

Geoenvironmental Engineering

Site and Contaminant Characterization,
Containment Facilities,
Solid Waste Materials, and
Contaminated Ground Interventions

Sponsored by the Geo-Institute
Geoenvironmental Engineering Technical Committee



Edited by
Dimitrios Zekkos, Ph.D., P.E.



Geoenvironmental Engineering

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Dimitrios Zekkos, Ph.D., P.E.

Sponsored by the
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Note: Per ASCE policy, the Blue-Ribbon Panel Reviewers were not involved in any manner in the preparation of the manual. During the review process, Dr Rudolph Bonaparte contributed extensive text in the Chapter 4 on Hazardous Waste and thus an additional ad hoc Blue-Ribbon Panel member, Professor Krishna Reddy, was invited to review that specific Chapter.

PREFACE

The Geoenvironmental Engineering Manual of Practice represents a major effort undertaken by the Geoenvironmental Engineering Technical Committee of the Geo-Institute of the American Society of Civil Engineers (ASCE). The effort started in 2016 and involved 50 authors and reviewers. The majority of the membership of the Geoenvironmental Engineering Technical Committee was engaged in this effort as well as additional leading geoenvironmental engineering professionals who were not members of the Geoenvironmental Engineering Technical Committee with expertise on the topics covered.

The manual is aimed to be a consensus document that provides concise, straight-to-the-point documentation of aspects of geoenvironmental engineering with an emphasis on engineering practice. It also outlines, when appropriate, design procedures and recommendations for use in engineering practice with the goal of developing a technical and scientific resource for geoenvironmental engineering professionals. Although the manual is a valuable technical source of information, and when necessary, appropriate references to the scientific literature are provided, it is not intended to provide an exhaustive state-of-the-art treatment of each topic or to include a comprehensive synthesis of the literature. Instead, the goal is to reflect the state of practice in the United States of America.

The manual preparation process was the following: Each chapter was led by an invited lead author who prepared the main content of a chapter. Subsequently, a minimum of two additional reviewers, or contributors, critically reviewed and provided edits and amendments to the document. Because the goal of the manual is to provide a consensus on each treated topic, the reviewers/contributors were not anonymous, but worked synergistically with the lead author to make amendments. For each chapter, there were at least two rounds of review, although commonly, several more rounds of review were conducted, until reviewers and

contributors concurred on the content of each chapter. For some chapters, depending on their contributions and the lead chapter author's decision, reviewers became coauthors. A minimum of one practitioner served as a reviewer/contributor to each chapter to ensure that the topic is presented in a manner that serves the professional community. During and following the completion of the reviews by all reviewers, the Editor also reviewed and provided edits for each chapter to ensure consistency throughout the manual. The entire manual was then submitted to a Blue-Ribbon Review Panel that consisted of leading geoenvironmental engineers in the field, who provided feedback and comments on the entire manual. These comments were addressed by the lead authors, and a revised document, along with responses to the review comments, was prepared and resubmitted to the Blue-Ribbon Panel Review that consisted of Prof. James K. Mitchell, Prof. Craig Benson, and Dr. Rudolph Bonaparte. Because Dr. Rudolph Bonaparte contributed extensive text in the chapter on Hazardous Waste, an additional ad hoc Blue-Ribbon Review Panel member, Prof. Krishna Reddy, re-reviewed that specific chapter.

The Geoenvironmental Engineering Manual of Practice covers a wide range of geoenvironmental engineering practice, including contaminant transport and fate, geomechanical and geochemical characterization, waste material characterization and properties, design of base and cover containment systems, static and seismic slope stability of waste containment systems, and permeable and impermeable (cutoff) barriers, as well as topics related to excavation, ground improvement, remediation, and mine waste geotechnics. Despite the breadth of content included in the manual, this manual does not exhaust the entire geoenvironmental engineering practice. In some cases, such as geoenvironmental remediation, we felt that extensive literature and manuals by the Environmental Protection Agency (USEPA) and others existed that treated these topics, whereas other topics were not completed during the manual preparation process. In the end, the Editor decided that additional chapters can be included in potential future revisions of the manual, and that the professional community would be better served by the publication of this first edition of the manual of geoenvironmental engineering practice rather than delay further publication of the important content that has been generated already.

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PART 1
INTRODUCTION

CHAPTER 1

CONTAMINANT TRANSPORT AND FATE

Joe Scalia and Charles Shackelford

1.1 INTRODUCTION

The purpose of this chapter is to provide a brief overview of the concepts of contaminant transport and fate through porous media (i.e., soil). The presentation is limited to one-dimensional (1D) transport of aqueous miscible chemical species or solutes (e.g., dissolved contaminants) through water-saturated porous media. The chapter is intended only to introduce basic concepts and serve as a guide to the relevant literature. References are provided to furnish the interested reader with additional relevant, and substantially more comprehensive, literature on the topic.

1.2 MASS TRANSPORT

Transport of aqueous miscible chemical species or solutes typically is governed by three primary processes: advection, diffusion, and dispersion.

Advection is the migration of solutes together with the flow of water (solvent) in response to a hydraulic gradient, that is, the solute is carried along with the flowing water. Nonreactive solutes are transported at an average rate (assuming all pores are equally effective at conducting flow) equal to the seepage velocity of water, v_s [LT^{-1} , where L = units of length and T = units of time], defined as follows:

$$v_s = \frac{v}{n} \quad (1-1)$$