4

Geology and Groundwater Flow

4.1 Introduction

As discussed in the previous two chapters, earth materials vary tremendously in their capacity to hold water (porosity) and their capacity to transmit water (hydraulic conductivity). As a result, our ability to find supplies of subsurface water or predict flow paths is only as good as our understanding of the distribution of porosity and permeability, which is a function of the geologic materials. Usually many different geologic processes combine to produce the distribution of geologic materials in a region. In New England, for example, glacial processes are largely responsible for surficial materials and tectonic processes are responsible for the underlying fractured igneous and metamorphic rock.

This chapter begins with coverage of the common methods used to explore and map the subsurface for groundwater studies. Then patterns of groundwater flow are discussed, first in a general way and then with reference to specific geologic settings. Additional reading on the subject may be found in books by Davis and DeWiest (1966), Heath (1984), Fetter (2001), and GSA (1988).

4.2 Exploring the Subsurface

Investigating groundwater conditions is difficult and costly, since almost everything we want to learn about is buried deep out of sight. It would be grand to have a complete picture of the actual distribution of geologic materials, hydraulic properties, hydraulic heads, and chemical conditions. The reality is that we get a sprinkling of isolated explorations and must use educated guessing and extrapolation to imagine what lies between the explorations.

Many clever techniques have been developed to investigate and map the distribution of groundwater and groundwater-bearing materials. Most groundwater field programs involve some amount of probing the subsurface to collect samples of materials and to create holes in which to install wells, piezometers, and other monitoring devices. In contrast to invasive techniques like drilling and well installation, geophysical methods sense properties of the subsurface without invading it. The most common field methods are summarized in the following sections.

4.2.1 Excavation

Digging by hand with shovels or hand augers is an inexpensive, but limited, way to sample shallow unconsolidated materials. Usually hand digging can go no deeper than a meter or two. With hand augers that are screwed into the ground, somewhat deeper sampling is possible, particularly in soft sediments.

Power excavators (backhoes) can dig deeper, as deep as four or five meters for the larger ones. A backhoe can dig test pits this deep at a rate of 10 or more per day. This is a good and inexpensive way to map unconsolidated surficial deposits.

With either hand or backhoe excavation, it is difficult to excavate much below the water table, especially in more permeable materials like sands or silts (see Section 5.4). If a backhoe works fast enough, it can excavate a meter or more below the water table, but it is a race against the clock. Below the water table, the excavation walls and base are unstable and they heave or cave in.

4.2.2 Direct-Push Probes

Since the 1980s, a variety of new direct-push exploration methods have been developed. With these, small-diameter probes and sensors are pushed directly down into unconsolidated materials without drilling out a borehole in advance. Probes generally consist of a small drilling pipe (37–49 mm outside diameter) with a cone-shaped tip on it and other instrumentation incorporated just behind the tip. Hydraulic or pneumatic jacks attached to a heavy truck push the probe into the ground with static, impact, or vibrational forces (Figure 4.1).

Compared to drilling, probes are a relatively quick and inexpensive way to explore to moderate depths, even below the water table. Probes work well in many sands, silts, and clays, but have difficulty penetrating dense or cobble-bearing materials. Probes can be advanced as deep as 30 m or more in ideal settings with soft, fine-grained sediments. Some probes are equipped to collect small-diameter soil core samples, but most are not.

Figure 4.1 Direct-push probe rig (photo courtesy of Geoprobe Systems, Kejr Engineering, Inc.).