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Interface between Surface Water and Groundwater

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INTERFACE BETWEEN SURFACE WATER AND GROUNDWATER

BY

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INTRODUCTION

Surface and ground waters represent two of the major components of the hydrologic cycle. They comprise the usable water for mankind activities. They are contrary but interrelated in their hydrologic, environmental and economic characteristics.

Groundwater accounts for about 67% of the global fresh water, by volume. If icecaps and glaciers are abstracted, the global fresh water volume can be distributed as 95% to groundwater, 3.5% for surface water and 1.5% for soil moisture. Such large water reserves pause mostly untapped even though local exploitation could be immense. Many of these water sources cannot be exploited due to their uneconomic depths or because of their degree of saturation that make its extraction almost impossible. As surface waters become more and more exhausted, in terms of quantity and/or quality, groundwater gains its importance.

Hydrologic studies usually separate groundwater from surface water due to the time constants involved in groundwater system. These time

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Then, the hydrologic cycle is completed. When sufficient water vapor again gathers in the atmosphere and the cycle repeats.

2. Surface and Groundwater Occurrence

Different forms of losses commonly face rainfall before it becomes available for use. The interception loss is the first type of losses. It represents the amount of water that could be intercepted by the vegetation leaves. This type of losses cannot be neglected in forests and or heavy agriculture areas. When rainfall drops reach the ground surface, it moves through the soil surface in a process that is called infiltration. Infiltration occurs both prior to and during the occurrence of surface runoff.

The Infiltration capacity or rate at which the soil is able to absorb rainfall is a variable depend upon many factors; such as soil type, vegetal cover, soil hydraulics, antecedent soil moisture conditions, etc. Water, which has infiltrated through the surface, passes first through the belt of soil water. In this belt, water is withdrawn by the transpiration of plants and by evaporation from the soil, which in arid climates may reach depths as great as 6.0 meters. Proceeding downward under the action of gravity, water leaves the belt of soil water and passes through an intermediate belt to reach the water table as shown in Figure 2. The water table is a surface marking the upper limit of a zone or underground reservoir in which the soil is completely saturated. If the water is added from above, the volume in the underground reservoir increases causing a rise in the water table. This addition of water is called groundwater recharge. When this recharge exceeds the saturation condition, deep percolation starts forming a groundwater aquifer system.

On the other hand, the non-infiltrated water flows over the ground surface and hence a portion is stored inside the flood plain depressions, i.e. depression storage losses. The remaining water produces the surface runoff. This portion is commonly called excess or effective rainfall. Surface runoff within a river basin is usually stored to supply the future water demands according to a specified operational policy. Surface runoff at rural wadi systems is used to flow freely to the sea or to plain areas at the outlet of watersheds. The latter allows natural recharge to the existing aquifer system.

conditions, developed countries have many advanced pollution control rules and technologies, they also suffer from the disposal of these contaminants. Furthermore, they have more complicated issues such as the leakage & disposal of radioactive materials.

Groundwater contamination became an acute problem, particularly in rural areas where groundwater is used for drinking. The agricultural community has become keenly aware about the impact of agricultural practices on groundwater quality. Excess use of chemicals may increase the risk of groundwater contamination, i.e. fertilizers, pesticides and antacids as main causes of nitrates. Nitrates are the primary forms of inorganic nitrogen within the soil. Its presence is crucial to the growth and development of a healthy crop. However, nitrates are very soluble and hence, very mobile within the soil solution. Meanwhile, this sort of contamination causes a serious trouble for human being especially for drinking water supply. Groundwater may become contaminated as a result of leakage From septic tanks, sewage effluent spreading grounds, garbage dumps, or similar features for the disposal of vegetable and animal wastes. Other sources of contamination which are becoming of increasing concern in many areas are improperly sealed wells, other subsurface structures and excavations, and those areas created by the disposal of oil field brines and industrial wastes through evaporation ponds, spreading fields, and disposal wells.

The three major problems that are associated with the depletion of groundwater basins are; (a) land subsidence, (b) seawater intrusion into coastal aquifers, and (c) deterioration in groundwater quality.

(a) land subsidence has become a serious problem in several areas of excessive groundwater pumpage. This is especially true in areas that contain unconsolidated alluvial deposits overlying semi-consolidated conglomerate material. This land subsidence is directly correlated with changes in artesian pressure. As the artesian pressure declines, subsidence takes place. When the artesian pressure increases the subsidence stops. The major damage from land subsidence comes from changes in stream gradients and damage to well casings. Compaction of layers, which cause subsidence also, has the adverse effects of greatly reducing the recharge capabilities of these aquifers. Thus permanent damage of the basin occurs.

(b) Seawater intrusion occurs in coastal aquifers when the seawater flow of fresh water is decreased or reversed due to excessive pumpage.

the optimal operational rules to augment the available water resources on the required water demands.

Several practices of conjunctive use are spread allover the world. Conjunctive use is a common practice at the agriculture rural areas of Egypt long time ago. Egyptian used to practice the conjunctive use using "Sakia" to produce groundwater from the phreatic aquifer system to supplement the irrigation requirements during summer season and droughts. Since mid 1950's abstractions of the phreatic aquifer systems in Nile Delta and Valley became a part of the national water budget. Therefore, conjunctive use became a national policy for the full utilization of Nile water. On the other hand, all of the national horizontal expansion projects depend upon conjunctive use. Major contribution of groundwater is planned in south valley project, parallel with the contribution of surface water. Expansions at west and east Nile Delta present another conjunctive use practices. Horizontal expansions in Upper Egypt practice conjunctive use to benefit from the aquifer system at the desert fringes.

In areas experiencing seasonal changes in surface water and/or seasonal changes in water requirements, the conjunctive use would be essential. Groundwater recharge can take place during low water requirements period and/or abundance of surface water, while the groundwater abstraction can follow during periods of high water requirements and/or shortage in surface water. This may be contrary with the objective of minimizing adverse impact on other sources. It may also impose higher pumping costs on the regular users of the aquifer, and may involve interregional transfer of water.

v- Water-Balance Equation :-

The water balance equation states that during a time interval Δt, the inflow Q1 to the groundwater system or aquifer equals the out flow Qo from the system plus the rate of change of water storage in the system. Inflow to a ground-water system may consist of natural recharge , drainage, artificial recharge, irrigation return flow, stream flow, and deep percolation out flow from a groundwater system may include pumping, artificial drainage, springs, subsurface out flow, and phrea-tophyte transpiration. Symbolically, fill, although the channel is dry. It is in the semiarid to arid areas, where irrigation is usually practiced, that water losses from canals and deep percolation from irrigation applications frequently alter natural groundwater conditions. Such alterations include water table rise and water- logging and salination of soils. Artificial drainage by open or buried pipe drains, wells, or other means is often required to lower the water table, maintain a salt balance, and permit the continued production of crops.

c) Artificial Groundwater Recharge:- In recent years, much interest has developed in recharging groundwater reservoirs with excess surface water. Such recharge is intended to maintain groundwater levels, store water for use during droughts, control salt water intrusion, dispose of treated sewage effluent, or for other purposes. In addition, pollutants such as oil field brines and toxic and radioactive industrial wastes are often disposed of by storing them in deep isolated aquifers.

d) Groundwater Reservoirs:-suitable surface water reservoir sites are becoming scarce. Consequently, interest has increased in the underground storage of water. While underground reservoirs are not as obvious or as readily delineated as surface reservoirs, they offer a possible alternative in many areas where conventional storoge would be costly or otherwise undesirable. As is true of all allternative solutions, each type of reservoir offers adventages and disadvantages. Table lists the major advantages of each type of reservoir. attached

7. Conclusions and Recommendations

Surface and Groundwaters play an important role in all of the mankind activities. They present the rigorous means of life for humans, plants and animals. Despite their contradictions, their interrelations and interactions facilitate the restoration of life.

Planning, development and management of these resources involve several complicated and interrelated aspects. Surface water still share the dominant contribution to supply water and energy demands. As a result, it is tapping its ultimate productivity ceiling. Mismanagement and poor distribution systems are the major produces of losses That must be overcome. Groundwater development should take its place to carry out a major portion of the vast increase in water demands. Pollution of water resources become a serious problem threatening the sustainability of life. A revolution in laws and administrative

Table , Advantages of Surface Versus Subsurface Reservoirs

Item	Subsurface Reservoirs	Surface Reservoirs
1	Many large capacity sites available	Few new sites available
2	Slight to no evaporation loss	High evaporation losses even in humid climate.
3	Require little land area	Require large land area
4	Slight to no danger of catastrophic structural failure	Ever present danger of Catastrophic failure
5	Uniform water temperature	Fluctuating water temperature
6	High biological purity	Easily contaminated
7	Safe from immediate radioactive fallout	Easily contaminated by Radioactive materials
8	Reservoir serves as conveyance system canals or pipelines across lands of other unnecessary	Water must be conveyed
9	Water must be pumped	Water may be available by gravity flow
10	Storage and conveyance use only	Multiple use
11	Water may be mineralized	Water generally of relatively low mineral content
12	Minor flood control value	Maximum flood control value
13	Limited flow at any point	Large flows
14	Power head usually not available	Power head available
15	Difficult and costly to investigate, evaluate, and manage	Relatively easy to evaluate, investigate, and manage.
16	Recharge opportunity usually dependent on surplus surface flows	Recharge dependent on annual precipitation
17	Recharge water may require expensive treatment	No treatment required
18	Continuous expensive treatment of recharge areas or wells	Minor treatment required

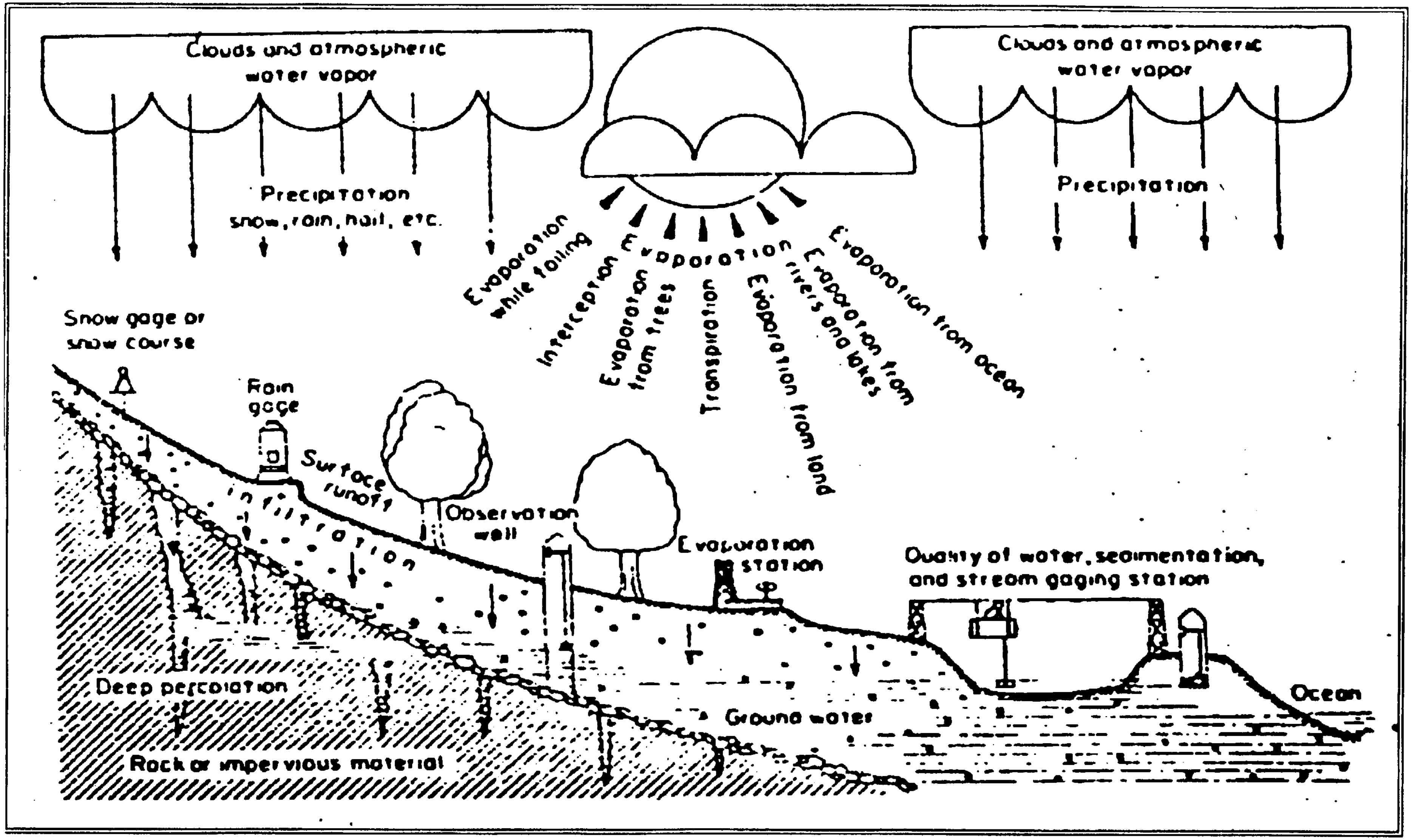

Figure.1 . Hydrologic Cycle (adapted from Walton)

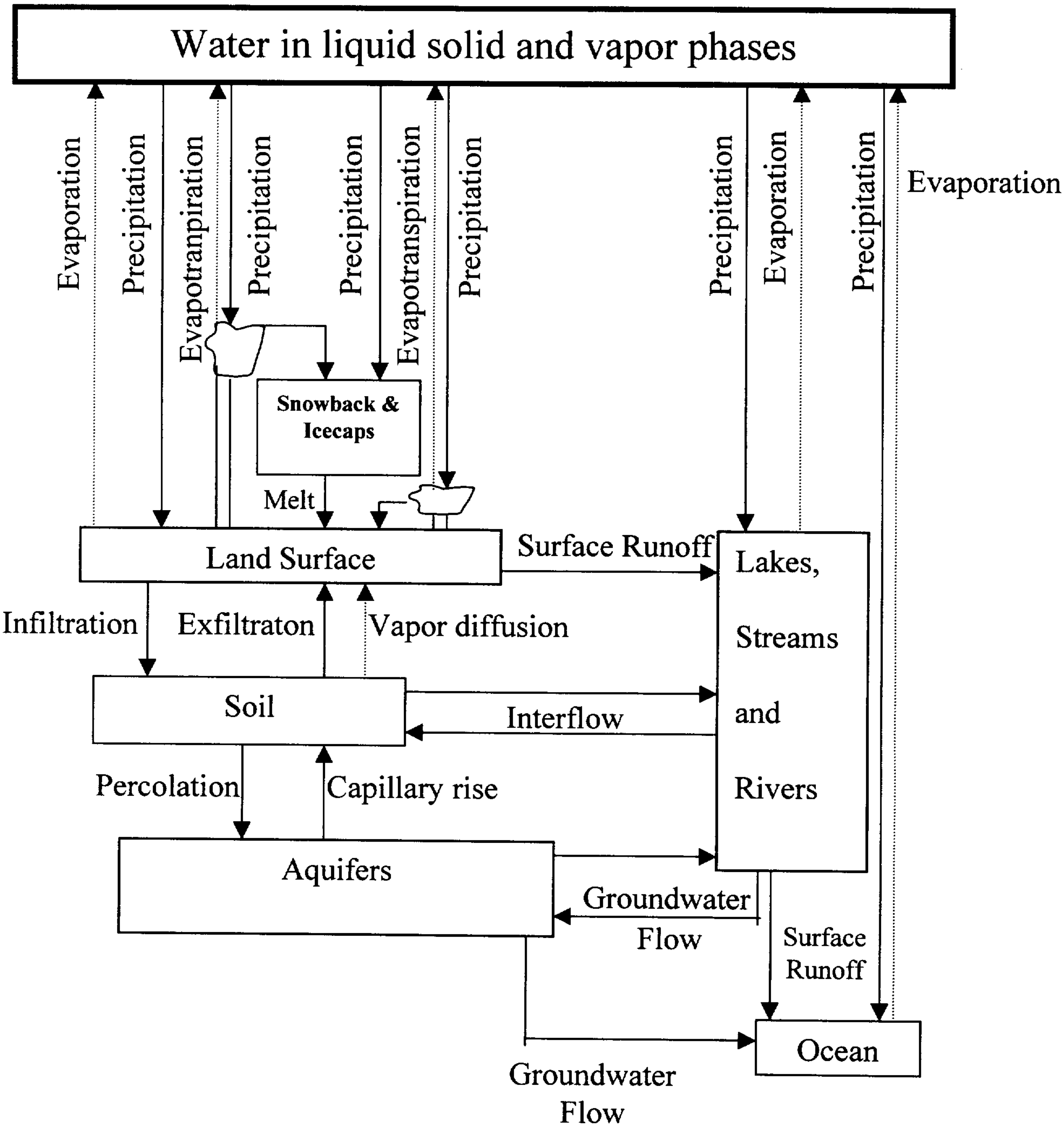

Fig 3 - Schematic view of the Hydrologic Cycle.
Source : Eagleson (1970)

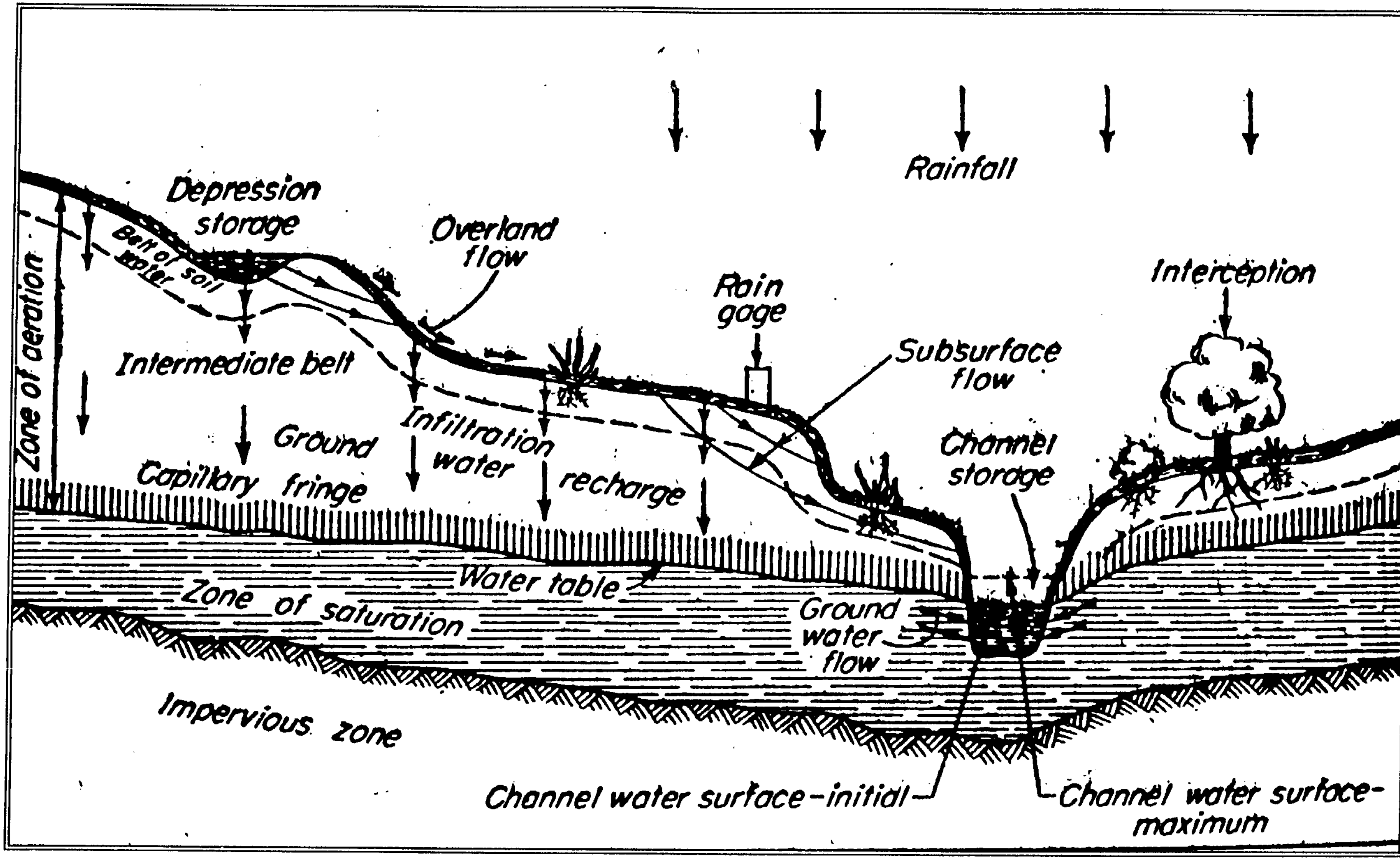

Figure.2 . Generalized Cross Section Defining Runoff Terms

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legislations are essential to conserve and protect the life of future generations.

The following recommendation may be beneficial to assess, evaluate, protect and enhance the surface and groundwater management.

1. Continuous quantitative & qualitative monitoring.
2. Producing new technologies and cropping patterns to improve the agriculture practices,
3. Introducing the appropriate technology for wastewater treatment and utilization.
4. More reliable and robust models are needed to assess and evaluate the water resources and their pollution.
5. Introducing the non-structural flood mitigation approaches will help integrate the planing and management of natural resources. Supporting pilot projects will be very encouraging.
6. Capacity building to enhance the manpower knowledge and capabilities via the modern techniques and new technologies seems essential.
7. Laws and administrative legislation should be adopted to protect natural resources.
8. A public awareness program for the conservation of fresh water resources is essential.

$$Q_I - Q_0 = S_t\,(d_v / dt) \qquad (1)$$

the storage V can be expressed as

$$V = Ah \qquad (2)$$

where A is the area of the aquifer, and h is the mean water level in the aquifer.

Differentiating Equation (2)

$$dv = Adh \qquad (3)$$

substituting Equation (3) into Equation (1)

$$S_t\,(dh/dt) = \{1/A\}\,(Q_I - Q_0) \qquad (4)$$

which is the spatially lumped continuity equation. A familiar storage-discharge relation is the one that applies to a linear storage element expressed as.

$$Q = aV \qquad (5)$$

Where Q is the discharge (L^3/T), and a is a storage constant (T^{-1})

By inserting equation (2) into equation (5) **$Q = aAh = a_* h$**

Where $a_* = a\,A$

6. Groundwater and Surface water Relation ships

a) Humid Area Relationships: Groundwater in humid areas maintains the base flow of streams by seepage into stream channels, However, the head water reaches of some streams may be above the water table, and therefore are dry during seasons of low precipitation. In such reaches, seepage from the streambed may charge an under-lying aquifer. Consequently, some reaches of a stream may be replenished by while others lose water to the ground water reservoir.

b) Arid Area Relationships: In many arid drainage basins, the perennial master streams receive seepage from the groundwater reservoir, whereas other streams may be above the water table, and streamflow occurs only during periods of high surface runoff. where the water table is below the streambed, practically all the streamflow may be lost by seepage to the groundwater reservoir. Beneath many such stream beds, considerable underflow may be present in the channel

As the seawater moves inland, groundwater aquifers become contaminated with salt that can cause permanent damage.

*(c) **Deterioration of groundwater quality*** can occur due to the artificial recharge of saline water. Salts can be added to the groundwater by the percolation of water through soluble soil materials. The factors governing groundwater quality include soil type and permeability, availability of irrigation-water drainage facilities, quantities of irrigation water applied, crop pattern, and climate.

Another major issue is the management of depleted groundwater reservoirs. Once the water table drops below the economic pumping depth, the planning agent must look for alternative surface water supplies. These surface water supplies must then be utilized to satisfy the municipal, industrial, and agricultural demands and to recharge the depleted groundwater basin.

The planning agent concerned with the management of a groundwater and surface-water system must notice these important problem areas and include their consideration in any optimization model.

The analysis of groundwater systems and conjunctive groundwater and surface-water systems can generally be divided into two broad problem areas:

1. The identification of the aquifer parameters, and.
2. The economic management of the aquifers conjunction with an overlying surface-water system.

The aquifer parameters of groundwater basin are the storage coefficient, the transmissivity and the boundary configuration of the aquifers. These characteristics can be determined through the analysis of the differential equation that governs the flow of water through porous media. The economic utilization of a groundwater basin in conjunction with a surface water system is concerned with minimizing the cost of the system configuration and its operation.

5. Surface and Groundwater Management

There are several policies for the planning and management to reach the full utilization of the water resources. These policies comprise highly complicated and interrelated issues. Conjunctive use is one of these policies that require high planning and management skills. It represents

3. Surface and Ground Waters Interactions

Several interactions are encountered between surface and ground waters. These interactions include those parts of the hydrologic cycle; namely, interflow and groundwater flow. These interactions alternate according to the water level of stream flow and groundwater aquifer.

The continuous infiltration and deep percolation from water ponds and wet lands are another types of interrelations. This relationship is also called the natural groundwater recharge.

On the other hand, vertical drainage to a bounded geologic formation or a brakish water aquifer poses other way of interaction. This process is used to conserve the ecological balance of the irrigated agriculture. Moreover, supplementary water can be pumped from the phreatic aquifer to water use schemes to satisfy the demands in dry seasons. This process would preserve the soil productivity and would maintain pre-specified water table and quality.

It should be noticed that groundwater development required energy, while surface water is used to generate hydropower. Accordingly, surface water is used to produce the necessary energy for large-scale groundwater development as another form of interactions.

4. Surface and Ground Waters Contamination

Natural resources pollution became a common and sounding issue in the last three decades. There are various reasons behind this issue. The vast industrial development, the rapid population growth and the vertical and horizontal agriculture expansions comprise the main reasons. Industrial wastewater involves several minerals, trace metals, toxic organic matters and chemical residuals that drain to water schemes providing serious negative environmental impacts. Municipal wastewater includes many contamination components such as detergents, human residuals, organic matters, pathogenic organisms, etc. Agriculture drainage also carries various contaminants as the chemical and organic residuals of pesticides and fertilizers.

Surface water pollution by these contamination sources is a common practice throughout the world. Surface water ponds or rivers are usually used as a natural disposal for such contaminants. These problems are although very acute in developing countries due to their economic constants are generally longer than those of many common surface water problems such as flood forecasting are. Nevertheless, problems, such as droughts, water supply, irrigation, and water pollution cannot be overcome without complete knowledge of both the surface and ground waters characteristics and conditions.

On the other hand, conjunctive use of surface and ground waters can excel to significant economic advantages. It can also rectify the repulsive environmental impacts. In semi-arid regions, conjunctive use will offset the paucity in dry seasons and permit storage and recharge of excess water during wet seasons.

1. Hydrologic Cycle

The Hydrologic Cycle is the endless sequence of precipitation, storage, runoff, and evaporation processes. During this cycle the total amount of water in the atmosphere and in/on the earth abides the same, however its form may change. Although minor quantities of magmatic water or water from other deep-seated sources may find its way to the surface, all water is assumed to be a part of the hydrologic cycle.

The hydrologic processes of the hydrologic cycle are illustrated in Figure 1. Water vapor in the atmosphere is condensed into ice crystals or water droplets that fall to the earth as a rain or snow or both together and called precipitation.

A portion of precipitation evaporates and returns to the atmosphere. Another portion flows over the ground surface until it reaches a stream, hence flows to the ocean. The remaining portion infiltrates directly into the ground and seeps downward. A part of this portion may transpire by plants or move back to the ground surface by capillary and evaporate. The remainder percolates downward then join the groundwater aquifer.

Groundwater returns to the ground surface through springs and groundwater flow to streams where it is subject to evaporation or is directly evaporated from the ground surface or transpired by vegetation.