells before reaching the buffer zone boundary.

A dilution contour defined plume boundaries. The contour was equal to the concentration of a conservative tracer (such as chloride) divided by the original concentration of the contaminant releases. Table 1 lists physical and chemical parameters for the problem.

Table 1. Physical and Chemical Parameters

Seepage velocity (m/d)	0.01, 0.1, 1.0, 10.0
Saturated thickness (m)	5.0
Longitudinal dispersivity (m)	1.0
Transverse dispersivity (m)	0.1
Effective molecular diffusion coefficient (m^2/d)	3.3×10^{-5}
Dilution contour	0.001
Retardation factor	1.0
Width of contaminant release (m)	1.0

RESULTS AND DISCUSSION

Each monitoring network performed consistently over the range of groundwater velocities (Figure 2, Table 2). Lower groundwater velocities typically yield higher detection efficiencies by allowing plumes to attain high width/length ratios. However, for a given hydrogeologic setting and buffer zone boundary, there is a velocity threshold beyond which plume narrowing is marginal and does not substantially reduce detection efficiency. In this case, there was very little reduction in detection efficiency beyond a groundwater velocity of 0.01 m/d.

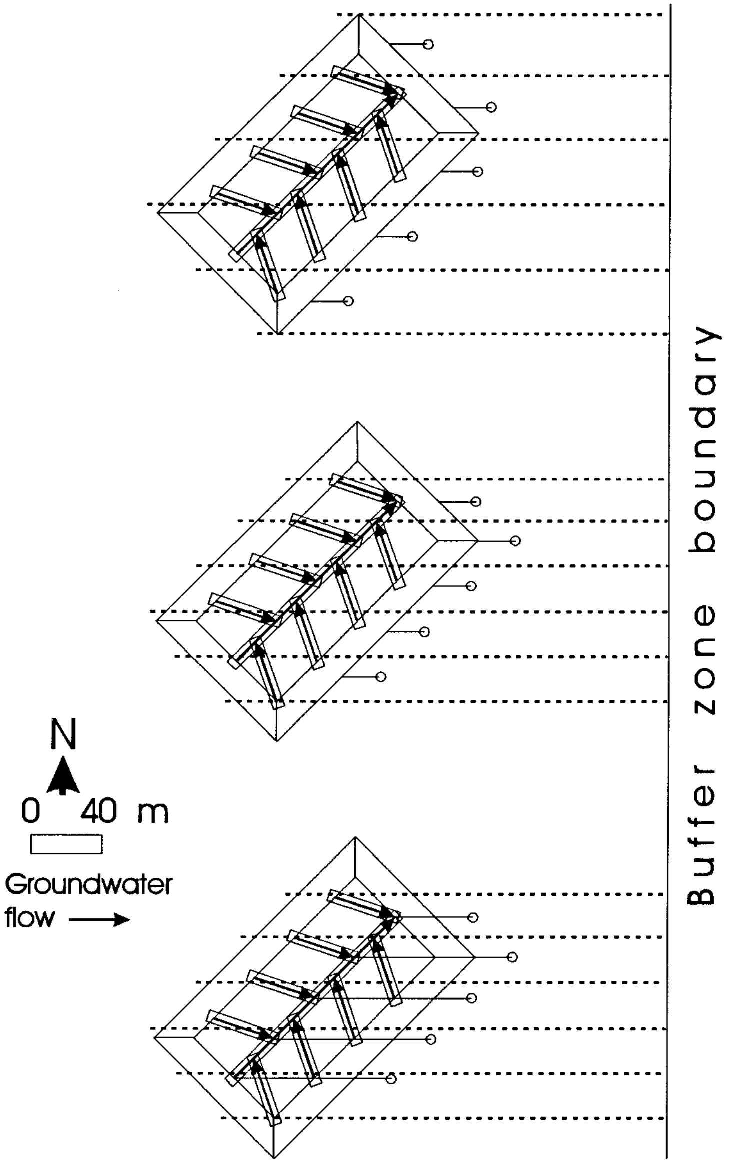

Figure 1. Plan view of Networks 1 (top), 2 (middle), and 3 (bottom); large rectangles depict sidewalls and floor of landfill; thin rectangles buffer leachate collection pipes (bold vectors); dashed lines depict groundwater flow lines; circles depict monitoring wells; solid lines attached to circles are construction lines.

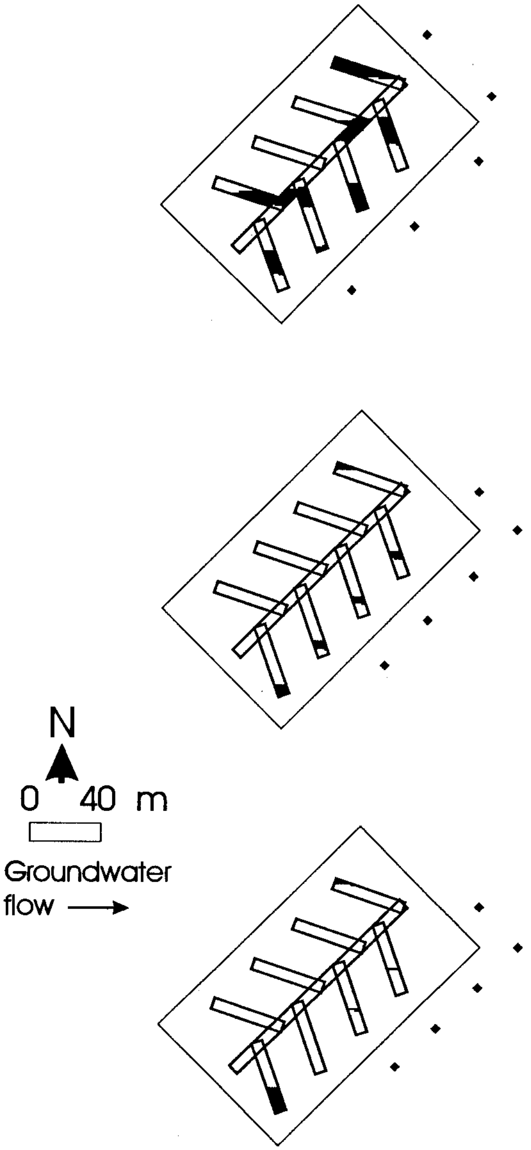

Figure 2. Releases (shaded) from which contaminant plumes were not detected in Networks 1 (top), 2 (middle), and 3 (bottom); diamonds depict monitoring wells.

Table 2. Detection Efficiencies (Percent)

Velocity (m/d):	0.01	0.1	1.0	10.0	Average
Network 1	66.7	65.8	65.7	65.7	66.0
Network 2	94.2	93.9	93.9	93.9	94.0
Network 3	95.4	95.2	95.2	95.2	95.3

There were large differences in average detection efficiency among monitoring networks (Table 2). Network 1 was least effective, detecting only 66.0 percent of the contaminant releases. Exterior wells in that network were not downgradient of contaminant releases, and there were large gaps between interior wells through which many contaminant plumes escaped (Figure 2). Especially large areas of undetected contaminant releases occurred in pipes nearly parallel to groundwater flow that were upgradient of well gaps.

Network 2 performed substantially better than Network 1, increasing the average detection effiency by 28.0 percentage points. It had a smaller well spacing in the critical area downgradient of leachate collection pipes. Network 3 left an area not monitored near the landfill's southern corner, but more effectively targeted critical flow paths and tightened spacings between wells. Overall, Network 3 yielded a slightly higher average detection efficiency, at 95.3 percent.

Each network could be enhanced by adding more wells. This would warrant shifting the wells in Figures 1 and 2 to uniformly cover the landfill. Five wells were used for each network to permit comparisons among alternative design strategies. The number of monitoring wells used in practice would depend upon the size and geometry of a landfill and buffer zone, groundwater flow conditions, budget constraints, and regulatory guidelines.

REFERENCES

Hudak PF (1998) Configuring detection wells near landfills. Ground Wat Monit Remed 18:93-96

Koerner (1994) Designing with geosynthetics. Prentice Hall, Englewood Cliffs, NJ

Meyer PD, Brill ED (1988) A method for locating wells in a groundwater monitoring network under conditions of uncertainty. Wat Resour Res 24:1277-1282

Storck P, Eheart, JW, Valocchi AJ (1997) A method for the optimal location of monitoring wells for detection of groundwater contamination in three-dimensional heterogeneous aquifers. Wat Resour Res 33:2081-2088
Wilson CR, Einberger CM, Jackson RL, Mercer RB (1993) Design of ground-water monitoring networks using the Monitoring Efficiency Model (MEMO). Ground Wat 30:965-970