



Seepage Modeling with SEEP/W 2007

An Engineering Methodology

Third Edition, March 2008

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1 Introduction

The flow of water through soil is one of the fundamental issues in geotechnical and geo-environmental engineering. In fact, if water were not present in the soil, there would not be a need for geotechnical engineering. This is a nonsensical statement: if there were no water in the soil, there would be no way to sustain an ecosystem, no humans on earth and no need for geotechnical and geo-environmental engineering. However, the statement does highlight the importance of water in working with soil and rock.

Flow quantity is often considered to be the key parameter in quantifying seepage losses from a reservoir or determining the amount of water available for domestic or industrial use. In engineering, the more important issue is the pore-water pressure. The emphasis should not be on how much water is flowing through the ground, but on the state of the pore-water pressure in the ground. The pore-water pressure, whether positive or negative, has a direct bearing on the shear strength and volume change characteristics of the soil. Research in the last few decades has shown that even the flow of moisture in the unsaturated soil near the ground surface is directly related to the soil suction (negative water pressure). So, even when flow quantities are the main interest, it is important to accurately establish the pore-water pressures.

In the past, the analyses related to groundwater have concentrated on saturated flow. As a result, flow problems were typically categorized as being confined and unconfined situations, such as confined or unconfined aquifers. Flow beneath a structure would be a confined flow problem, while flow through a homogeneous embankment would be unconfined flow. Historically speaking, unconfined flow problems were more difficult to analyze because the analysis required determining the phreatic surface. The phreatic surface was considered an upper boundary and any flow that may have existed in the capillarity zone above the phreatic line was ignored.

It is no longer acceptable to take a simplified approach and ignore unsaturated flow above the phreatic surface. Not only does it ignore an important component of moisture flow in soils, but it greatly limits the types of problems that can be analyzed. It is mandatory to deal with unsaturated flow in typical situations such as modeling infiltration of precipitation. Transient flow problems are another good example. It is nearly impossible to model a situation where a wetting front moves through an earth structure without correctly considering the unsaturated component

of flow. Fortunately, it is no longer necessary to ignore the unsaturated zone. With the help of this document and the associated software, unsaturated flow can be considered in numerical modeling and the door is opened to analyzing almost any kind of seepage problem.

The term *seepage* usually refers to situations where the primary driving force is gravity controlled, such as establishing seepage losses from a reservoir, where the driving force is the total hydraulic head difference between the entrance and exit points. Another cause of water movement in soils is the existence of excess pore-water pressure due to external loading. This type of water flow is usually not referred to as seepage, but the fundamental mathematical equations describing the water movement are essentially identical. As a result, a software formulation for the analysis of seepage problems can also be used to analyze the dissipation of excess pore-water pressures resulting from changes in stress conditions. In the context of the discussions and examples in this document and in using the SEEP/W software, the term seepage is used to describe all movement of water through soil regardless of the creation or source of the driving force or whether the flow is through saturated or unsaturated soils.

Modeling the flow of water through soil with a numerical solution can be very complex. Natural soil deposits are generally highly heterogeneous and non-isotropic. In addition, boundary conditions often change with time and cannot always be defined with certainty at the beginning of an analysis; in fact, the correct boundary condition can sometimes be part of the solution. Furthermore, when a soil becomes unsaturated, the coefficient of permeability or hydraulic conductivity becomes a function of the negative pore-water pressure in the soil. The pore-water pressure is the primary unknown and needs to be determined, so iterative numerical techniques are required to match the computed pore-water pressure and the material property, which makes the solution highly non-linear. These complexities make it necessary to use some form of numerical analysis to analyze seepage problems for all but the simplest cases. A common approach is to use finite element formulations and SEEP/W, the subject of this book, is an example of a numerical software tool.

While part of this document is about using SEEP/W to do seepage analyses, it is also about general numerical modeling techniques. Numerical modeling, like most things in life, is a skill that needs to be acquired. It is nearly impossible to pick up a tool like SEEP/W and immediately become an effective modeler. Effective numerical modeling requires some careful thought and planning, and it requires a good understanding of the underlying fundamental physical concepts. Aspects such

as discretization of a finite element mesh and applying boundary conditions to the problem are not entirely intuitive at first. Time and practice are required to become comfortable with these aspects of numerical modeling.

A large portion of this book focuses on the general guidelines of how to conduct effective numerical modeling. Chapter 2, Numerical Modeling: What, Why and How, is devoted exclusively to discussions on this topic. The general principles discussed apply to all numerical modeling situations, but are used in the context of seepage analyses in this document.

Broadly speaking, there are three main parts to a finite element analysis. The first is discretization; dividing the domain into small areas called elements. The second part is specifying and assigning material properties. The third is specifying and applying boundary conditions. Separate chapters have been devoted to each of these three key components within this document.

Saturated and unsaturated seepage numerical modeling is a highly non-linear problem that requires iterative techniques to obtain solutions. Numerical convergence is consequently a key issue. Also, the temporal integration scheme, which is required for a transient analysis, is affected by time step size relative to element size and material properties. These and other numerical considerations are discussed in Chapter 8, Numerical Issues.

Chapter 12 has been dedicated to presenting examples in a brief, introductory format. The details of all examples along with the actual project files are available on a separate DVD or by download from our web site. You should scan over this chapter and see the many verification examples and case examples to get a feel for what the software is capable of doing.

Chapter 13, Theory, is dedicated to theoretical issues associated with the finite element solution of the partial differential flow equation for saturated and unsaturated soils. Additional finite element numerical details regarding interpolating functions and infinite elements are given in Appendix A, Interpolating Functions.

Chapter 11, Modeling Tips and Tricks, should be consulted to see if there are simple techniques that can be used to improve your general modeling method. You will also gain more confidence and develop a deeper understanding of finite element methods, SEEP/W conventions and data results.

In general, this book is not a “how to use SEEP/W” manual. It is a book about how to model. It also describes how to engineer seepage problems using a powerful calculator; SEEP/W. Details of how to use the various program commands and features of SEEP/W are given in the online help inside the software.

