PHYSIOGRAPHY

The Millers River basin lies wholly within the New England upland physiographic province (Fenneman, 1938). To the west is the Connecticut Valley Lowland; to the east is the Seaboard Lowland.

The physiography is closely related to lithology and structure of the underlying bedrock. Glaciation and the distribution of glaciofluvial deposits have modified the topography and the drainage pattern.

BEDROCK GEOLOGY

The basin is bounded on the west by the downfaulted Triassic rocks of the Connecticut Valley and on the east by the Fitchburg pluton. The Triassic border fault lies at the present confluence of the Millers and Connecticut Rivers. To the east of the confluence are the gneiss domes that compose the core of the Appalachian tectonic belt. East of these domes are the intrusive granites and metamorphic rocks that make up the Upland Plateau of central New England.

Rocks underlying the Millers River basin have been divided into the Ammonoosuc Volcanics and Partridge Formation of Middle Ordovician age; the Paxton Quartz Schist of probable Ordovician and Silurian age; the Clough and Fitch Formations of Silurian age; the Littleton Formation of Early Devonian age; and the Kinsman Quartz Monzonite of probable Late Devonian age. The Hardwick and Concord Granites and the Spaulding Quartz Diorite of probable Late Devonian age are mapped as a unit designated "Granite, undifferentiated."

Field evidence indicates that the Hardwick Granite is a differentiate of the New Hampshire Plutonic Series, and that the Hardwick includes types of the Kinsman and Concord (Mook, 1967). The New Hampshire Plutonic Series includes the Concord Granite, the Kinsman Quartz Monzonite, and the Spaulding Quartz Diorite, all of Late Devonian(?) age. The age of the Hardwick Granite has been changed to Late Devonian(?) age.

The Paxton Quartz Schist is considered the equivalent of the Eliot and Berwick Formations of New Hampshire of probable Ordovician and Silurian age. The age of the Paxton Quartz Schist has accordingly been changed to Ordovician and Silurian age.

GEOLOGIC STRUCTURE

The Millers River basin is replete with a wide variety of structural features. The triassic border fault, only part of which is shown on the bedrock geology map at the mouth of the basin is a normal fault, downdropped on the west. Moore (1949) has estimated the displacement as at least 15,000 feet and probably more than 25,000 feet near the New Hampshire line.

SURFICIAL GEOLOGY

Introduction

The Millers River basin contains large quantities of unconsolidated sand, gravel, silt, and clay, which are capable of storing and transmitting large quantities of water. Such deposits may form aquifers atop the bedrock or "ledge" as it is locally known. To understand these aquifer systems and the movement of water through them necessitates extensive knowledge of the surficial geology of the basin. (Surficial Geologic Map and Sections).

Glaciation

The basin was glaciated several times during the Pleistocene Epoch but evidence of the pre-Wisconsin glaciations has been obscured by the last of the glacial advances: The Wisconsin. From 12,000 to 14,000 years ago, the Wisconsin ice sheet began to retreat but in New England the retreat has been likened to a wasting away as the glacier broke up and gradually melted in place.

POST-GLACIAL DEVELOPMENT OF THE DRAINAGE BASIN

During the latest phase, the Winchendon and Gardner areas where draining into Lake Templeton. With the melting of the South Royalston ice block Lake Templeton drained to the west exhuming an old channel through the Hardwick Granite and building a delta at Athol in Lake Orange. Lake Orange finally began to drain into the North Pond Brook-Orcutt Brook system as the ice block between Orange and North Pond Brook melted, thereby completing the drainage to the Connecticut River.

In summary, the Millers River began exhuming its preglacial drainage boundaries in late Pleistocene time. The profile of the river is indicative of the disequilibrium of the bedrock profile and the steps by which adjoining basins were annexed in the Tertiary Period (see fig. 1).

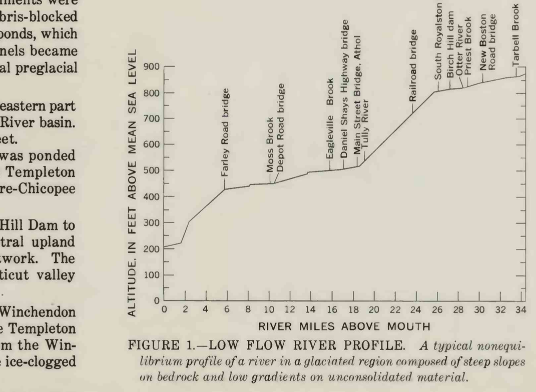
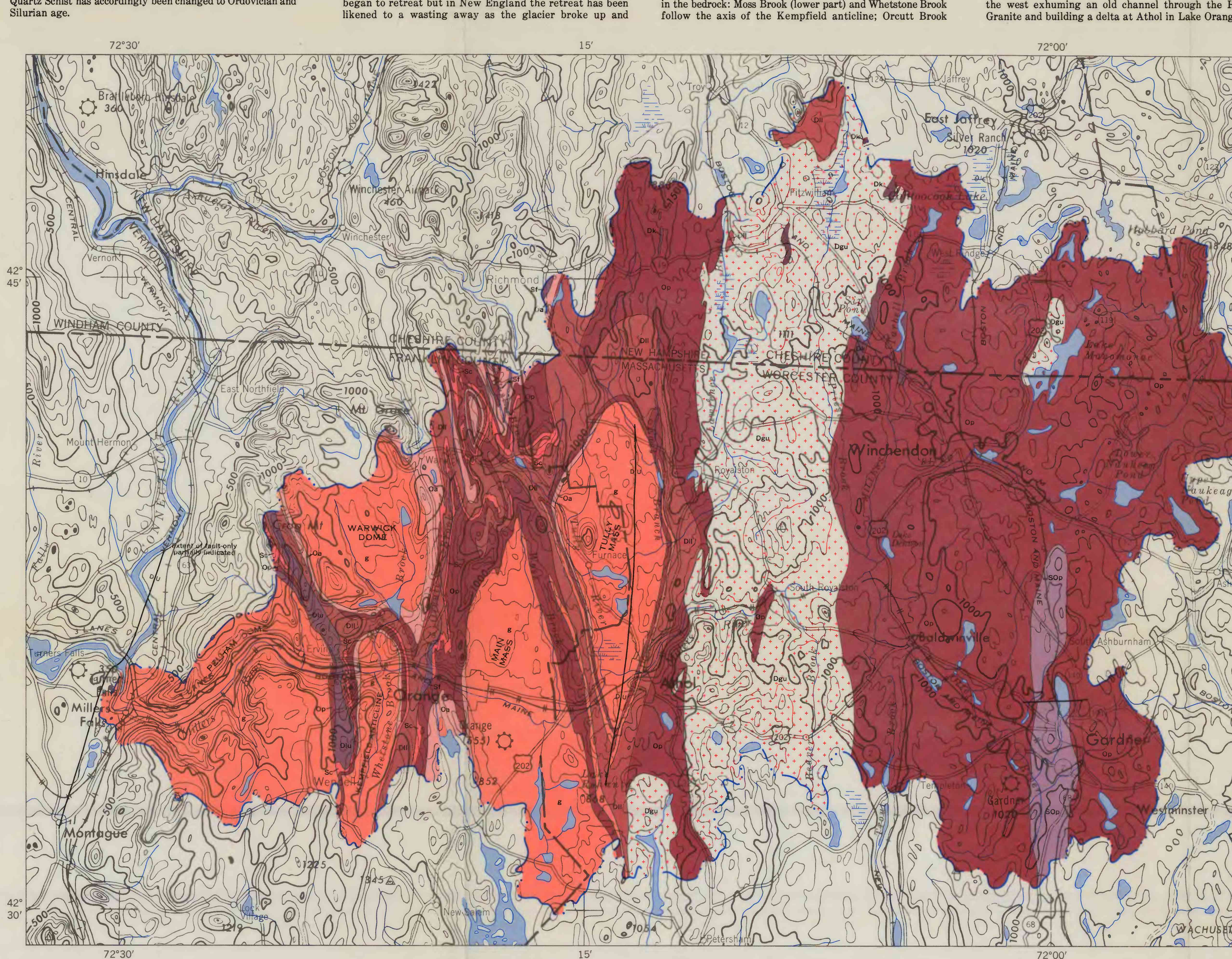


FIGURE 1.—LOW FLOW RIVER PROFILE. *A typical nonequilibrium profile of a river in a glaciated region composed of steep slopes on bedrock and low gradients on unconsolidated material.*

The basin divide is not static. Differential crustal rebound has tilted the basin to the south, hence the northern tributaries have enlarged the basin toward the north, and the south edge of the basin tends to remain static because gradients are low.



BEDROCK GEOLOGIC MAP

EXPLANATION

Kinsman Quartz Monzonite (Dk) — Upper Devonian(?)

Granite, undifferentiated (Dgu) — *Includes Hardwick and Concord Granites and Spaulding Quartz Diorite*

Littleton Formation (Dll, Dlu) — Lower Devonian

Fitch Formation (Sf) — Middle Silurian

Clough Formation (Sc) — Lower Silurian

Paxton Quartz Schist (SOp)

Partridge Formation (Op) — Middle Ordovician

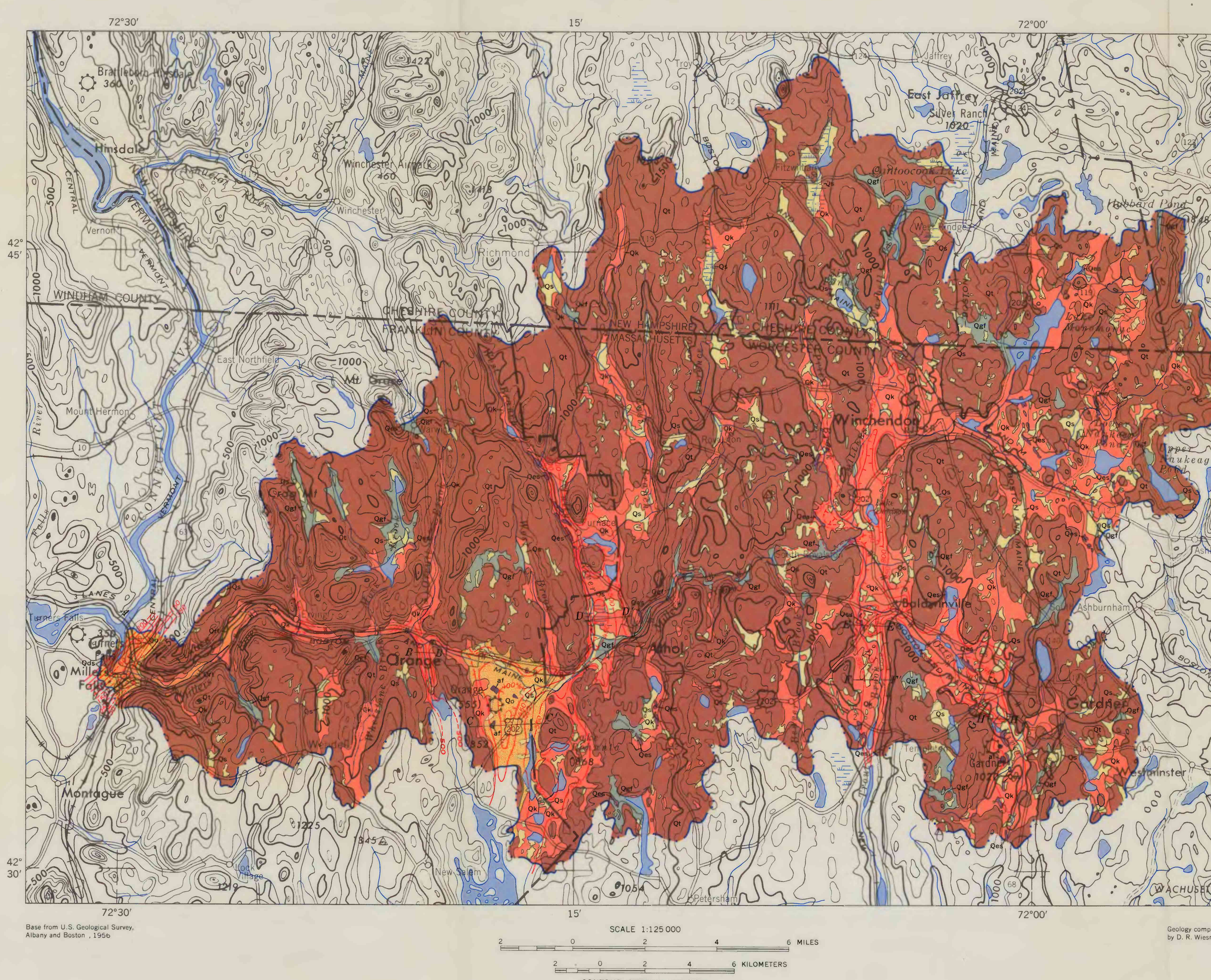
Ammonoosuc Volcanics (Oa)

Gneiss, undifferentiated (gn)

Contact; Fault (D, downthrown side; U, upthrown side); Basin boundary

SCALE 1:125 000. CONTOUR INTERVAL 100 FEET. DATUM IS MEAN SEA LEVEL

Base from U.S. Geological Survey, Albany and Boston, 1956



RECONNAISSANCE SURFICIAL GEOLOGIC MAP

EXPLANATION

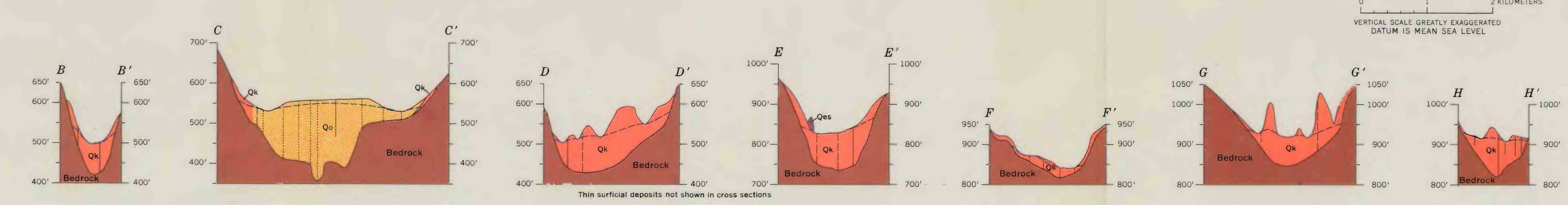
Recent: Artificial fill (af) — *Only large fills are shown*; Swamp deposits and alluvium (Qs) — *Chiefly muck and peat but includes alluvium*

Pleistocene: River-terrace deposits (Qrt) — *Sand, silt and gravel; includes flood-plain deposits and higher terraces along Millers River*; Eolian deposits (Qes) — *Chiefly dune sand in the Connecticut Valley*; Glacial-outwash deposits (Qo) — *Sand, silt, and clay; includes lake deposits in Orange Plains and delta deposits at mouth of Millers River*; Esker deposits (Qes); Undifferentiated glaciofluvial deposits (Qgf); Ice-contact deposits (Qk) — *Sand and gravel laid down in contact with glacial ice*; Glacial till (Qt) — *Consists of poorly sorted silt, sand, pebbles, and boulders*

Contact; Bedrock contour; Basin boundary

In cross sections: vertical solid lines are wells or borings; vertical dashed lines are wells or borings projected into line of section; vertical dotted lines are seismic shot points. The horizontal dashed (blue) lines represent the water table. While the general location of the sections is shown on the map the sections were prepared from maps at scale 1:24,000 so that details could be shown. Swamp deposits and artificial fill not shown on sections

Geology compiled and mapped by D. R. Wiesnet, 1956–67



SECTIONS. Thin surficial deposits not shown in cross sections. VERTICAL SCALE GREATLY EXAGGERATED. DATUM IS MEAN SEA LEVEL

WATER RESOURCES OF THE MILLERS RIVER BASIN, NORTH-CENTRAL MASSACHUSETTS AND SOUTHWESTERN NEW HAMPSHIRE

By
M. R. Collings, D. R. Wiesnet, and W. B. Fleck

1969

GROUND WATER

HYDROGEOLOGY

The water-favorability map shows those areas best suited for ground-water development, which, in general, are the areas of stratified glacial drift in the stream valleys (Surficial Geologic Map and Sections). The map is based on geologic mapping and on water-well and aquifer-test data generously supplied by the well drillers of the Commonwealth, local water superintendents, industrial concerns, and homeowners. (Wiesnet and Fleck, 1967.)

Ground water furnishes most of the rural inhabitants of the basin with their domestic supply. Water sufficient for domestic use is available almost everywhere in the basin. Areas where the ground water can be tapped for high yields are much more restricted. Even in favorable areas, well design is critical and should be carefully planned by competent engineers to achieve optimum yields of water. Table 1 lists the areas most likely to yield moderate to large amounts of ground water; hydrogeologic maps of several of these areas—Birch Hill, Otter River, Athol-Tully and Orange—are presented (figs. 2 and 3). The areas of greatest saturated thickness (fig. 3) are favorable for exploration. A thick saturated zone coupled with coarse deposits at depth is desirable for high-yield wells.

The yield of a well is the amount of water that can be pumped from the well. The specific capacity is the amount of water that is pumped per foot of drawdown of the water surface within the well.

The permeability of the aquifer is also a factor influencing well yield, and hydrologists find the term "transmissibility" useful. Transmissibility (T) is the rate of flow of water at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent (Theis, 1935).

The coefficient of storage, S, of an aquifer is the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. In water-table aquifers such as those found in the Millers River basin, the coefficient of storage is equal to the amount of water that will drain from the aquifer owing to gravity. This is sometimes called the gravity yield or specific yield of the aquifer.

Another factor that must be considered in aquifer yields and in individual well yields is the effect of induced recharge, that is, the water that will infiltrate into the ground from nearby lakes or rivers. All the existing municipal wells in the basin—Athol, Orange, and Templeton—derive some benefit from induced recharge.

The thickness and saturated-thickness data where taken from drillers' records, records of U.S. Geological Survey auger holes, or Department of Public Works highway and bridge boring records. A few wells in the Otter River area were not drilled to refusal (bedrock) and the thickness data were estimated on the basis of the bedrock contour shown on the Surficial Geologic Map.

Aquifer characteristics were determined from aquifer-test data supplied by drillers and/or towns except in the Orange area, where Stallman's method of numerical analysis of water levels was used to determine S and T (Stallman, 1956). No satisfactory pumping-test data were available from the Birch Hill area, the Orange area, the Priest Brook area, the Connecticut Valley area, the Winchendon Lower Naukeag area, and the Lake Monomonac area.

Although a network of 19 observation wells was installed for this study, the period 1965-66 was the latter part of the most prolonged drought in New England's history and the annual water-level change data (table 1) are undoubtedly not representative of normal conditions. (See figs. 4 and 5.)

Recharge is the volume of precipitation that reaches the zone of saturation in the ground. Under natural conditions, it is effectively equal to the discharge of the aquifer plus the change in subsurface storage.

Owing to our inability to measure underflow and ground water evapotranspiration, table 1 provides estimates rather than precise measurements of recharge. These estimates are based on the modification of a relationship determined by Randall and others (1966) in Connecticut, in which he determined that recharge to glacial stratified-drift aquifers during a year of normal precipitation was approximately 1 mgd per sq mi of the aquifer and somewhat less (0.43 mgd per sq mi) for areas of glacial till contiguous with the stratified drift.

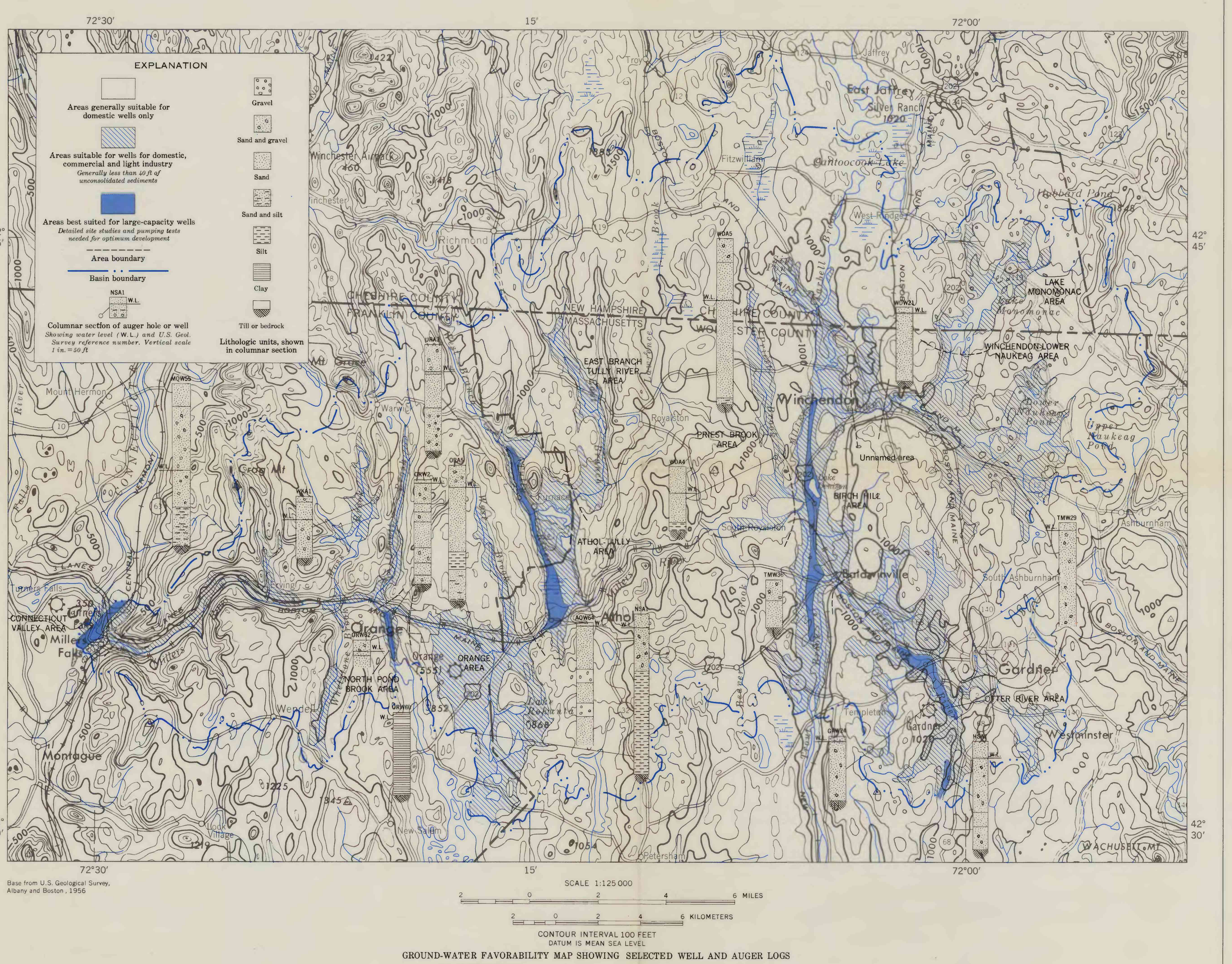
The potential water available in an aquifer over an extended period is equal to the average recharge, but perennial supply of ground water is assured by not exceeding the capabilities of storage. To partially overcome the effect of drought years a factor of 0.5 (0.5 times recharge) was introduced. The resulting sustained yield of the aquifer is a conservative estimate of the water that can be obtained, with adequate storage, from the ground-water reservoir without depleting it. If recharge from streams and lakes was the yield induced by pumping from adjacent wells, estimates should be increased by the amount of replenished water.

Bedrock

No attempt is made to assess the potential yields of bedrock. Ground water in rock travels through joints, faults and other openings in the rock, and the yields of individual wells are dependent on the number and size of fractures penetrated by the well. Only general guides can be provided for the location and construction of bedrock wells.

1. The number of fractures in bedrock decreases with depth.
2. Fractures are generally more abundant near tectonic features such as faults and folds.
3. Granite and gneiss tend to fracture parallel to their rounded hilltops, this is known as sheeting; where sheeting is prevalent bedrock well yields are higher.

The effect of lithology on well yield was investigated to determine whether some bedrock units were better aquifers than others. The results are shown on figure 6. Schist seems to be slightly more productive, but more importantly, the figure shows the typical low yield of the bedrock wells (see also fig. 7).



GROUND-WATER FAVORABILITY MAP SHOWING SELECTED WELL AND AUGER LOGS

EXPLANATION: Areas generally suitable for domestic wells only; Areas suitable for wells for domestic, commercial and light industry; Areas best suited for large-capacity wells; Area boundary; Basin boundary; Columnar section of auger hole or well; Lithologic units, shown in columnar section: Gravel, Sand and gravel, Sand, Sand and silt, Silt, Clay, Till or bedrock

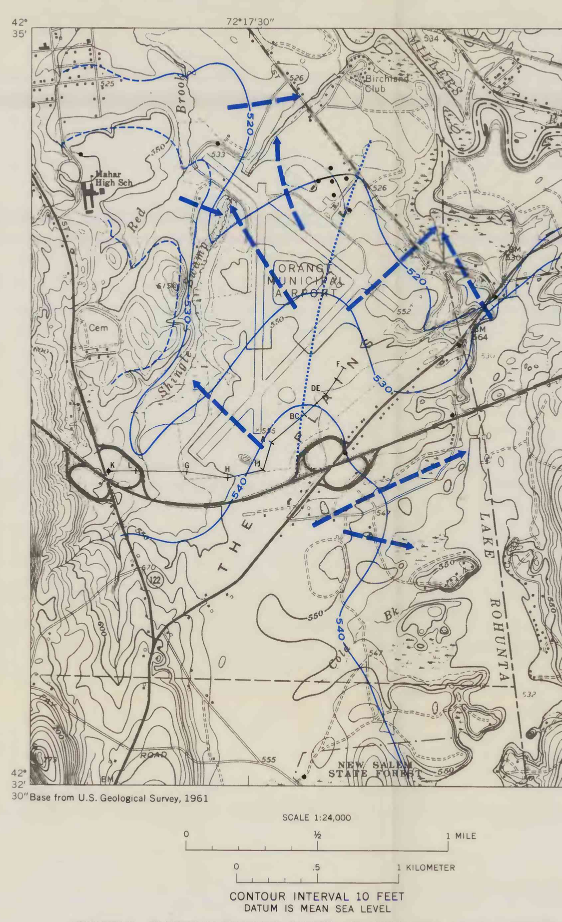


FIGURE 2.—WATER-TABLE MAP OF THE ORANGE AREA, MASSACHUSETTS

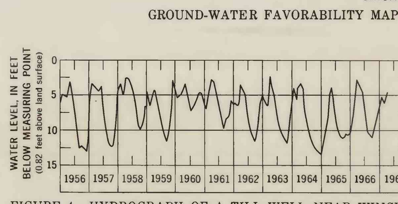


FIGURE 4.—HYDROGRAPH OF A TILL WELL NEAR WINCHENDON, MASS.

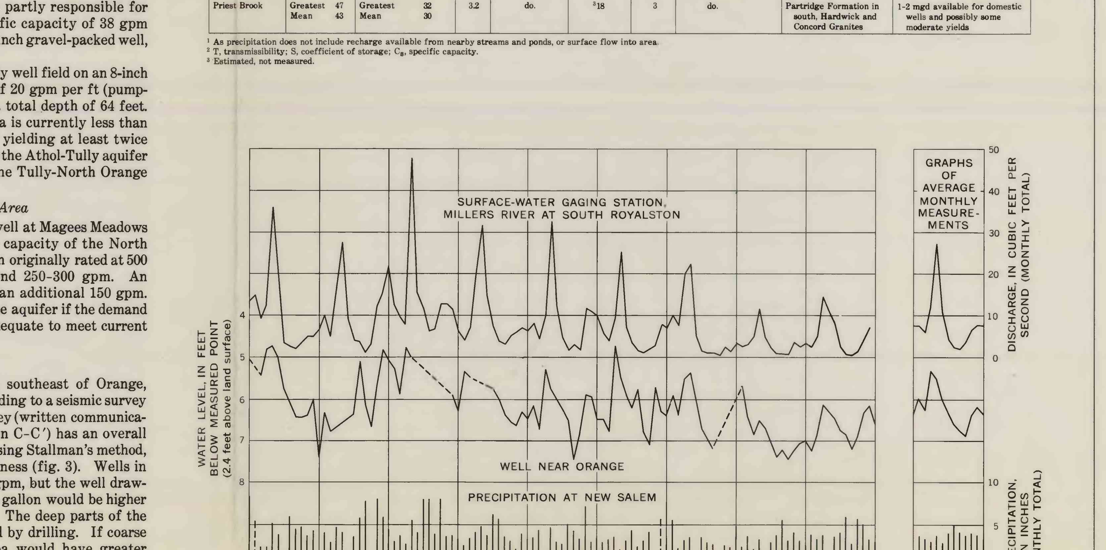


FIGURE 5.—GRAPH OF THE RIVER DISCHARGE, GROUND-WATER LEVELS, AND PRECIPITATION.

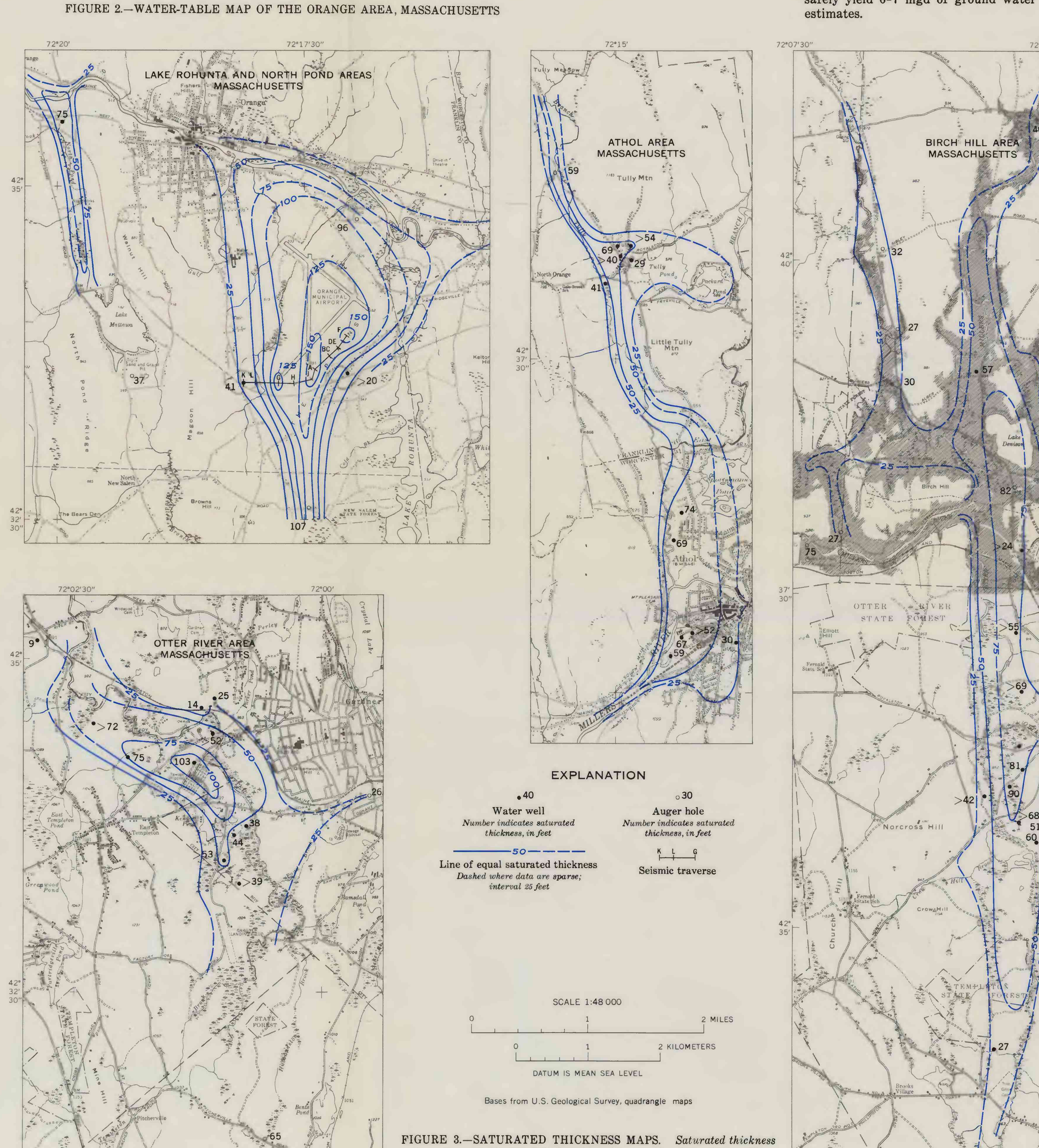


FIGURE 3.—SATURATED THICKNESS MAPS.

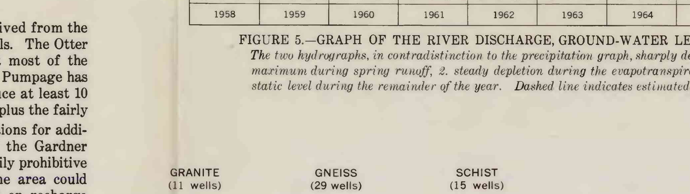


FIGURE 6.—HISTOGRAMS SHOWING RANGE IN WATER YIELD FROM WELLS LOCATED IN GRANITE, GNEISS, AND SCHIST.

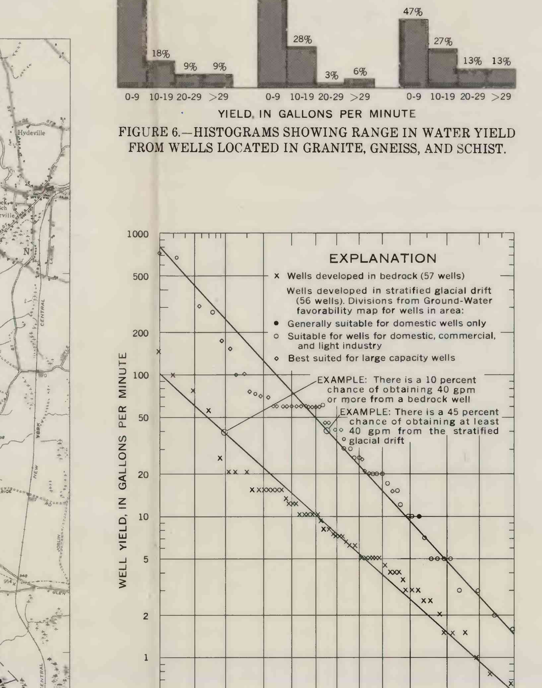


FIGURE 7.—GRAPH SHOWING PROBABILITY OF WELL YIELD.