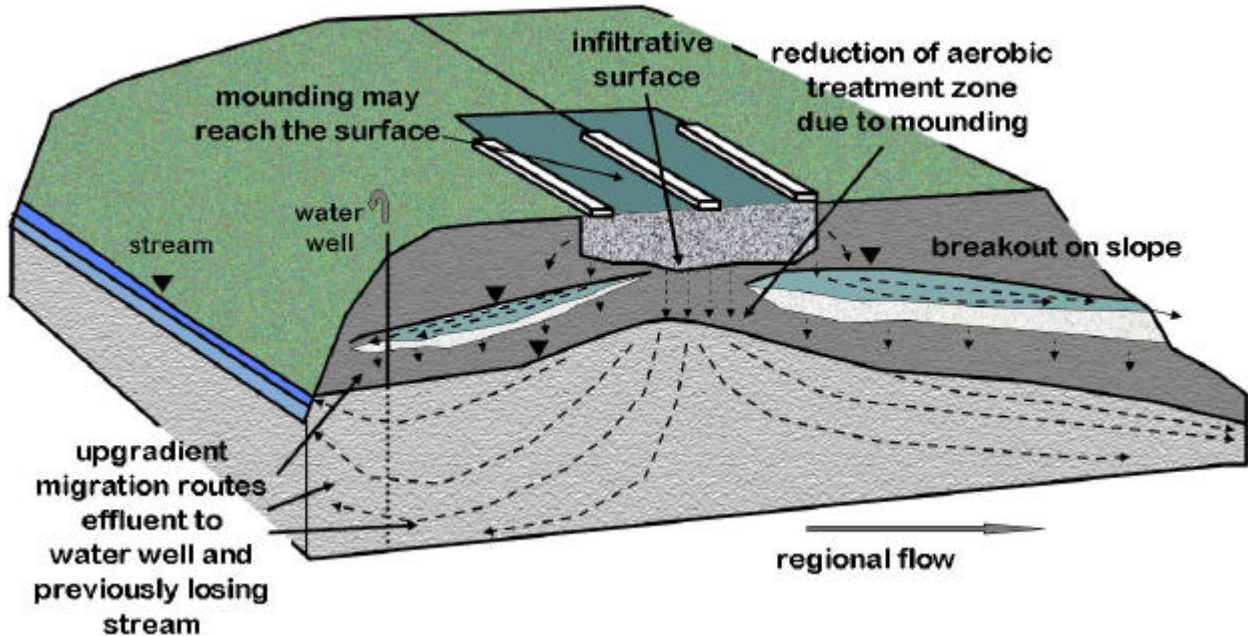


Executive Summary



Guidance for Evaluation of Potential Groundwater Mounding Associated with Cluster and High-Density Wastewater Soil Absorption Systems

Colorado School of Mines
Golden, Colorado

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Guidance for Evaluation of Potential Groundwater Mounding Associated with Cluster and High-Density Wastewater Soil Absorption Systems

**Submitted by International Groundwater
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EXECUTIVE SUMMARY

Cluster and high-density wastewater soil-absorption systems (WSAS) (those receiving more than 2,000 gallons of water per day or GPD) are increasingly required to serve development. In the past, system designers and regulators focused on vertical movement of water from WSAS because most systems are small and isolated. However, insufficient capacity may result in (see Figure ES-1):

- Significant groundwater mounding on low hydraulic conductivity lenses or elevation of the water table (which may alter saturated flow direction or reach the surface)
- Lateral movement of water, which may affect nearby water supplies or water bodies, or may cause effluent breakout on slopes in the vicinity

Rationale and Purpose

For the purpose of this report, failure is considered to be excessive mounding. Some mounding will not cause hydraulic breakout at the surface or side slopes or insufficient treatment of the wastewater, but may impact performance efficiency of the WSAS, or cause the system to be out of compliance with local regulations. This report focuses on the methodology for determining the magnitude of mounding, vertically and laterally. Once that magnitude is known, the designer must determine whether the WSAS function will be acceptable based on treatment requirements and local regulations.

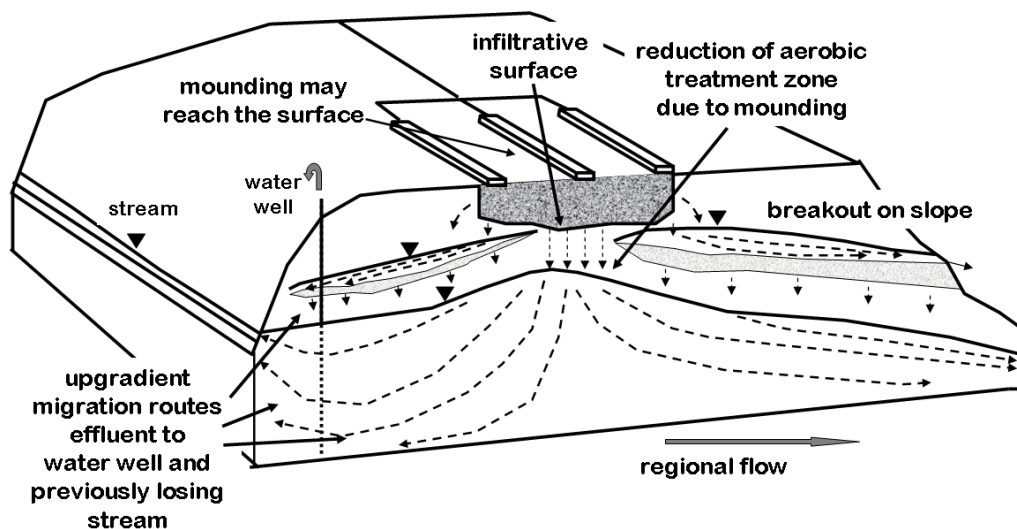


Figure ES-1
Potential Groundwater Mounding Below WSAS

Hydrologic evaluation is important because it ensures a site has sufficient hydraulic capacity to assimilate water in excess of natural infiltration. Practitioners and stakeholders must be informed of the issues so they will be able to complete the proper investigations and evaluations. Most critical is evaluation of the potential for reduction of the vadose (unsaturated) zone thickness, which could result in inadequate retention times and conditions for treatment of wastewater pollutants.

This report presents a methodology for:

- Evaluation of site-conditions and system-design influences on the potential for groundwater mounding and lateral spreading
- Selection of investigation techniques and modeling approaches based on site conditions, system parameters, and the severity of the consequences of excessive mounding

Methodology

Evaluation of the potential for groundwater mounding and break-out on the surface or side slopes requires different levels of effort depending on the characteristics of the subsurface and the consequences of system failure. The phased approach indicates more investigation as the risk of mounding increases and the consequences of failure due to mounding become more severe. A flowchart guides preliminary assessment and indicates subsequent steps, based on preliminary site investigation to determine depth to groundwater and soil types (Figure ES-2). Specific sections of the report elaborate on these steps.

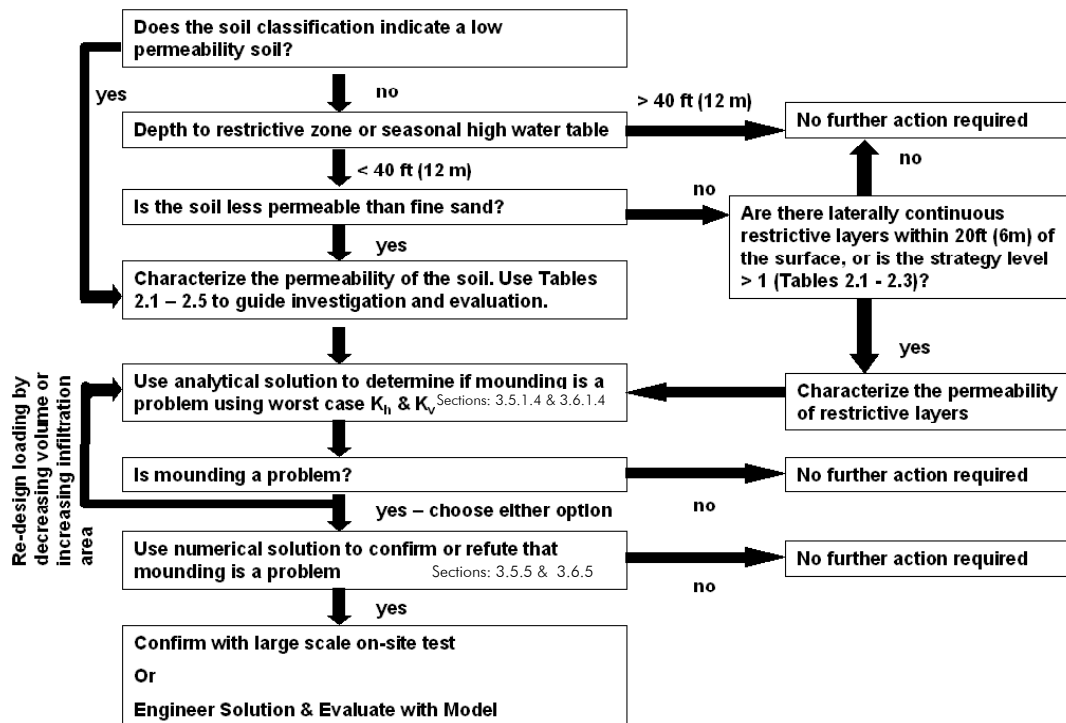


Figure ES-2
Flowchart for Preliminary Assessment of the Potential for Groundwater Mounding Guides Subsequent Steps of the Assessment Process

Decision-Support Tool

A decision-support tool quantifies a subjective strategy level that defines the intensity of site characterization and modeling appropriate for a given site, following the philosophy that the degree of characterization and associated cost should be considered in light of the potential for mounding and the consequences should mounding occur. The decision-support tool utilizes additional qualitative information relative to the flowchart as well as site-specific quantitative data from field investigations to determine the strategy level for site assessment. The strategy level provides a guide to the magnitude and intensity of field investigation and the sophistication of modeling. Guidance on site investigation is provided in Chapter 2, while guidance on modeling is presented in Chapter 3 of this report. Associated costs of field investigations and model assessment are discussed at the end of Chapters 2 and 3.

Levels of Site Investigation

Sites with hydraulic conditions that indicate low risk of mounding, and have minimal consequences in the case of mounding, can be assessed using minimal site investigation (Chapter 2, sections 2.2 through 2.4) and using analytical solutions to estimate mound height (Chapter 3, sections 3.5.1 through 3.5.4 for evaluation of vadose zone mounding; and sections 3.6.1 through 3.6.4 for saturated zone modeling). Spreadsheets for evaluating mounding of the water table ([WaterTableMounding_EnglishUnits.xls](#) or [WaterTableMounding_SIUnits.xls](#)) are available electronically with this report on the CD and online at www.ndwrcdp.org. In these low-risk cases, the estimated height of mounding is added to the high water table to determine if the design will be acceptable.

Sites with hydraulic conditions that indicate risk of mounding, and where the consequences of mounding are severe, require more intense field investigations (Chapter 2, sections 2.5 and 2.6) and sophisticated numerical models to estimate mound height (Chapter 3, section 3.5.5 for evaluation of vadose zone mounding of water on low hydraulic conductivity layers; and section 3.6.5 for mounding of the water table based on flow in the saturated zone). Advanced assessment is particularly important for sites where mounding has serious consequences, and sites that exhibit strong heterogeneity and/or anisotropy, sites with complicated boundary conditions, and those with significant time-varying hydraulic conditions.

Hydraulic Conductivity of the Soil And Aquifer

For evaluation of mounding, the most significant factor is the hydraulic conductivity of the soil and aquifer, as indicated by example calculations presented in this report. Accurate measurement of hydraulic conductivity (K) is difficult because its value varies substantially over short distances due to heterogeneity. Therefore, careful attention must be given to this important parameter.

Hydraulic conductivity cannot be accurately estimated from simply knowing the soil type because K of a given soil type may vary by orders of magnitude. Therefore, obtaining reliable measurements of K when performing engineering analysis for cluster systems is important. Suggested methods for measurement of K in unsaturated and saturated soil are outlined in Chapter 2, section 2.6. Errors on the order of a factor of 10 would not be unusual; even when site-specific measurements are collected.

Analyzing the statistics on several measurements provides insight on the error associated with K measurements. If the designer has not collected detailed measurements of K , but has obtained a reasonable estimate based on soil classification or a few measurements, then the site should be evaluated using a range of K , including the expected value and a factor of 10 above and, most importantly, below the expected value for estimating mound height.

Analytical and Numerical Modeling

Whether the assessment requires analytical or numerical modeling, the designer must consider two possibilities:

- Wastewater may mound on low hydraulic conductivity layers in the vadose zone
- Wastewater may cause mounding of the water table beneath the infiltration area or the perched mound

Analytical models provide estimates of both types of mounding with little investment of the designer's time. If the analyses use conservative parameter values and the results indicate mounding is not excessive, then more expensive and time-consuming analyses are not required.

Limitations of analytical models should be recognized so that conservative parameter values can be selected. These limitations are summarized in the following section. Guidance on coping with the limitation is provided in this report. The limitations include:

- The analytical solutions provided for estimating mounding on a low hydraulic conductivity layer in the vadose zone do not consider unsaturated-flow physics due to the computational complications such consideration would generate. Consideration of these processes would delay the time of mound development, but decrease its magnitude; thus their omission is reasonable.
- The analytical solutions do not account for anisotropic hydraulic conductivity. Hydraulic conductivity, K , is a soil property describing how easily water flows through the soil. Anisotropy is the situation where K varies with direction. Generally the vertical hydraulic conductivity is less than the horizontal; however, the reverse is sometimes found in soil deposited by wind.

- The analytical solutions do not account for heterogeneity. Heterogeneity is the variation of K in space. If heterogeneities are randomly distributed, then the best value to use for K is the geometric mean of the various K values. However, collecting sufficient data for a reasonable assessment of the geometric mean is unfeasible. Thus, a conservative (low) value for K must be chosen, probably based on the results of several spatially variable estimates or measurements of K. If a discontinuous layer exists, then assuming the layer is continuous would provide a conservative estimate (over prediction) of the mound height and extent because some of the wastewater would travel between the discontinuous low-K zones and would not mound in these areas. For severely heterogeneous systems, several pilot-scale infiltration tests should be conducted.
- The analytical solutions do not consider the possibility of heavy rainfall causing short-term increased mounding. To address this issue, one needs to use a numerical model that can simulate transient, unsaturated flow. However, as a conservative assumption, the designer could assume that the mound height would increase by the total rainfall accumulated during the storm divided by porosity of the soil. A more reasonable estimate could be obtained by subtracting an estimated amount for runoff.

Although simplifying assumptions are made when using analytical models, expediency warrants their use before numerical modeling is considered. When there is potential for problematic mounding as judged by preliminary assessment and design changes cannot sufficiently reduce that potential, then use of a numerical model is appropriate. Setting up numerical models for a specific site is time consuming and requires a significant level of expertise in hydrology, soil physics, numerical methods, and computer operation, and is therefore quite expensive. However, if the risks associated with excessive mounding are serious, the expense may be worth the effort.

Getting Started

Practitioners seeking to utilize the methods presented in this report can best accomplish this by working through the recommendations of Chapter 2, *Site Evaluation for Groundwater Mounding Potential* and moving on to sections of Chapter 3, *Evaluating Groundwater Mounding With Models* as needed.

The first consideration in design of a large system is to specify an overall size of the infiltration area that, when coupled with the anticipated volumetric loading rate, results in an infiltration rate that is less than the vertical hydraulic conductivity of the soil to prevent the development of ponding of wastewater over the infiltration area. That is:

$$\frac{Q}{A} < K_v$$


for consistent dimensional units of volume, length, and time. Next, recognizing spatial constraints of the site and reasonable dimensions for construction, strive to elongate the infiltration area in the direction perpendicular to groundwater flow beneath the site. Preliminary data acquisition as outlined in Chapter 2, *Site Evaluation for Groundwater Mounding Potential*, will provide approximate values for K_v and flow direction.

After establishing this reasonable design, the designer must consider the potential for perching and mounding of water on low hydraulic conductivity layers in the vadose zone and ultimately the rise of the water table required to carry the wastewater away from the site. Site-scale hydraulic conductivities are extremely important to performance of the WSAS, but are difficult to determine with certainty. Chapter 2, *Site Evaluation for Groundwater Mounding Potential*, guides the designer in evaluating the amount and type of field investigation appropriate for a site and refers the designer to Chapter 3, *Evaluating Groundwater Mounding With Models* for analytical, and if necessary, numerical modeling.

The analytical modeling recommended in this report is readily accomplished using a calculator in the case of estimating mounding on low hydraulic conductivity layers in the vadose zone, and the spreadsheets that accompany the report ([WaterTableMounding_EnglishUnits.xls](#) or [WaterTableMounding_SIUnits.xls](#)) in the case of water table mounding of the saturated zone.

Unless the designer is knowledgeable in the area of numerical modeling, he or she will likely enlist a modeler to assist with the work. In spite of this, the sections on numerical modeling (Chapter 3, sections 3.5.5 and 3.6.5) are recommended reading because they are not directions on how to conduct numerical modeling, but rather illustrations of how mounding is likely to vary for conditions that cannot be evaluated with analytical models. The insight they provide is useful to all phases of investigation and design. Hypothetical site dimensions and conditions are evaluated to illustrate generic system responses. Actual values of mound height and extent can only be determined for site-specific properties, dimensions, and boundary conditions.

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