● 普通高等教育本科教材

水文地质专业英语

SPECIALTY ENGLISH OF HYDROGEOLOGY

周训　方斌　赵亮　李占玲　编

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内 容 简 介

本书提供20篇水文地质专业英文短文或阅读材料，内容涉及水文循环、地下水的分布、地下水的运动规律、地下水的补给与排泄、地下水水化学、地下水与地质环境、同位素水文地质、地下热水、地下卤水、海岸带地下水等领域的基本概念、基本原理和研究实例；难度适中且由浅入深；英文专业词汇和语法规范。通过仔细阅读和学习本书的内容，对读者了解和掌握水文地质专业的有关知识、提高阅读理解能力及英文表达能力等方面会有所帮助。

本教材可以作为地下水科学与工程、水文地质与工程地质、水文与水资源工程等本科专业的教学用书，也可以作为从事相关专业的生产、科研和管理人员的参考用书。

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前　　言

为了流利地阅读水文地质专业的英文文献、了解国外同类领域的研究现状，学生在学习基础英语和水文地质专业基础课程的基础上，在本科生阶段有必要学习专业英语，掌握基本的专业词汇，熟悉常用的科技英语表示方法和相关知识，提高阅读理解英文文献的能力，同时也有助于提高科技英文论文的写作能力，为研究生阶段进一步学习专业英语以及为今后查阅英文文献和开展水文地质领域的科学研究奠定基础。

最近十多年来，高等学校陆续为本科生和研究生开设专业英语课程，专业英语越来越受到师生们的重视，现已成为在校本科生和研究生的必修、必选或选修课程。但是，多年来在水文地质专业英语的教学过程中，一直没有系统完整的教材，多是零星复印国外书刊中的若干章节作为教学材料，这在一定程度上影响专业英语课程的教学效果。经过多年的教学实践，我们积累了较多的素材，编写成校内教材，在试用的基础上再加以修改补充，分别编写和出版供本科教学使用的《水文地质专业英语》教材和供研究生教学使用的《地下水科学专业英语》教材，前者重在培养学生对原文的阅读理解能力，后者重在提高学生的英文论文写作能力。

本教材适合本科教学使用，其内容为精选国外本专业英文教科书中的章节和在国际期刊上发表的英文论文，将这些英文材料加以增减、修改和编辑，形成20篇独立的短文或阅读材料，内容涉及水文地质有关的基本概念、基本原理和研究实例，在每篇短文之后均给出部分单词、词组和中文含义，并给出部分难点或重要表示法的注解。本教材内容丰富，难度适中且由浅入深，英文专业词汇和语法规范。通过阅读和学习本教材的内容，读者既能了解和掌握水文地质专业的有关知识，又能在提高阅读理解能力和英文表达能力等方面有所帮助。

由于编者在编写过程中时间仓促，本教材的疏漏和不当之处在所难免，恳请读者予以指正。联系地址：北京市海淀区学院路29号中国地质大学（北京）水资源与环境学院；邮编：100083；E-mail：zhouxun@cugb.edu.cn

编　者
2010年1月

目　　录

Unit 1 The Hydrological Cycle and the Global Water Budget

1.1 The Hydrological Cycle

The motion of water can be described at many different scales. The fundamental concept of hydrology is the *hydrological cycle* — the global-scale, endless recirculatory process linking water in the atmosphere, on the continents, and in the oceans. We can think of this recirculatory process in terms of reservoirs or compartments that store water (the oceans, atmosphere, etc.) and the movement of water between them. Within the various compartments of the hydrological cycle, water can be stored in any one of three separate phases or states: gas (vapor), liquid or solid. For example, water in the atmosphere can exist as vapor (the concentration of water vapor is expressed as humidity), in liquid (cloud droplets, rain drops), or in solid phase (ice crystals, snowflakes). Similarly, all three phases of water can be found on and below the land surface. Movement of water from one compartment to another can occur in any of the three phases. For example, the movement of water between the oceans and atmosphere occurs in vapor phase (evaporation from the ocean surface), liquid phase (rain onto the ocean surface), and solid phase (snowfall onto the ocean surface).

Solar energy drives the hydrological cycle, gravity and other forces also play important roles. The dynamic processes of water vapor formation and transport of vapor and liquid in the atmosphere are driven largely by solar energy. Precipitation and the flow of water on and beneath the Earth's surface are driven primarily by gravity. Within partially dry soil, gravitational and other forces are responsible for the movement of water.

The hydrological cycle can be considered to "start" anywhere, but let us consider atmospheric water first (Figure 1.1). As hydrology is concerned mainly with water at or near the Earth's surface, from our point of view the dominant process involving atmospheric water is the precipitation of water upon the land surface. The portion of the precipitation that reaches the land surface as solid precipitation (mostly snowfall) can be retained temporarily on vegetation or ground surfaces, or accumulate in seasonal snowpacks or in permanent snowpacks known as glaciers. Considering liquid precipitation (rain), a portion also can be retained temporarily on vegetation surfaces or in surface depressions, a portion enters the soil (infiltration) and a portion flows over the land surface first into small rivulets and ultimately into larger streams and rivers. This last process is called surface runoff, which can be augmented by runoff during periods of snowmelt (snowmelt runoff). The portion of rainfall that infiltrates into the soil can also follow one of several paths. Some of the water evaporates from the soil and some is returned to the atmosphere by plants (transpiration). We often refer to the total evaporation and transpiration from vegetated land surfaces by the term evapotranspiration. The remaining water continues to move downward through the soil and recharges the saturated portion of the subsurface, becoming groundwater. At lower elevations, groundwater discharges into streams and rivers, or directly to the ocean (groundwater runoff). Water evaporates from the surface of the oceans and thereby replenishes the water in the atmosphere. Thus we have returned to the particular compartment that we considered first, atmospheric water.

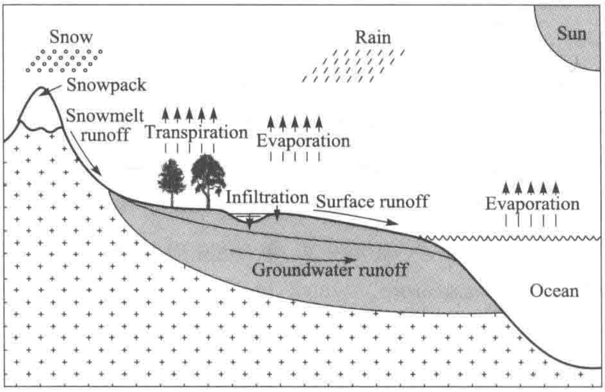

Figure 1. 1 Mechanisms of water movement within the hydrological cycle

Water movement from the atmosphere to the oceans and continents occurs as precipitation, including rain, snow, sleet, and other forms. On the continents, water may be stored temporarily, but eventually returns to the oceans through surface and groundwater runoff or to the atmosphere through evapotranspiration

1.2 The Global Water Budget

The hydrological cycle can be described quantitatively by applying the principle of conservation of mass, which often is referred to as a *water balance* or *water budget* when used in this way. A simple statement of conservation of mass for any particular compartment (usually referred to as a control volume) is that the time rate of change of mass stored within the compartment is equal to the difference between the inflow rate and the outflow rate. For example, if we are adding two grams of water to a bucket every minute and one gram of water is leaking out each minute, then the mass stored within the bucket is increasing at the rate of one gram per minute. Symbolically, we can write this as:

$$\frac{\mathrm{d}M}{\mathrm{d}t} = I' - O' \qquad (1.1)$$

where M is mass within the control volume [M]; t is time [T]; I' is mass inflow rate

[MT^{-1}]; O' is mass outflow rate [MT^{-1}]. The expressions in square brackets are the mass-length-time dimensions associated with the defined quantity; for example, the dimensions of I' are mass per time or [MT^{-1}].

In many instances, the density of water can be taken as approximately constant and the conservation law expressed in terms of volume. The terms involving mass in Equation (1.1) can be expressed in terms of density times volume and density can be canceled from both sides of the equation. Thus, Equation (1.1) can be rewritten as:

$$\frac{dV}{dt} = I - O \qquad (1.2)$$

Where V is volume of water within the control volume [L^3]; I is volume inflow rate [L^3T^{-1}]; O is volume outflow rate [L^3T^{-1}].

We can construct a global water budget by applying the principle of mass conservation [Equation (1.2)], using the continents as our control volume. The quantity V is then the volume of water stored on or within the continental land masses. Inflow is precipitation and outflow consists of evapotranspiration (evaporation and transpiration combined) and runoff (both surface water and groundwater). Note that in addition to ignoring density variations we must express the rate of evaporation or transpiration — outflows of water vapor from the continents to the atmosphere — in "liquid water equivalent" or LWE units. Otherwise, density is varying (water vapor is much less dense than liquid water), and mass, rather than volume, is the conserved quantity.

If we consider only average annual conditions for our water budget, the dV/dt term in Equation (1.2) becomes negligible. That is, over a period of years the average amount of water stored as ice (icecaps and glaciers), as surface water (rivers and lakes) and as subsurface water (groundwater) does not change significantly. Over much longer time periods such as centuries or millennia this may not be true if there is a dramatic shift in climatic conditions. If there is no change in storage over time, we say that the system is at steady state. For any given control volume at steady state, a completely general water budget equation can be written (using bars over the terms to indicate that they are annual average quantities):

$$\frac{d\overline{V}}{dt} = 0 = \overline{p} + \overline{r}_{si} + \overline{r}_{gi} - \overline{r}_{so} - \overline{r}_{go} - \overline{et} \qquad (1.3)$$

where $\overline{V}$ is average volume of water stored, and assumed to be constant; $\overline{p}$ is average precipitation rate; $\overline{r}_{si}$ is average surface water inflow rate; $\overline{r}_{gi}$ is average groundwater inflow rate; $\overline{r}_{so}$ is average surface water outflow rate; $\overline{r}_{go}$ is average groundwater outflow rate; $\overline{et}$ is average evapotranspiration rate. All terms in the equation have dimensions of volume per time [L^3T^{-1}]. For the continents, we will simplify Equation (1.3) by neglecting the inflows and outflows of groundwater, because they tend to be very small. We also will neglect surface water inflows, because surface water flows from the continents to the oceans, and will refer to surface water outflows as runoff, r_s. With these simplifications, Equation (1.3) becomes:

$$\frac{d\overline{V}}{dt} = \overline{p} - \overline{r}_s - \overline{et} = 0 \qquad (1.4)$$

or

$$\overline{p} = \overline{r}_s + \overline{et} \tag{1.5}$$

where $\overline{p}$ is average precipitation rate $[L^3T^{-1}]$; $\overline{r}_s$ is average surface runoff rate $[L^3T^{-1}]$; $\overline{et}$ is average evapotranspiration rate $[L^3T^{-1}]$.

To quantify the global hydrological cycle we can examine the relative sizes of the various storage compartments and the magnitudes of the various flows to and from these compartments (Figure 1.2). Nearly 97% of all water on the Earth is stored in the oceans, while only about 0.001% is stored in the atmosphere (Table 1.1). Considering only freshwater (defined as having a concentration of total dissolved solids less than 0.5 parts per thousand and considered potable), which accounts for about 2.5% of the total storage, 69.6% is contained in the polar icecaps and glaciers while 30.1% is contained in groundwater. The freshwater contained in lakes, streams, rivers, and marshes represents only 0.296% of all freshwater and 0.008% (80 drops in a million!) of all water on the Earth. Another useful concept for thinking about the size of the various reservoirs in relation to the flows of water into and out of them is the *residence time*. The residence time, $t_r [T]$, is a measure of how long, on average, a molecule of water spends in that reservoir before moving on to another reservoir of the hydrological cycle. The residence time is easily calculated for systems at steady state, when the inflow and outflow rates are identical:

$$t_r = \frac{V}{I} \tag{1.6}$$

The residence time has dimensions of time, because volume divided by volume per time is time. The residence time provides an indication of the time scales for flushing a solute out of that particular reservoir. Water in the oceans has a residence time approaching 3000 years, while water in the atmosphere has a residence time of only 0.02 years or about 8 days; the

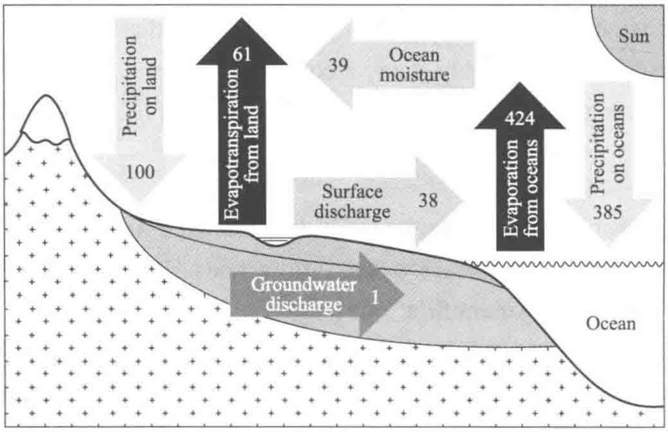

Figure 1.2 Flows within the hydrological cycle

Units are relative to the annual precipitation on the land surface ($100 = 119 \times 10^{12}$ m^3/a). Upward arrows depict flows to the atmosphere, downward arrows depict flows to land or oceans, and horizontal arrows indicate lateral flows residence time of water in rivers is 0.05 years or about 18 days (Table 1.1).

Table 1.1 Sizes and residence times for major reservoirs in the hydrological cycle

	Volume/($10^9 m^3$)	Percentage of total/%	Percentage of freshwater/%	Residence time/a
Water in land areas	47971710	3.461		
Fresh lakes	91000	0.007	0.26	
Saline lakes	85400	0.006		4.0
Rivers	2120	0.0002	0.006	0.05
Marshes	11470	0.0008	0.03	
Soil moisture	16500	0.0012	0.05	
Fresh groundwater	10530000	0.76	30.1	20000
Saline groundwater	12870000	0.93		
Biological water	1120	0.0001	0.003	
Icecaps and glaciers	24364100	1.76	69.6	
Atmosphere	12900	0.001	0.04	0.02
Oceans	1338000000	96.438		2650
Total	1385984610	100	100	

The water budget for all the land areas of the world is: $\overline{p} = 800$ mm, $\overline{r}_s = 310$ mm, and $\overline{et} = 490$ mm (Figure 1.2) (Note that we now are referring to the volumes divided by the areas being considered. It is sometimes more convenient to use depth rather than total volume, because the volumes can be quite large; also, we are probably more familiar with the statement, "20 mm of precipitation was recorded at Smith Airport" than "Smith Airport received 20000 m^3 of water"). On average, 39% of precipitation to the continents runs off and 61% is returned to the atmosphere through evapotranspiration. In other words, the runoff ratio ($\overline{r}_s/\overline{p}$) is equal to 0.39. The balance is, of course, affected by many topographic and climatic factors and the budgets for individual continents can be quite different from the average (Table 1.2). The budget for North America is $\overline{p} = 670$ mm, $\overline{r}_s = 290$ mm, and $\overline{et} = 380$ mm. Thus, in North America 43% of precipitation runs off and 57% evapotranspires on average.

Table 1.2 Average annual water budget for the continents excluding Antarctica*

Continent	Area /($10^6 km^2$)	$\overline{p}$/mm	$\overline{r}_s$/mm	$\overline{et}$/mm	Runoff ratio($\overline{r}_s/\overline{p}$)
Africa	30.3	690	140	550	0.20
Asia	45	720	290	430	0.40
Australia	8.7	740	230	510	0.31
Europe	9.8	730	320	410	0.44
North America	20.7	670	290	380	0.43
South America	17.8	1650	590	1060	0.36

* Values for average annual precipitation, runoff, and evapotranspiration are reported as depths of water over each land area. The total volume may be calculated by converting the depths to km and multiplying by the land areas. Note that several estimates of these quantities exist, all of which are uncertain to some degree.

(Source: Hornberger et al., 1998)

Words

concentration	含量,浓度
depression	洼地，凹陷，坳陷
discharge	排泄
droplet	雾滴
evapotranspiration	蒸发蒸腾
glacier	冰川
humidity	湿度
icecap	冰盖
marsh	沼泽
millennia	千年
precipitation	降水，降水量
recharge	补给
recirculatory	重复循环的
replenish	补给,补充
rivulet	小河，溪流
runoff	径流
sleet	冻雨,雨夹雪
snowfall	降雪,降雪量
snowflake	雪片,雪花
snowmelt	融雪
snowpack	积雪,积雪量
transpiration	蒸腾

Notes

A rather than B	是 A 而不是 B
hydrological cycle	水文循环
surface runoff	地表径流
to be referred to as...	称为……
to refer to ... as ...	称……为……
total dissolved solids（TDS）	总溶解固体，矿化度
water balance	水均衡
water budget	水均衡

Unit 2 Groundwater and Aquifers: Definitions

Groundwater, or *subsurface water*, is a term used to denote all the waters found beneath the surface of the ground. However, the groundwater hydrologist is primarily concerned with the water contained in the zone of saturation and uses the term groundwater to denote water in this zone. In drainage of agricultural lands, or agronomy, the term groundwater is sometimes used also to denote the water in the partially saturated layers above the water table. Practically all groundwater can be thought of as part of the *hydrologic cycle* (Figure 2. 1). Very small amounts, however, may enter the cycle from other sources (e. g. , magmatic water).

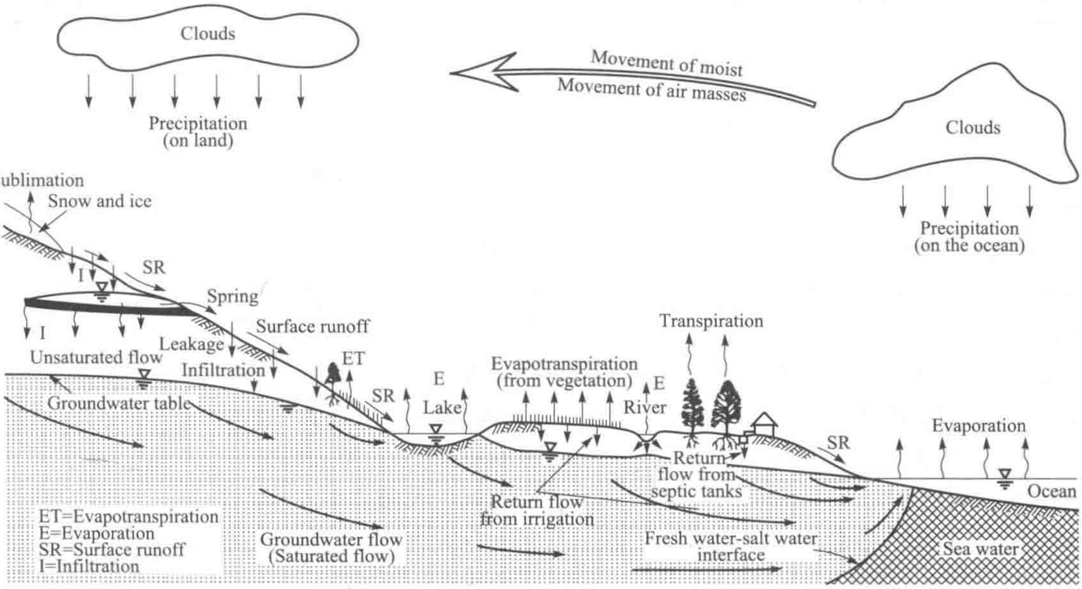

Figure 2. 1 Schematic diagram of hydrologic cycle

An *aquifer* is a geologic formation, or a group of formations, which ① contains water and ② permits significant amounts of water to move through it under ordinary field conditions. Other terms often used are: *groundwater reservoir* (or *basin*) and *water-bearing zone* (or *formation*). Todd in 1959 traced the term aquifer to its latin origin: *aqui* comes from *aqua*, meaning water, and *-fer*, from *ferre*, to bear.

In contradistinction, an *aquiclude* is a formation which may contain water (sometimes in appreciable quantities), but is incapable of transmitting significant quantities under ordinary field conditions. A clay layer is an example of an aquiclude. For all practical purposes, an *aquiclude* is considered an *impervious formation.*

An *aquitard* is a geologic formation which is of a semipervious nature: it transmits water at a very low rate compared to the aquifer. However, over a large (horizontal) area, it may permit the passage of large amounts of water between adjacent aquifers which it separates from each other. It is often referred to as a *semipervious formation* or a *leaky formation.*

An *aquifuge* is an impervious formation which neither contains nor transmits water.

That portion of the rock formation which is not occupied by solid matter is the void space (or pore space). In general, the void space may contain in part a liquid phase (water), and in part a gaseous phase (air). Only connected interstices can act as elementary conduits within the formation. Interstices may range in size from huge limestone caverns to minute subcapillary openings in which water is held primarily by adhesive forces. The interstices of a rock formation can be grouped in two classes: original interstices (mainly in sedimentary and igneous rocks) created by geologic processes at the time the rock was formed, and secondary interstices, mainly in the form of fissures, joints, and solution passages developed after the rock was formed.

(Source: Bear, 1979)

Words

agronomy	农艺学
aquiclude	隔水层
aquifer	含水层
aquifuge	隔水层,不透水层
aquitard	弱透水层
cavern	洞, 洞穴
conduit	管道
drainage	排水, 排泄
fissure	裂缝, 裂隙
igneous	火成的
impervious	不透水的
infiltration	入渗
interstice	空隙
joint	节理,裂隙
leakage	越流,泄漏, 渗漏
leaky	越流的,渗漏的
magmatic	岩浆的
opening	空隙,通路
pore	孔隙, 小孔, 气孔
semipervious	半透水的
spring	泉
subcapillary	亚毛细的
sublimation	升华
void	空隙

Notes

adhesive force	黏着力，黏附力
geologic formation (stratum/stratigraphic sequence)	地层
huge(vast/giant)	巨大的
in contradistinction(in contrast)	相反
return flow of irrigation	灌溉回归水流
septic tank	化粪池
solution passage	溶蚀管道，溶蚀通道
to be concerned with...	关心……，关注……，涉及……
to be referred to as...(to be known as...)	称为……
to range from...to...(to range between...and...)	变化范围从……到……
water-bearing formation	含水地层
water-bearing zone	含水带

Unit 3 Moisture Distribution in a Vertical Profile

Subsurface formations containing water may be divided vertically into several horizontal zones according to the relative proportion of the pore space which is occupied by water. Essentially, we have a *zone of saturation* in which all pores are completely filled with water, and an overlying *zone of aeration* in which the pores contain both gases (mainly air and water vapor) and water.

Figure 3. 1 shows a schematic distribution of subsurface water in a homogeneous soil. Water (e. g. , from precipitation and/or irrigation) infiltrates through the ground surface, moves downwards, primarily under the influence of gravity, and accumulates, filling all the interstices of the rock formation, above some impervious bedrock. The saturated zone in Figure 3. 1 is bounded from above by a *water table* (*phreatic surface*). We shall see below that under different circumstances, the upper boundary can be an impervious one. The term groundwater is used by groundwater hydrologists to denote the water in the zone of saturation. Wells, springs, and effluent streams act as outlets of water from the zone of saturation. The phreatic surface is an imaginary surface at all points of which the pressure is atmospheric (conveniently taken as $p=0$). In Figure 3. 1 it is revealed by the level at which water stands in a well just penetrating the aquifer. When the flow in the aquifer is essentially horizontal, the depth of penetration is immaterial. Actually saturation extends a certain distance above the water table, depending on the type of soil.

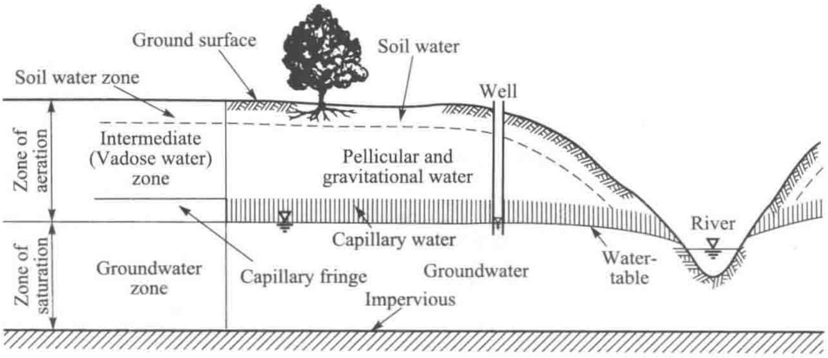

Figure 3. 1 The schematic distribution of subsurface water

The zone of aeration extends from the water table to the ground surface. It usually consists of three subzones: the soil water zone (or belt of soil water), the intermediate zone (or vadose