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A Summary of Ground-Water Conditions In the Piedmont Province of Virginia

by

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Introduction

The general ground-water conditions in the Piedmont Province of Virginia (Figure 1) are described in this report. Systematic studies have been made in Halifax, Pittsylvania, Prince William, Fairfax, and Loudoun counties, and results of these ground-water investigations have been published by the Virginia Division of Mineral Resources. The preparation of this summary was brought about by the urgent need for general information about the ground-water resources of the Piedmont.

The generalizations set forth in this report should be helpful in solving many well problems and in answering some questions about ground-water conditions. Any attempt to apply a generalization to a particular problem should be tempered with the knowledge that local geologic conditions control local ground-water conditions.

Much of the material in this summary has been adapted from "Geology and Ground-Water Resources of Pittsylvania and Halifax Counties," a manuscript in preparation for publication by the Division of Mineral Resources.

Geologic Setting

The Piedmont Province includes a wide belt of rolling land extending westward from the Coastal Plain to the Blue Ridge Mountains. The upland areas, connecting the high points of the inter-stream areas, represent a plateau that was dissected by numerous streams. Varying intensities of downhill movement of soil and weathered rock has resulted in slopes that are hilly and gently rolling. Almost everywhere a mantle of soil with a cover of vegetation hides the underlying rock.

Igneous and metamorphic rocks, extending from Pennsylvania to Alabama, underlie the Piedmont Province, as well as the Blue Ridge Province. Also, within the Piedmont Province are several narrow belts of sedimentary rocks of Triassic age, which are characterized by flatter topography and redder soils than those developed on the typical igneous and metamorphic rocks. This report pertains to the igneous and metamorphic rocks and to a lesser extent to the Triassic rocks.

The igneous and metamorphic rocks are very complex in character and occurrence, but for this discussion they will be considered as either massive, granite-like rocks, or banded, layered rocks that are referred to as gneisses, schists, and slates. Many of the rocks were deformed by earth movements so that their bevelled edges are observed at the land surface where the soil zone was stripped away.

The rocks contain fractures or joints through which water from precipitation can enter. Some of these fractures may extend to depths of several hundred feet, although they are more prominent at shallow depths. Chemical and physical actions of water and air in the fractures near the land surface cause the rocks to disintegrate and decay and eventually produce soil layers. A layer of soil and weathered material called residuum, or mantle rock, underlies the land surface throughout the Piedmont. A vertical section through the residuum revals three distinct layers having different characteristics for the percolation of water (See Figure 2). The surface soil, including the zone commonly plowed, has a loose sandy or sandy clay texture. Beneath the surface soil is a subsoil zone consisting of a compact clay or grit with a clay mixture. The subsoil grades downward into a zone in which the rock has been leached of some of its mineral matter. The term saprolite is commonly applied to this softened rock that retains its original structure and much of its texture. The saprolite grades downward into hard fresh rock. The thickness of the residuum varies locally with the rate at which weathering occurs in relation to the rate of removal of the weathered materials. On mountain tops and along some steep slopes bare rock is exposed. At other places the saprolite crops out, but commonly the entire soil profile is present. The residuum, the greater part of which is softened rock, is as thick as 60 feet on many of the broad upland areas.

Occurrence and Movement of Ground Water

Water that may be pumped from wells or flows from springs is called ground water. Water is stored in the open spaces of the clay, sand, and fractures in the rocks in what might be termed an underground reservoir. The underground reservoir is, to some extent, similar to a surface reservoir, but it differs from a surface reservoir in that its boundaries are not definite.

The underground reservoir consists of two contrasting types of material. These are (1) the clayey and sandy soil, subsoil, and weathered material that underlies the surface to depths generally ranging from several feet to several tens of feet and (2) the underlying bedrock. In the soil, subsoil, and weathered or soft rock, water occurs between individual mineral grains, but in the bedrock below water occurs only in fractures. These fractures do not have an even distribution but may be an ich or two or several feet apart. As shown in figures 2 and 3, many fractures are connected so that water may move through them to a well or to a low place in a valley. In some places the fractures are only a fraction of an inch wide, although there is a great difference in size. The size and number of fractures appear to decrease with depth. As a result, most ground water occurs at a depth of less than 150 feet—much of it in the upper 30 feet of bedrock. Therefore, the lower limit of the reservoir is a thick, indefinite zone; the top, however, is a definite though fluctuating surface known as the water table. Because there is a layer of soil and weathered rock almost everywhere in the Piedmont Province and because the rocks are commonly fractured to some extent, we can say that the underground reservoir underlies nearly all of the region. Because of local geologic conditions, not all wells yield the same amount of water.

Underground water is not fixed and stationary but is constantly in motion. Its source is the rain and snow that falls on the land surface above. The underground reservoir does not have high priority on the water that falls on the land but must wait until other demands of nature are satisfied. A part of the precipitation runs off the land immediately and is not available to the underground reservoir. Some of the water that falls is returned to the atmosphere by evaporation and by transpiration from vegetation. The combined effects of evaporation and transpiration are commonly referred to as "evapotranspiration."

Water beneath the ground moves under the influence of gravity, and the rate of flow varies directly with the hydraulic gradient. Water that enters the ground on the upland areas tends to move downward but is eventually shunted to a low place in a stream valley where is is discharged either as a spring or as water vapor.

Significance of the Water Table

The water table is the upper surface of the underground reservoir. Its position below the land surface can be determined by measuring the depth to water in a well. It actually can be seen in valleys because it is the surface level of creeks and rivers. The depth to the water table depends on the topography and on the transmitting characteristics of the residuum and fractures in the rock. Beneath the hills and upland areas the water table generally lies in the residuum or rotten rock and may be as close to the surface as 20 feet or as far as 70 feet below the ground. In all cases the water table beneath a hill is higher above the surface level of the closest stream (although deeper below the ground) than in a low area (Figure 3).

The slope of the water table toward the stream results in a constant movement of water out of the underground reservoir. Some of the water seeps into the streams to give them a year-round flow. Some of the water, as it comes near the ground in low swampy areas, is lost by evaporation and by transpiration from trees and other plants. This constant outflow, or discharge, of ground water causes a gradual lowering of the water table except during and immediately after periods of significant precipitation when recharge to the underground reservoir is greater than discharge from it; as a result of the periods of precipitation, the water table rises.

Since water is always moving out of the ground, the lowering of the water table covers a longer

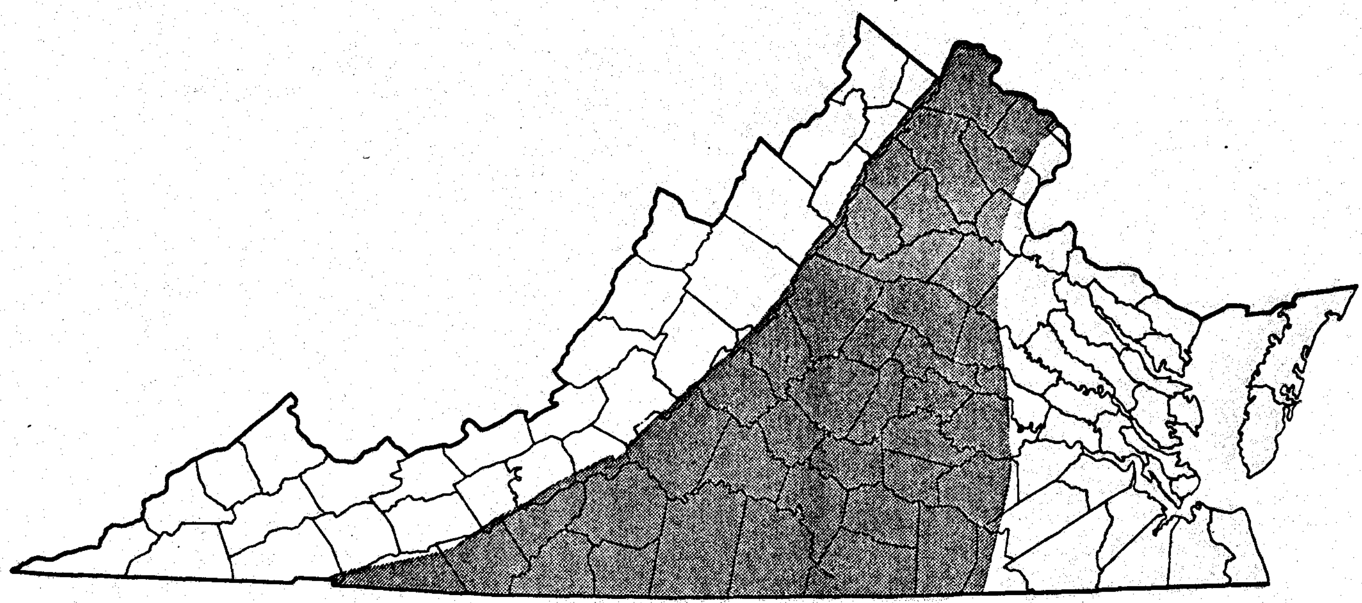

Figure 1. Outline Map of Virginia showing the Piedmont Province of Virginia.

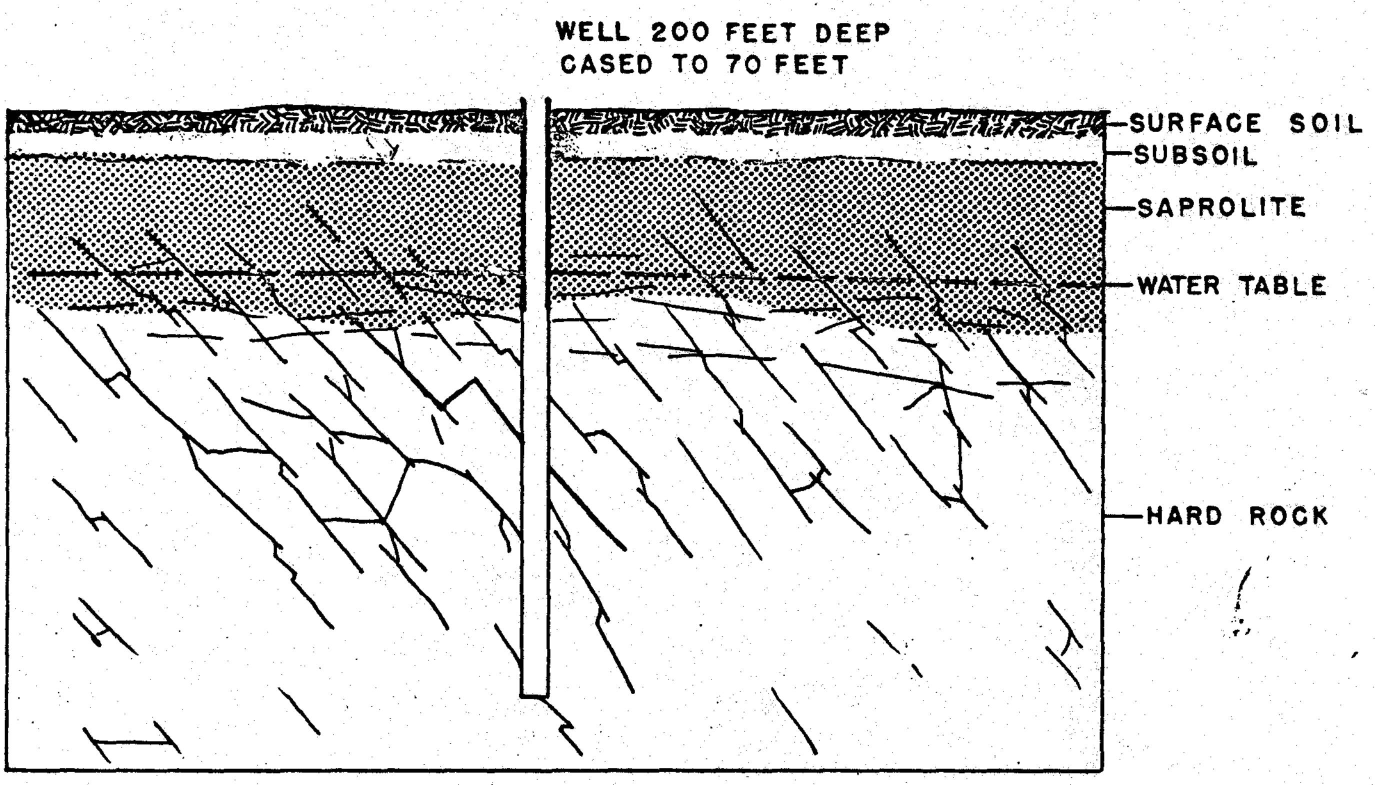

Figure 2. Typical subsurface cross section showing the character of materials penetrated by a well on an upland area.

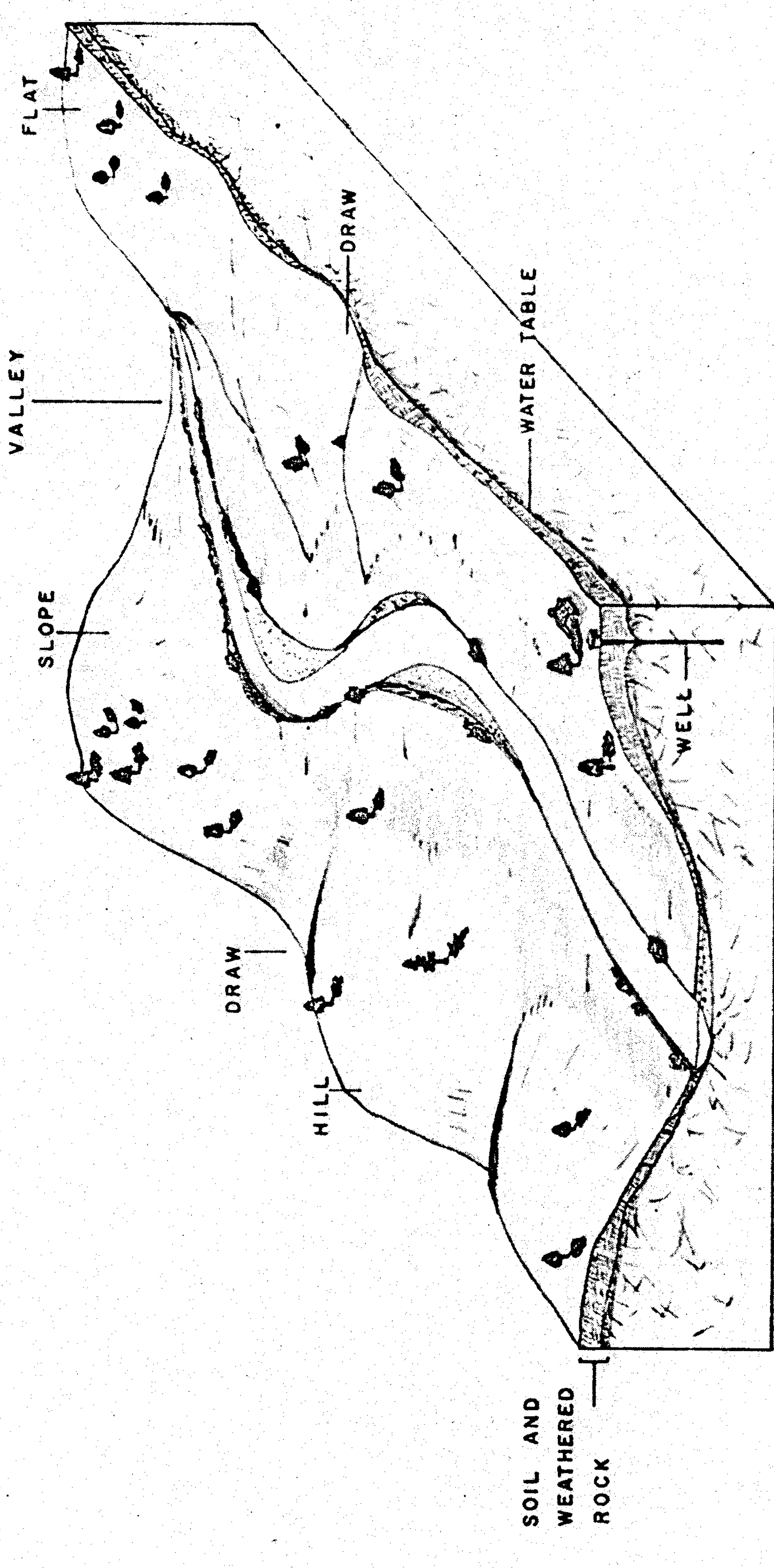

Figure 3. Diagrammatic sketch showing types of topography and typical subsurface cross section in the Piedmont of Virginia.

period during a year and is more gradual than its recovery. In a year of average rainfall, the replenishment to the underground reservoir is about equal to the discharge from it so that the water table at the end of the year is at about the same level as at the beginning of the year.

There is a noticeable change in the water table with the seasons. It begins to fall in April and May when the vegetation starts using more water and when evaporation increases. Although there are slight rises of the water table following heavy summer showers, the water table tends to decline during the summer in spite of abundant rainfall in July and August. By November and December, when much of the vegetation is dormant and evaporation is low, a larger amount of the precipitation reaches the reservoir, causing the water table to rise until it reaches another high stage about April or May of the next year. In areas that are not influenced by wells, the water table changes about five feet from its highest to lowest stages, although in places beneath sharp hills the annual fluctuation may be as much as ten feet.

Although many wells are used in the Piedmont, the lowering of the water table around the individual wells does not affect the regional water table. The effect of pumping a well is felt no farther away than a few hunderd feet.

Springs

To a great extent, roads tend to follow upland courses to avoid stream crossings. A casual observer might get the impresssion that streams and springs are scarce. This is not the case, and in fact, it is difficult to find a spot which is a mile from a spring or stream. Many of the slopes are steep enough to cut into the water table, allowing water to leak from the underground reservoir. The leakage of water may be small and scattered in a swampy place, where evaporation and transpiration use it all, leaving none to run into streams; in other places the leakage is concentrated enough to form a small spring. These springs commonly emerge from a cove or re-entrant, near the bottom of a hill. Most of the springs yield 1 to 2 gallons per minute and have a nearly steady year-round flow. In addition to the permanent type of spring, some springs of a temparary nature develop during wet seasons when the water table rises to a position at which more water emerges from the slopes.

Springs are a source of water for some rural dwellings, but their unfavorable locations in valleys, perhaps several hundred yards from the place where water is needed, result in their limited use. Almost all water from springs in the Piedmont is of excellent chemical character. Spring water contains much less mineral matter in solution than does well water because spring water generally circulates more rapidly and at shallower depths through the rocks.

Characteristics of Wells in the Piedmont Province

There has been a gradual change in the methods of obtaining ground water. In the days of the early Virginia settlers, springs were the chief source of water, and, as a result, homes and villages were built near springs. Later, dug wells became the most common source of water supply. Today, however, drilled wells and bored wells are increasing greatly in number. Many dug wells are being abandoned and very few springs are now used.

Since the water table generally lies in the zone of soft, weathered rock, shallow dug or bored wells can be developed in many places a few feet below the water table. These wells are normally adequate for rural domestic use, but some go dry when the water table falls during droughts. Larger and more dependable supplies can be obtained from drilled wells that draw water from fractures in the bedrock.

There is a great range in the yield of water from individual drilled wells even in the same type of rock and in the same area. One well may be a good producer whereas another a short distance away may yield an insufficient amount of water for rural domestic use. This great difference in yield from place to place has caused many people to turn to the water dowser for help in locating wells. The apparent success of the dowser is due to the fact that sufficient water for rural domestic use is available almost everywhere; in fact, it would be much more difficult to locate a place where is not available. In spite of common reports of the success of dowsing, there is no basis for the belief that water can be found with a divining rod.

The great majority of drilled wells in the Piedmont yield more than 3 gallons per minute but less than 60 gallons per minute. The typical well for rural home use yields about 6 to 10 gallons per minute, whereas the typical well for municipal and industrial use yields about 20 to 30 gallons per minute.

The yield is not directly related to the depth of a well because the wells are not capable of transmitting water uniformly at all depths below the water table. Deeper wells, commonly those for municipal and industrial uses, have higher average yields than the relatively shallow wells for home use. This fact is related to specific water needs. For example, the industrial and municipal wells are pumped at greater rates and have greater drawdowns of the water level than rural domestic wells. On the other hand, wells less than 100 feet deep generally have a greater yield per foot of well than do wells deeper than 100 feet. This fact becomes apparent when it is noted that the number and size of fractures decrease greatly with depth. The depth of a well is, in many cases, the result of a personal decision and is not necessarily the depth at which water was struck. Since most of the interconnecting fractures occur in a zone no deeper than 150 feet below the land surface, it may be wise to drill no deeper than 150 feet if the yield is very poor, or no deeper than 300 feet in almost all cases.

One of the most important considerations is the selection of a site at which to drill a well. Most of the rural domestic wells are on hills and are located specifically to be near the place of use and uphill from any source of possible contamination. Experience has shown however, that hilltops and convex, upland slopes are likely to be the poorest locations insofar as high-yielding wells are concerned. The most favorable locations for large-yielding wells are in draws or in other relatively low, concave topographic situations. For example, a study of topographic locations of wells in Pittsylvania and Halifax counties showed that the average yield of wells in draws is about 42 gallons per minute, whereas the average yield of wells on hills is about 7 gallons per minute.

Another consideration is the thickness of residuum that overlies the rock. A thick layer of soil and soft weathered rock suggests that fractures occur in the underlying rock. Where a thin soil zone is present, or where rock is exposed, the underlying rock is not likely to be fractured greatly. Some ground water is stored in the residuum from which bedrock fractures draw water continuously, even in long periods of dry weather. Therefore, large-yielding dependable wells are more likely to be developed where a thick residuum occurs than where bare rock is exposed.

Chemical Quality of the Water

In addition to the yield of a well, an important consideration is the chemical quality of the water. As water percolates downward through the soil, any harmful bacteria that might be present on the ground tends to be removed, and the water becomes suitable for drinking after passing through the soil and rocks. However, the water tends to dissolve mineral matter from the rocks, and all natural water contains some minerals in solution. In comparison with ground water in widely scattered regions of the world, the ground water in the Virginia Piedmont ranks among the best in chemical quality. Yet, some of the water contains objectionable amounts of hardness or iron; some water tends to be corrosive and to "pick up" iron from the pipes.

Iron in water is the most common complaint. As little as 0.4 part per million of iron in water will cause a red stain on plumbing fixtures. About 5 of every 10 wells in the Piedmont yield water with less than 0.3 part per million of iron. About 4 of 10 wells yield water with just enough iron to cause a slight stain, and about 1 of 10 wells has water that has considerable iron. In addition to the iron dissolved from the rocks, some water is sufficiently corrosive to pick up iron as it moves through the pipes. It is important to determine the source of the iron, whether dissolved from the rocks or from the pipes, before methods for its removal are employed.

It is not possible to determine the quality of water before a well is drilled. Most of the water is satisfactory for use without any type of treatment. Yet, an analysis of the water should be made as soon as a well is drilled to determine if treatment is necessary.

Summary

1. Ground water may be considered as occurring in an underground reservoir, the water being held in the open spaces of the rock materials. The water table, representing the top of the reservoir, generally lies in the clay, or disintegrated rock materials. In the lower part of the reservoir, water occurs in interconnecting fractures in bedrock; the fractures diminish in number and size with depth. Drilled wells draw water from fractures, but this water enters the fractures by gravity from the overlying clay. The source of this water is precipitation in the general area of a well and not some remote place.

2. The water table has a "hill and valley" relation that approximately conforms with surface topography, although the water table is somewhat flatter. For example, a creek or river is the surface expression of the water table in a valley, but beneath a hill the water table may be 30 to 70 feet below the ground surface. Ground water, like surface water, has the tendency to drain away from the hills to the valleys. This tendency helps in planning the location of wells in relation to other wells and to sources of possible contamination.

3. The relation of the depth of a well to yield is not simple. In spite of some belief, water already available to a well is rarely lost by drilling deeper. Therefore, there is always a chance of getting a larger supply by drilling deeper; but this chance becomes poorer as the well deepens because the interconnecting fractures, and the ability of the rocks to store and transmit water decreases significantly with depth. More than 90 percent of all ground water occurs in the first 100 feet below the water table. In almost all

cases two wells 200 feet deep each will yield more water than one well 400 feet deep.

4. The relationship of topography to yield is emphasized. The great majority of wells are located on hills or smooth upland slopes because of convenience and because these locations appear safe from sources of contamination. Yet, the percent of low-yielding wells is much greater on hills and upland convex slopes than in lowlands or draws (concave slopes that lead upward from a valley to a saddle or sway-backed position in a ridge).

5. In general, wells are more productive and tend to have a more stable year-round yield where a thick mantle of soil occurs than where bare rock crops out. The presence of a soil cover and the absence of rock outcrop suggest that water moves downward into the rock and is not readily shunted toward the adjacent valley; in fact, the soil cover suggests that interconnecting rock fractures are available to store water and transmit it to wells. Where there is a good soil cover the water table generally lies in it and, therefore, the storage capacity in the vicinity is much greater than where bare rock is exposed and the only water in storage is in the rock fractures that might be quickly drained.

6. Simple clear-cut statements about the water-yielding properties of the various types of rocks in the Virginia Piedmont are not easy to make. There are many varieties of igneous and metamorphic rocks, but for a discussion of their ground-water properties they may be grouped as follows: (1) somewhat massive igneous rocks, such as granite, and (2) metamorphic rocks such as schists, gneisses, and slate, which may show an alinement of minerals or an alinement of cleavage planes or openings along which water may move. In some places a type of rock may have distinctive water-bearing characteristics, but, if so, it is also likely to show distinctive topographic and soil-mantle features. Topography and soil-mantle features are readily observed and may be used as criteria for predicting the water-yielding potential of a well site, whereas the inherent water-bearing characteristics of a type of rock by itself may be obscure. At any rate, there are too many complex factors involved to justify generalizations about the yield of wells in individual types of rock.

7. Whenever water is pumped from a well, the water level is lowered in and around the well. The drawdown increases with an increase in the rate of pumping although this is not a simple relation. For example, a well yielding 20 gallons per minute with a drawdown of 50 feet will not double its yield by increasing the drawdown to 100 feet. Instead, it will yield less than 40 gallons per minute and perhaps no more than 25 to 30 gallons per minute with a drawdown of 100 feet.

8. Some wells that are pumped heavily tend to decline gradually in yield. This fact may be due to the following circumstances. The size and setting of a pump is determined from a short bailer or pumping test when the well is completed. Such a short test may not indicate the long-term yield of the well because the first water is withdrawn from storage in the rock materials, and many hours, days, or even months may pass before there is a stable adjustment between the amount of water that the fractures can feed into the well and the amount of water available to drain through the overlying clay into the fractures feeding the well. Failure to have knowledge of water-level fluctuations as a result of pumping is the cause of many well problems and is the cause of the erroneous conclusion that well supplies are not dependable. If a well tends to have an unstable yield, it is probably over-pumped. A reduction in the rate of pumpage and, consequently, a raising of the water level will result in a perennially safe yield. Constant pumping at a moderate rate does not damage a well.

9. There is a tendency for rocks underlying a light-colored soil to yield water that is soft and low in dissolved mineral matter. On the other hand, rocks underlying darker soils (dark red, brown, and yellow) tend to yield water that is slightly hard, or hard, and that may contain objectionable amounts of iron.

NEW MAP

Mineral Industries and Resources Map of Virginia

The first mineral economics map of Virginia published by the Division of Mineral Resources is now available. Illustrated on the "Mineral Industries and Resources Map of Virginia" are locations of the State's principal mineral resources and mineral producers. Included in this color edition is a chart depicting the production of mineral materials and coal in Virginia from 1932 to 1959. Areas of the State underlain by coal, limestone, sand and gravel, manganese, soapstone, granite and other resources are represented in color. This wall map which measures 27 x 57 inches has been printed on a scale of one inch equals approximately eight miles. The map may be obtained from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, Virginia for $1.00.

NEW PLANT

The Hydraulic Company recently began producing masonry mortar sand from a floodplain deposit along South Fork of the Rivanna River near Charlottesville, Albemarle County.