HYDROGEOLOGIC APPRAISAL OF A STRATIFIED-DRIFT AQUIFER NEAR SMYRNA, CHENANGO COUNTY, NEW YORK

By Richard J. Reynolds and G. Allan Brown

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(in pocket)

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CONVERSION FACTORS AND ABBREVIATIONS

The following factors may be used to convert units of measurement in this report to the International System (SI) of units (metric system).

Multiply inch-pound unit	by	To obtain SI units
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.59	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
million gallons per day (Mgal/d)	3,785	cubic meters per day (m^3/d)
million gallons per day per square mile [(Mgal/d)/mi^2]	1,461.4	cubic meters per day per square kilometer [(m^3/d)/km^2]
gallons per day per square mile [(gal/d)/mi^2]	0.001462	cubic meters per day per squarer kilometer [(m^3/d)/km^2]
gallon per day per foot [(gal/d)/ft]	0.0001437	liter per second per meter [(L/s)/m]
	Hydraulic Units	
transmissivity, feet squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
hydraulic conductivity, feet per day (ft/d)	0.3048	meter per day (m/d)

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ABSTRACT

A broad, Y-shaped valley near Smyrna, Chenango County, N.Y., contains extensive water-table and confined aquifers that are, to a large extent, hydraulically separated from the nearby Chenango River to the east. Accordingly, ground-water pumpage from this valley would not appreciably decrease streamflow in the Chenango River by induced infiltration and could, therefore, be used for several specialized needs, such as a regional supply or as a year-round supply of cooling water.

The aquifers in the valley are capable of sustaining a long-term total withdrawal of about 12.8 million gallons per day during a prolonged drought similar to that which affected most of the Northeast in the mid-1960's. Larger withdrawals could be made on a short-term basis or during periods of normal or above-normal precipitation.

Saturated thickness of undifferentiated stratified-drift deposits in the valley range from 20 feet in the northwestern part of the valley to more than 300 feet at its southern terminus. A pumping-test analysis indicated that the coarser fraction of the extensive kame terraces flanking the valley has a hydraulic conductivity of approximately 245 feet per day. This value cannot be applied to the aquifer system as a whole, however, because of the highly variable lithology of the various units within the system.

Recharge to the valley from precipitation, streams, and runoff from adjacent hillsides, as well as storage in the aquifers, were estimated by a method that applies regional recharge rates to the dimensions of the specific aquifers. Direct areal recharge accounts for approximately 56 percent of the total recharge to the valley, infiltration from streams accounts for 24 percent, and runoff from till-mantled hillsides accounts for 20 percent. Together, the water-table and confined aquifers within the valley are conservatively estimated to hold 19.6 billion gallons of usable ground water in storage.

INTRODUCTION

A proposal prepared by the Susquehanna River Basin Commision (SRBC) in 1977 called for a basinwide ground-water study to define the base flow of major streams, aquifer locations, aquifer potential, and interaction between surface water and ground water. The results of such a study would aid in evaluating the potential for economic development, in resolving conflicts over allocation of water supply from all sources, and in resolving conflicts among competing land uses that stem from growth pressure. One of the primary concerns to SRBC is the extent to which large ground-water withdrawals from aquifers will affect streamflow within the basin.

The only aquifers within the Susquehanna River basin in New York that are capable of yielding more than a few tens of gallons per minute to individual wells are sand and gravel aquifers within valley-floor deposits of stratified drift. Because most of these aquifers are in hydraulic contact with major rivers, large ground-water withdrawals can be expected to cause comparable reductions in streamflow by induced infiltration after several weeks of pumping. However, several broad valleys in the New York part of the basin are known or suspected to contain extensive aquifers that are largely separated from nearby rivers by ridges of till or bedrock. These "separated valleys" deserve special attention in water-resources planning because they can be treated as ground-water storage reservoirs from which large withdrawals could be made during seasonal low-flow periods with only a minimal short-term effect on flow in nearby rivers.

From 1979 through 1982, several studies were done by the U.S. Geological Survey in cooperation with the Susquehanna River Basin Commission (SRBC) as part of the basinwide ground-water investigation program administered by SRBC. Three related investigations in New York were conducted by the U.S. Geological Survey, the SRBC, and signatory State agencies and were financed on a cost-share basis with Federal funds made available by the Water Resources Council.

Location and Extent of Study Area

One separated valley containing a productive aquifer system is the Y-shaped valley within the Chenango River basin near Smyrna, in the north-central part of Chenango County (fig. 1). The aquifer area encompasses the towns of Smyrna, Sherburne, and North Norwich and has an area of about 7 mi^2. The valley is comparable in width and depth to the nearby Chenango River valley but is drained only by small streams and is separated from the Chenango valley by bedrock hills except at the three valley outlets--northeast of Smyrna, southwest of Sherburne, and at North Norwich (fig. 1). The surrounding bedrock hills rise to a maximum of 700 feet above the valley floor.

Purpose and Scope

The purpose of this study was to investigate the hydrogeology of the separated valley at Smyrna and to characterize its potential as a ground-water source. A program of well inventory and test drilling, conducted during 1979-81, was designed to provide subsurface geologic information concerning the extent of stratified-drift aquifers in the valley. Water-level measurements taken in private wells in 1980 provided information on the water-table configuration and the general direction of ground-water flow in the valley.

This report describes the hydrogeologic framework of the separated aquifer system at Smyrna, presents estimates of well and aquifer yields, and proposes aquifer-management alternatives. It includes maps of the water-table altitude; bedrock-surface altitude; surficial geology; location, type, and saturated thickness of stratified drift; and locations of wells, springs, and test borings.

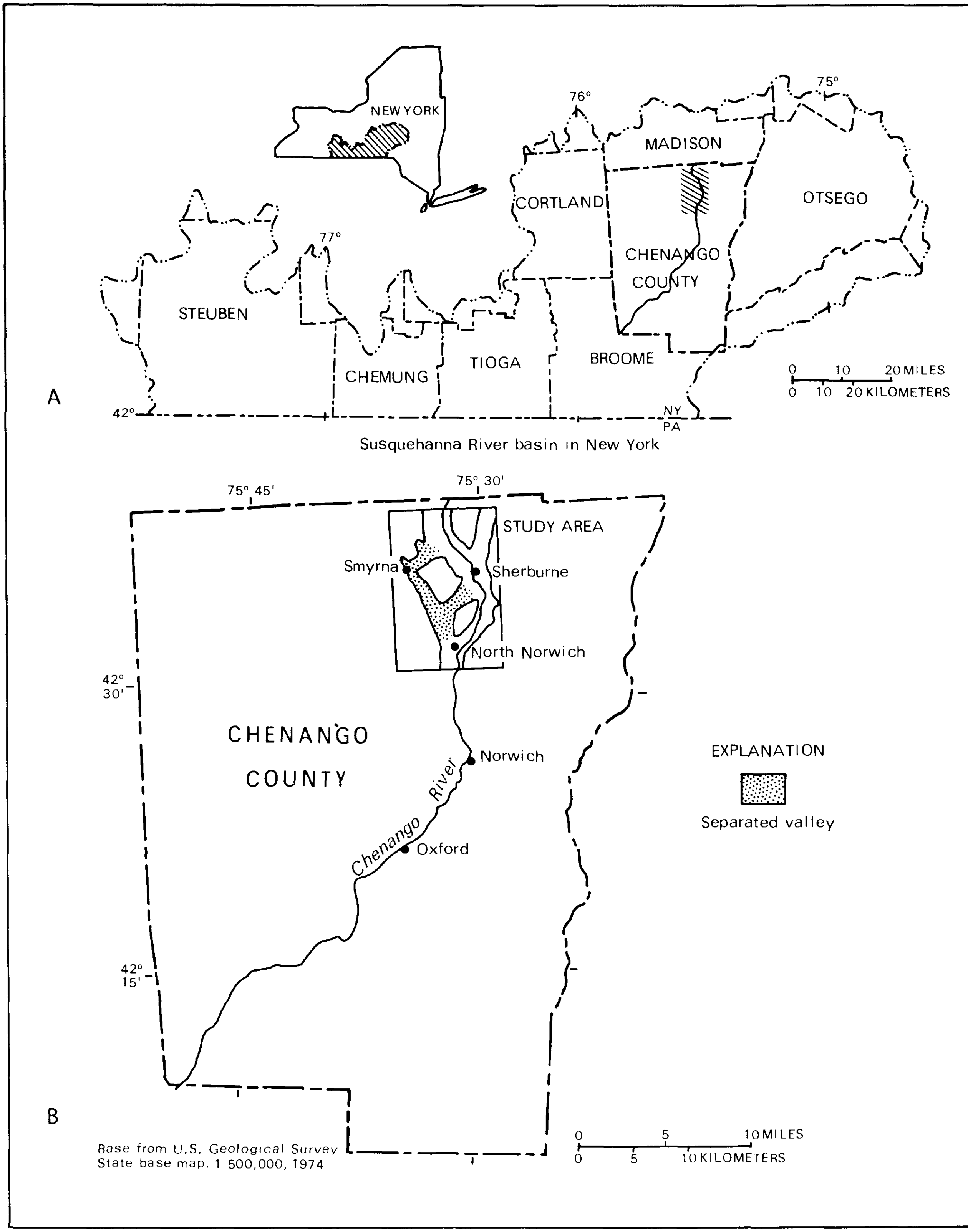


Figure 1.--A. Location of Chenango County within the Susquehanna River basin.
B. Location of separated valley at Smyrna.
(Detailed maps of separated valley are given in plates 1-6.

Well-inventory and water-level measurements provided most of the data. Test holes were drilled to further define the thickness of stratified drift and to determine the presence and extent of major buried aquifers. Seismic-refraction studies were conducted across the east and west limbs of the valley to yield information on their cross-sectional shapes and relative depths. Estimates of aquifer yield and average annual recharge were calculated through a regionalized method applied to the valley dimensions.

Methods of Investigation

Hydrogeologic investigation of the Smyrna separated valley consisted primarily of a complete well inventory in 1980. Hydrogeologic information on ~~150~~ 105 wells was obtained and is listed in appendix I. Locations of these wells are shown on plate 1; selected statistics on these wells are given in table 3. The well inventory entailed visiting each well site, interviewing each owner to obtain as much information as possible about the well, supplementing and verifying the information by comparison with the driller's records, where possible, and measuring the depth to water in accessible wells.

Test drilling was done from September 1980 through January 1981 to supplement the available data. Six test holes were drilled--two with a U.S. Geological Survey-owned auger rig and four with a cable-tool rig provided by a private contractor. Four of the test holes went to bedrock, and a 6-inch-diameter observation well was installed in one of the remaining two holes for incorporation into the U.S. Geological Survey's Statewide observation-well network. The logs of these and several other test holes are given in appendix II.

To obtain additional information about the geometry of the east and west limbs of the valley, two seismic-refraction lines were run in November 1980 with equipment and personnel provided by the New York State Department of Environmental Conservation. The data were interpreted through a modeling technique developed by Scott and others (1972) in which a digital computer is used to generate a two-dimensional model representing a layered-earth depth interpretation. The interpreted seismic-refraction profiles are given in appendix III; with a short explanation of the method. The data from test drilling and seismic lines were used as the basis for the geologic and water-table maps (pls. 2, 4-6) as well as the geologic sections (figs. 2A-2C).

GLACIAL GEOLOGY

Bedrock Topography

The valley configuration at Smyrna reflects the flowpaths of a preglacial drainage system. During the Wisconsinan glaciation, tongues of glacial ice occupied all three limbs of the valley as well as the Chenango River valley to the east (fig. 1). These ice tongues further eroded the three limbs, forming overdeepened valleys and carving through the Devonian shales, siltstones, and sandstones of the Genesee Group (which form the surrounding bedrock hills) into the underlying Devonian shales and sandstones of the Hamilton Group (Fisher and others, 1970).

Bedrock erosion in the east and central limbs went substantially deeper than in the west limb (pl. 2). As indicated by the bedrock-surface map (pl. 2), the deepest point along the axis of the west limb is about 1,060 ft above sea level, whereas the deepest point of the east limb is 920 ft above sea level. Along the central limb, the bedrock surface slopes southward to an altitude of 740 ft above sea level at North Norwich, where it forms a hanging valley tributary to the Chenango valley, whose bedrock surface is approximately 80 ft lower. This would seem to indicate that ice movement was greater in the main stem of the Chenango River valley than in the limbs of the separated valley and was greater in the east and central limbs of the separated valley than in the west limb.

Glacial erosion generally tends to reshape valleys into a semicircular or U-shaped cross section (Flint, 1970). Although this is true of the east and west limbs, available well data suggest that the oversteepened central limb is more parabolic in cross section, as seen in section C-C' (fig. 2C). Two seismic-refraction profiles (appendix III) across the west and east limbs reveal many small longitudinal ridges and valleys, approximately 20 to 40 ft in relief, superimposed on the general U-shape. These suggest either that the ridges consist of more resistant bedrock or that the rock was scoured along the edges of tunnels that commonly formed at the base of a glacier. Geologic section A-A' (fig. 2A) shows the longitudinal bedrock profile from Smyrna to North Norwich with the prominent hanging valley where the central limb intersects the Chenango River valley. Figure 2B shows the longitudinal profile along the east limb; figure 2C shows the oversteepened, parabolic shape of the central limb.

Geomorphology of Stratified Drift

The glaciofluvial features in the Smyrna area reflect the manner in which the area was deglaciated (Cadwell, 1972). Stratified drift associated with valley glaciers may be deposited in a variety of distinct landforms, as described below. The composition, location, and thickness of several types of stratified drift are described and illustrated in figures 3 and 4; their areal distribution is shown in figure 5.

Kame Terraces and Kame Deltas

Perhaps the most abundant glaciofluvial features in the separated valley at Smyrna are the kame terraces and kame deltas, which together constitute approximately 48 percent of the stratified drift exposed at land surface.

Kame terraces.--These features consist of stratified drift that was deposited by meltwater streams flowing between the side of a glacier and the valley walls. When the ice melted, these deposits were left as flat-topped, irregularly shaped terraces along the valley walls (fig. 3).

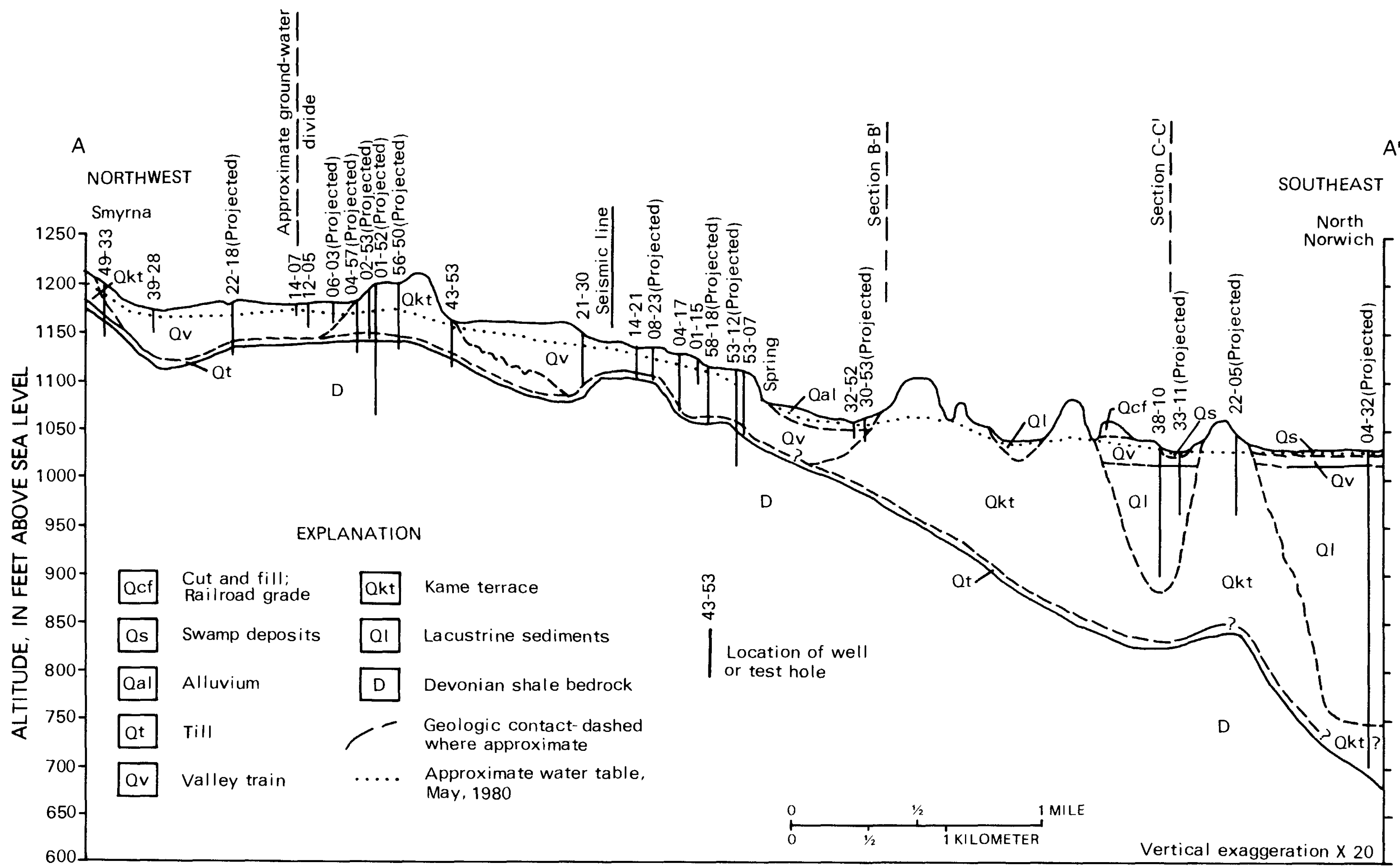


Figure 2A.--Geologic section A-A' along west and central limbs of the valley. (Location of section is shown in plate 1.)

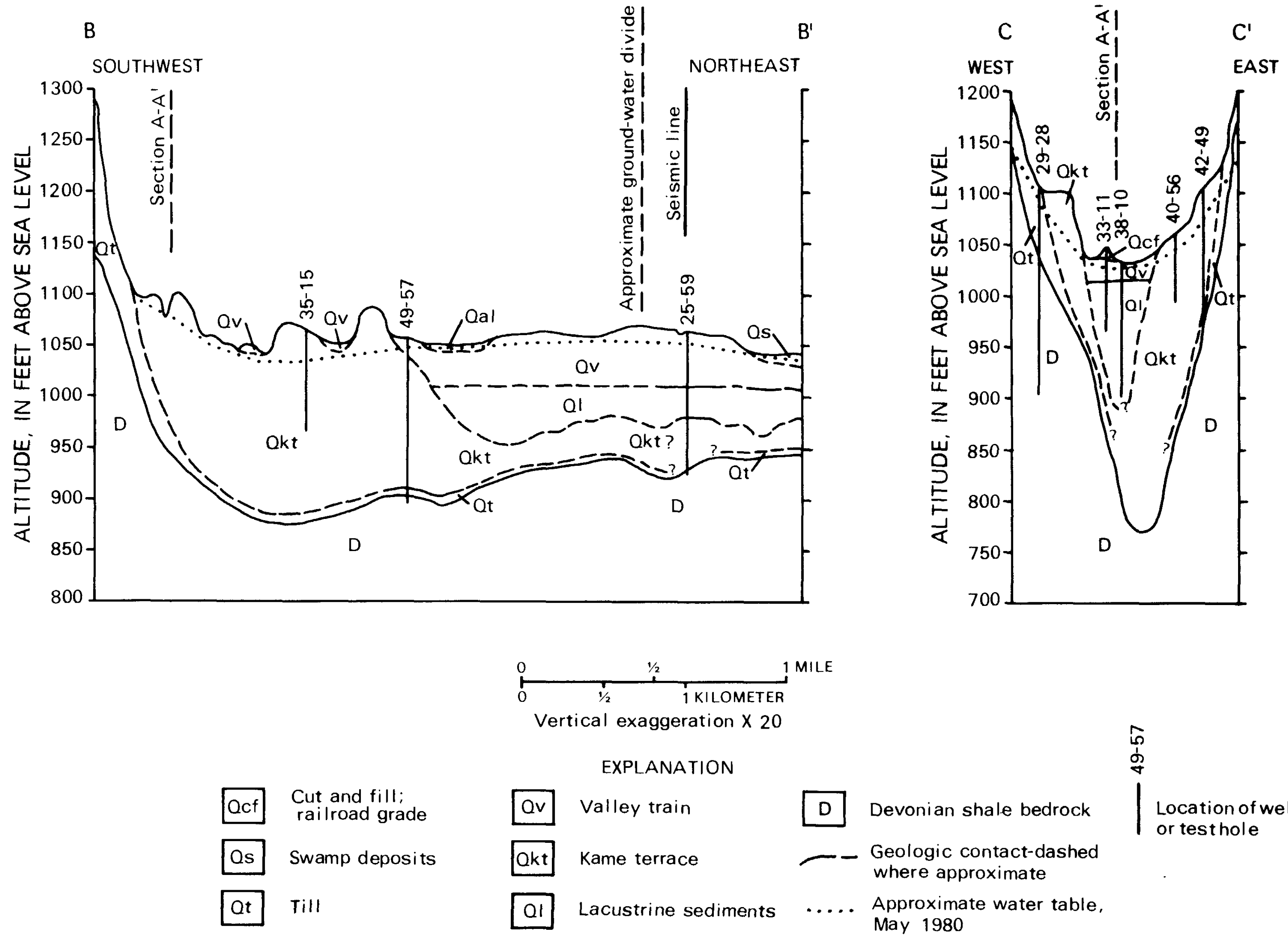


Figure 2B.--*Geologic section B-B' along east limb of the valley. (Location of section is shown in plate 1.)*

Figure 2C.--*Geologic section C-C' across central limb near North Norwich. (Location of section is shown in plate 1.)*

Kame terraces commonly occur in pairs along both sides of the valley and may extend locally into the center of the valley from both sides to form a "plug." Such a plug is visible near the junction of the east and west limbs (pl. 3). The kame terraces flanking the Smyrna valley range in width from 200 to 2,000 ft and in height from 60 to 100 ft above the present valley floor. Cadwell (1972) notes that the kame terrace occupying the west side of the western and central limbs, from Smyrna to just south of North Norwich, is the longest in the Chenango River basin. This terrace is more than 5 mi long and has a maximum width of 2,000 ft and a southward gradient of 32 ft/mi.

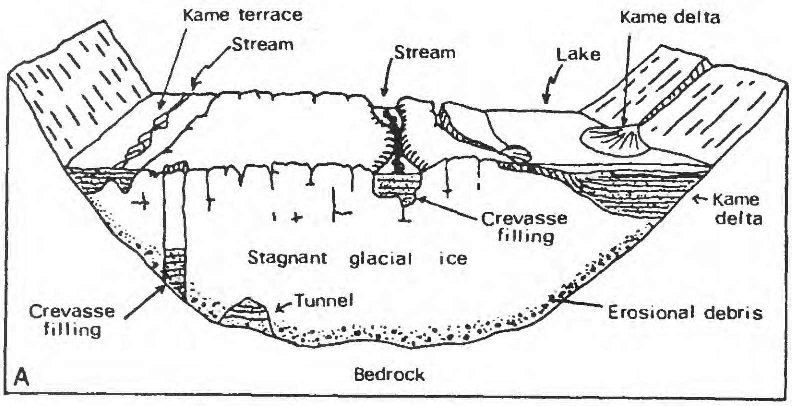
The kame terraces in the separated valley are characteristically heterogeneous, consisting of interbedded, poorly sorted silty sand and gravel, cobbles, silt, and clay layers, and having abrupt bedding contacts and bed thicknesses generally ranging from 0.5 to 2 ft. These beds are commonly warped or faulted near the former ice contact as a result of collapse when the ice that originally supported them melted.

The extreme variability in composition of kame terraces is related to the manner in which the sediment was deposited. Streams bordering an ice tongue deposited fine-grained material during periods of slow ice melting and deposited coarse-grained to cobble-size material during periods of rapid melting; thus the seasonal alternation formed a repeating, distinctly bedded structure visible in figure 4. The highly varied composition of kame terraces makes difficult the analysis of pumping-test data from a well screened in this type of material. (See pumping-test analysis in appendix IV.)

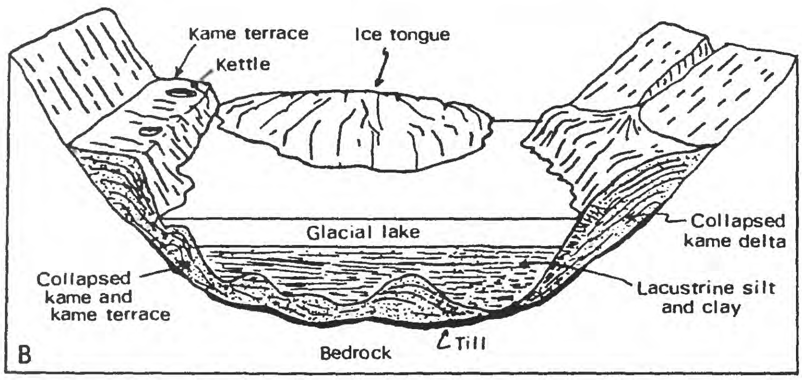
Many kame terraces have collapsed components extending from the surface exposure toward the center of the valley and to bedrock at depth (fig. 3B and 3C). This material was originally deposited in thin sheets and in hollows on the ice surface, but when the ice melted, the material collapsed to form partly stratified kames on the bedrock surface (fig. 3B). One purpose of the test drilling in this study was to determine whether collapsed kame-terrace deposits now buried beneath later lacustrine and outwash deposits on the valley floor are extensive. Both test-drilling and well-inventory data indicate a substantial thickness of collapsed and buried kame-terrace material along the valley limbs (figs. 2, 3; pl. 5).

The western limb south of the village of Smyrna contains an extensive kame-terrace deposit overlain by outwash and alluvium (fig. 5). Together these sediments form a single water-table aquifer averaging 60 ft in thickness (fig. 2A). The eastern limb also contains an extensive deposit of collapsed kame-terrace material but is overlain by lacustrine silt and thus forms a confined aquifer (fig. 2B). This confined aquifer is estimated to range from 30 to 50 ft in thickness on the basis of data from test hole 25-59 (pl. 1). The central limb contains mostly collapsed kame-terrace material; in the northern part this material averages 140 ft in thickness and is overlain by swamp deposits. In the southern part, near North Norwich, it is overlain by a thick section of lacustrine silt and clay and thus forms a confined aquifer 40 ft thick. This lacustrine silt and clay is in turn overlain by a veneer of outwash (figs. 2A-2C).

Tongues of glacial ice extend southward down broad valleys a few miles ahead of the main ice sheet. As the ice thins during deglaciation, the tongues may stagnate (cease to flow) and provide temporary support for sediments deposited by meltwater streams. (Modified from Flint, 1971.)



As the ice tongue continues to recede, the previously deposited sediments lose their support and partly collapse. A lake may form between the receding ice and older deposits downvalley, allowing lacustrine silt and clay deposits to accumulate.



Typical postglacial geomorphology and stratigraphy of most glaciated valleys within the Susquehanna River basin. (Modified from Flint, 1971.)

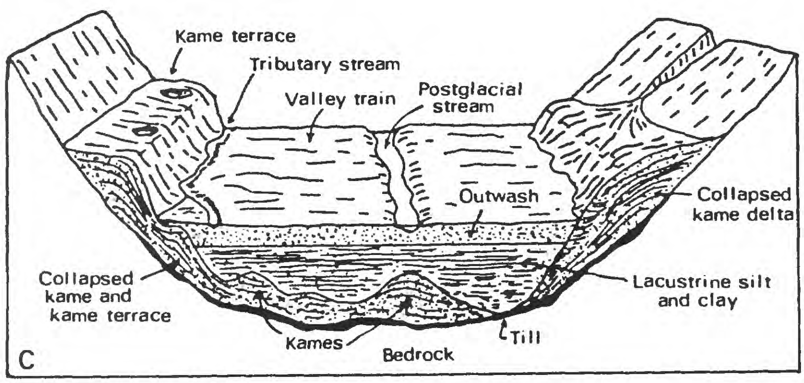


Figure 3.--Origin of typical stratified-drift features within the Susquehanna River basin.

Figure 4.--Section of kame terrace exposed in gravel pit 1.75 miles north of North Norwich showing the extreme variability in grain size and ice-contact warping of beds.

Kame deltas.--These features are found in two locations in the valley--one at the village of Smyrna, the other on the east side of the east limb (pl. 3). Kame deltas are ice-contact depositional features similar to kame terraces except that they were deposited in standing water by individual meltwater streams. Kame deltas were deposited either outward from the ice or inward against the ice (Flint, 1971) and, as the supporting ice melted, they partly collapsed to form irregular mounds or fan-shaped structures. Their steeply dipping foreset beds distinguish them from kame terraces, kames, and other ice-contact depositional features.

Lacustrine Deposits

These sediments, which consist of interbedded fine sand, silt, and clay, were deposited in lakes that developed between older sediment deposits down-valley and the retreating ice front. Meltwater streams carrying a mixture of gravel, sand, silt, and clay under high velocity deposited the coarser fraction of their sediment loads at the edge of these lakes to form kame deltas and carried the lighter fraction, consisting of silt and clay, further into the lake, where it gradually settled out to become bottom sediment. A thick section (approximately 265 ft) of lacustrine silt and clay underlies the southern part of the central limb near North Norwich (figs. 2C, 5), and a much thinner section, about 35 ft thick, underlies much of the east limb (figs. 2B, 5). A thin, narrow tongue of lacustrine sand and silt also underlies the west limb northeast of Smyrna (fig. 5, pl. 5).

Valley-Train Deposits

This type of material, a form of outwash deposit, consists of generally well-sorted sand and gravel but is typically much less silty than kame-terrace or kame-delta material. In the west limb, valley-train deposits form the bulk of the valley-floor sediments and are thicker than in the other limbs. Here they range from 50 to 70 ft thick and overlie collapsed kame-terrace material. In the eastern part of the east limb, valley-train deposits average about 40 ft in thickness and overlie lacustrine sediments, whereas toward the junction of the east and west limbs, they overlie collapsed kame deposits (pls. 3, 5).

Postglacial Alluvial Deposits

These sediments, which consist of sand and gravel overlain by silty fine sand, were deposited by modern drainage systems. They commonly overlie valley-train deposits along the valley floors and seldom exceed a few feet in thickness (pls. 3, 5).

Swamp Deposits

After the flow of meltwater ceased, organic matter accumulated in low-lying areas to form silt, peat, and organic muck deposits. Today such deposits are found between high kame terraces in the central and east limbs. The thickness of these deposits is unknown but may reach a few tens of feet, particularly in the central limb (pls. 3, 5).

Deglaciation Chronology

An understanding of the deglaciation history of this area is fundamental to interpreting the stratigraphy and geomorphology in relation to ground-water availability. Deglaciation in the Smyrna area, as in all of the Chenango valley, progressed in stages and resulted in the formation of various geomorphologic structures at successive ice-front locations (fig. 5).

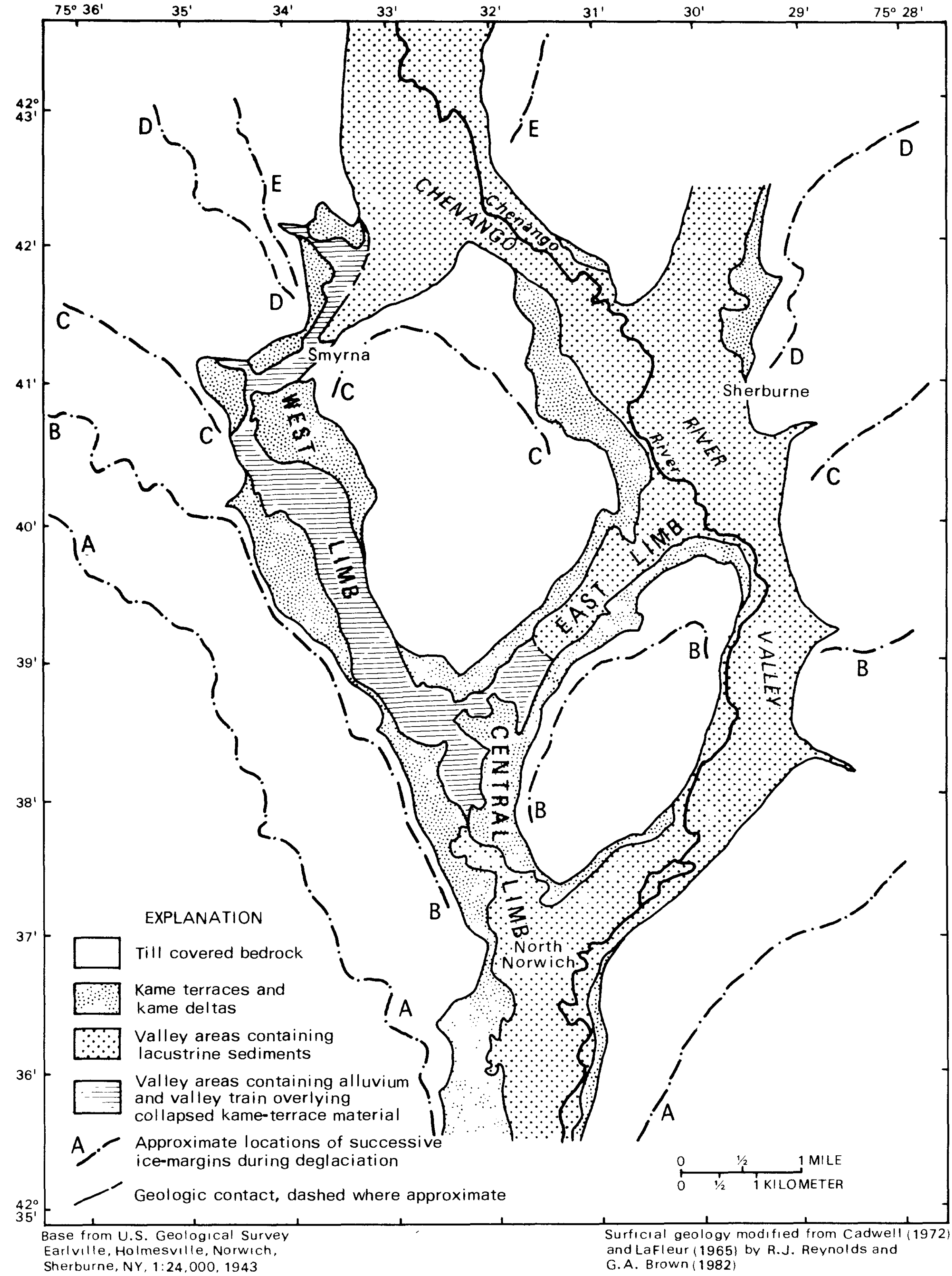


Figure 5.--Areal distribution of kame terraces, lacustrine sediments, alluvium, and valley train, and probable location of temporary ice margins.

During retreat of the ice margin northward through the study area, a "valley plug" of stratified sand, gravel, and till blocked the Chenango River valley about 20 mi south of Smyrna, near Oxford, creating a large temporary lake between the plug and the retreating ice front (Cadwell, 1972). A thick sequence of lacustrine silt and clay that was deposited as bottom sediment in this lake remains in the Chenango River valley at Norwich and in the central and east limbs of the separated valley.

As the ice front receded northward through the area from margin A to margin B (fig. 5), the terminus of the glacier was approximately at Norwich, 6 mi south of the area. Meltwater flowing between the ice tongue and the valley walls deposited kame terraces between Norwich and North Norwich, as depicted in figure 3A (Cadwell, 1972). As the ice receded from margin B to margin C, meltwater was flowing primarily in the west limb and produced the large kame terrace on the west edge of the valley. After the ice reached margin C, however, most of the meltwater began to flow southward through the east limb, creating the kame terrace there while depositing valley train along the west limb. During this period, ice still remained in the main Chenango valley to the east (Cadwell, 1972).

As the ice retreated north from margin C, the ice tongue of the Chenango valley, which was thicker than that occupying the separated valley, provided meltwater and sediment to the lake between the ice front and the valley plug 20 mi to the south at Oxford (fig. 3B). Present topography at the site of the valley plug suggests that the controlling elevation for the lake surface was 1,080 ft. The lake extended north from this point up the Chenango valley and into the southern part of the central limb, where it may have occupied the ice-block depression that is now a swamp (pls. 3, 5). The lake also extended southwestward from the main Chenango valley into the east limb and occupied the area between the kame terraces. The approximate area occupied by the lake is indicated by the distribution of lacustrine deposits within the study area (fig. 5).

At North Norwich, the sequence of lacustrine silt, sand, and clay occupying the Chenango valley is relatively thick, approximately 265 ft (fig. 2A), but in the east limb of the separated valley (fig. 2B) it is comparatively thin, approximately 35 ft. The lacustrine deposits in the east limb probably formed during the same depositional period as those in the central limb because the upper contact with the overlying outwash in both areas is at the same altitude, 1,010 ft above sea level (figs. 2A, 2B). In the west limb, where the lake was mostly shallow, little if any silt and clay was deposited over the early kame-terrace deposits, but after the meltwater shifted its course from the west limb to the east limb, lacustrine sand and silt accumulated northeast of Smyrna to altitudes as high as 1,110 ft. Today they are overlain by approximately 20 ft of valley train and postglacial alluvium.

After the ice front had receded well north of the separated valley, the temporary glacial lake drained southward by breaching the valley plug at Oxford. Subsequently, glacial meltwater from the distant ice front flowed through the Chenango River valley east of the separated valley and deposited a veneer of outwash throughout its course.

GROUND WATER

Ground-water availability in valley aquifers similar to those in the study area is determined by such factors as (1) hydraulic characteristics of the aquifers, (2) their saturated thickness, (3) whether the aquifers are under water-table or confined (artesian) conditions, (4) the presence of nearby surface-water bodies that may contribute recharge, (5) the amount, sources, and areal distribution of annual recharge, and (6) in part by the three-dimensional ground-water flow within the aquifer system. In addition, proper well construction can prove to be the most important factor in determining the potential yield of a well.

Sources of Recharge

Sources of recharge to the aquifers in the separated valley consist primarily of (1) direct areal recharge from precipitation, (2) overland runoff from adjacent till-covered bedrock hillsides, and (3) infiltration from streams draining the adjacent uplands and crossing kame terraces and valley-bottom deposits. Leakage to the confined aquifers under pumping conditions through the overlying lacustrine material and from the underlying bedrock, although small, provides additional recharge. The quantity of recharge from these sources is summarized in table 1.

Direct Precipitation

The Smyrna area receives an average of 40 inches of precipitation per year (Ku and others, 1975); a regional water-budget analysis by Ku and others (1975) indicates that annual runoff in this locality averages 21 inches. MacNish and Randall (1982) considered that recharge to surficial stratified drift could be estimated conservatively as equal to basinwide average runoff, having observed that most runoff in stratified-drift areas infiltrates into the ground. Actually, recharge to the water table exceeds runoff from most areas of stratified drift because some of the ground water is lost to the atmosphere by evapotranspiration in areas where the water table is at or near land surface, such as near swamps and streams.

Ground-water evapotranspiration has been estimated to constitute 21 percent of total evapotranspiration in parts of Pennsylvania and Connecticut (Olmsted and Hely, 1962; Randall and others, 1966). If the same is true of the Smyrna area, recharge from direct precipitation may be as great as 21 inches plus 4 inches, a total of 25 inches per year. If withdrawals from large-scale ground-water development were to lower the water table several feet below natural levels within the separated valley, ground-water evapotranspiration would be greatly reduced, and the amount of recharge available for ground-water development might approach 25 inches per year, which is equivalent to 1.2 (Mgal/d)/mi^2. This rate is used in subsequent calculations. Average annual direct recharge calculated for the Smyrna valley is given in table 1.

Table 1.--Summary of average annual recharge from local sources.

[Values are in million gallons per day.]

Area	Direct areal recharge	Leakage to confined aquifers from lacustrine material and bedrock	Runoff from adjacent hillsides	Infiltration from streams	Total average annual recharge	Percentage of total recharge
West limb, north half	2.15	0.03	0.79	1.96	4.93	33.1
south half	2.23	--	0.76	1.01	4.00	26.9
Central limb	2.08	0.02	0.68	.55	3.33	22.4
East limb	1.84	0.04	0.74	--	2.62	17.6
TOTAL	8.30	.09	2.97	3.52	14.88	100.0
Percentage of total recharge	55.8	0.6	20.0	23.6	100.0	

Runoff from Adjacent Uplands

Most stratified-drift aquifers within the Susquehanna River basin are bordered by till-covered bedrock hills. Because the till contains a large percentage of silt and clay (Ku and others, 1975), only a small amount of rainfall or snowmelt can infiltrate before runoff begins. In areas where the hills slope directly toward a stratified-drift aquifer rather than an upland stream, runoff from the hills infiltrates directly to the water table once it reaches the sand and gravel deposits in the valley.

The percentage of average annual recharge derived from hillside runoff is primarily a function of annual precipitation and the size of upland areas that slope directly toward the aquifer. Within the Susquehanna basin, the contributing upland area has been found to be closely correlated with the length of the aquifer along the valley axis (MacNish and Randall, 1982). In calculating recharge rates from upland runoff, an average runoff rate of 160,000 gal/d per mile of valley wall was used, as outlined in MacNish and Randall (1982). Table 1 includes average annual recharge from these adjacent hillsides.

Infiltration from Small Streams

Where the water level in a surficial aquifer is lower than that in a stream crossing the aquifer, the stream will lose water to the aquifer. This occurs in the Susquehanna River basin primarily where small streams enter major valleys (Ku and others, 1975). Recharge to valley aquifers from such streams, which flow from till uplands onto alluvial fans or valley-train deposits, can form a significant part of the total recharge to the aquifer.

Randall (1978) has shown that such streams begin to lose water rapidly downstream from the point at which the depth to underlying till or bedrock begins to increase, and that the rate of loss to the aquifer or alluvial fan is controlled principally by the hydraulic conductivity of these materials, not by the streambed itself.

A conservative loss rate estimated for small stream reaches such as those within the Susquehanna River basin is 650 gal/d per foot of stream reach (Randall, 1978). This rate applies only to the stream reach downstream from the point where the extension of the main valley bedrock wall crosses the stream (MacNish and Randall, 1982). Small streams such as these commonly lose some water upstream from this point, but at rates that are small compared to those in the downstream reach. Estimated recharge to each valley limb from stream infiltration is included in table 1.

This loss rate of 650 gal/d per foot of stream reach was applied to the four upland streams in the study area that are large enough to contribute significant recharge to the aquifers; estimates of average annual recharge from these streams, derived from procedures outlined by MacNish and Randall (1982), are given in table 2.

Table 2.--Selected data on four upland streams in the Smyrna valley.

[Stream locations shown on plates 1-6.]

Stream	Drainage area upstream from losing reach (mi^2)	Length of stream reach from which recharge can occur (ft)	Average annual recharge to aquifer from stream losses (Mgal/d)
Cold Spring Brook/ South Lebanon Creek	14.49	2000	1.08
Pleasant Brook	19.07	1500	.88
Crooked Brook	1.86	5880	1.01
Fly Creek	1.02	3900	.55
Total average annual recharge from streams			3.52

Leakage to Confined Aquifers Through Overlying Lacustrine Sediments

Where extensive lacustrine deposits lie within or above a body of stratified drift, the aquifers below cannot receive direct recharge from precipitation, storm runoff, or streambed infiltration but must be recharged by ground water from adjacent material. If confined aquifers are in contact with only lacustrine sediments, till, or bedrock, recharge to these aquifers will be limited by the low hydraulic conductivity of the surrounding material. If pumping from a confined unit lowers the potentiometric surface substantially below the water table in the overlying surficial aquifer, however, leakage through the overlying lacustrine sediments may be induced and would add some recharge to the confined aquifer.

MacNish and Randall (1982) suggest that the maximum potential annual leakage to confined aquifers from overlying deposits can be estimated by assuming a leakage rate of 60,000 $(gal/d)/mi^2$ of confined aquifer, which is the approximate rate at which water would flow through clayey silt under a steep hydraulic gradient. The small additional amount of recharge that would originate from the underlying bedrock under pumping conditions is included in this figure. Estimates of potential recharge from leakage to the confined aquifers in the Smyrna area are shown in table 1; procedures for estimating leakage are outlined by MacNish and Randall (1982). However, as indicated in the geologic sections (figs. 2B, 2C, and 7), the confined aquifers in the east and central limbs are hydraulically connected to the shallow surficial aquifer through kame terraces along both sides of the valley. Therefore, the yield of both the surficial and confined aquifers must be considered collectively because withdrawal of water from one will reduce the yield available from the other.

Table 1 shows that the primary source of recharge to the separated valley (55.8 percent) is direct areal recharge, with infiltration from streams the next largest (23.6 percent), and recharge from till hillsides the third largest (20 percent). Potential recharge to confined aquifers from the thick lacustrine materials and underlying bedrock in the area accounts for less than 1 percent of the total recharge. Of the total recharge to the separated valley, the west limb receives about 60 percent, and 33 percent of all recharge occurs in its northern part. This is because the west limb contains 54 percent of the total surface area of stratified drift as well as three of the four upland streams, two of which are in the northern part of the limb.

Ground-Water Discharge

Ground water is discharged from the Smyrna valley mainly by (1) seepage to small streams on the valley flat or to the Chenango River, (2) evapotranspiration, (3) ground-water flow from all three valley outlets to the Chenango River valley, and (4) ground-water pumpage. Much of the seepage to small streams probably occurs along Fly Creek, which drains the western and central limbs of the valley and is a tributary to the Chenango River.

The greatest amount of ground-water discharge probably occurs through evapotranspiration from swampy areas. All three valley limbs contain swampy depressions in which the water table is seasonally at or slightly above land surface. The largest of these is in the central limb and occupies a depression between two opposing kame terraces. These swampy areas in the central and east limbs (pls. 3, 5) serve as ground-water discharge areas or "sinks." During summer, a substantial amount of ground water is lost from these areas through evapotranspiration and, in turn, reduces the amount of ground water discharged from the valley outlets to the Chenango River valley. During winter, when evapotranspiration is practically zero, the ground-water flow out of the valleys increases proportionally.

Ground water from all three valley outlets occurs in both surficial water-table and buried confined aquifers. Most of the ground water that discharges from the surficial water-table aquifer eventually reaches the Chenango River as seepage. Ground water also leaves the valley through the confined aquifer to a hydraulically connected confined aquifer in the Chenango River valley.

Discharge from the system through ground-water pumpage is considered to be insignificant compared to the other losses because most pumpage in the valley is for domestic uses; thus, most of the water is returned to the aquifer system through septic tanks. Consumptive ground-water loss occurs only if the water is used to irrigate crops, where by some would be lost through evapotranspiration or discharged to streams as runoff.

Water-Table Configuration

The average water-table altitude in the separated valley near Smyrna is depicted in plate 4. The map is based primarily on water-level measurements made in wells during May 1980. Water-level records from three observation wells screened in Pleistocene sand and gravel deposits elsewhere in Chenango County and in adjacent Madison and Broome Counties indicate that ground-water levels in this region during May 1980 were slightly above average; therefore, the water-table configuration as shown in plate 4 probably represents ground-water levels which are slightly above the annual average.

Average depth to water ranges from approximately 140 ft in the kame terraces near Smyrna to less than 10 feet along the valley floor. The water-table altitude beneath the valley floor ranges from approximately 1,160 ft in the west limb just south of Smyrna to about 1,020 ft at North Norwich. This represents an average gradient of approximately 0.01, or about 52 ft/mi along the axis of the west limb.

Potentiometric Heads

The thick lacustrine silt and clay unit, up to 265 ft thick at the south end of the central limb and approximately 35 ft thick at the north end of the east limb, constitute large blocks of material of low hydraulic conductivity that inhibit recharge to the underlying kame deposits. This silt and clay unit does not span the entire valley at either location, however, and ground water is therefore able to move downward through the kame terraces along the valley sides to recharge the confined aquifer at and south of North Norwich.

Both the lacustrine materials and the confined aquifer extend southward out of the study area. Well records from Norwich, approximately 6 mi south of North Norwich, indicate a deep gravel aquifer confined beneath 100 to 250 ft of silt and clay (Randall, 1972), similar to the deep aquifer at North Norwich (figs. 2A and 2C) and quite possibly continuous with it. Potentiometric heads in confined units such as this are commonly 2 to 3 ft above the water table and are generally highest in areas flanked by kame terraces, which serve as recharge areas to the confined units. The generalized ground-water flow paths in a confined valley aquifer such as this are depicted in an idealized cross section in figure 6. At a U.S. Geological Survey test hole in the east limb, the potentiometric head in the confined aquifer is about 3 ft above the water table. Potentiometric heads in deep wells tapping the confined aquifer at Sherburne are much higher than those in adjacent shallow wells tapping the valley-train deposits (Randall, 1972), and furthermore, potentiometric heads in the bedrock along the valley axis are commonly higher than in wells screened in the overlying water-table aquifer. Water levels in the shallow, large-diameter dug well that serves as the municipal supply for the village of Smyrna are lower than those in a nearby bedrock well (appendix I, well 08-05), which indicates upward movement of water from the bedrock into the water-table aquifer. Upward gradients such as this cause water quality at the base of the overlying sand and gravel aquifer to be similar to that in the underlying shale bedrock. In this area, wells finished in sand and gravel a short distance above the shale bedrock commonly yield hydrogen sulfide gas--a characteristic of shale bedrock, particularly under heavy pumping conditions.

The west limb of the valley does not contain extensive lacustrine sediments, and the collapsed kame terraces and overlying valley train together form a single water-table aquifer, thus permitting recharge over the entire area of stratified drift. In contrast, the east and central limbs contain varying thicknesses of lacustrine material that inhibits direct recharge to the underlying sand and gravel; thus, most of the recharge to the confined, lower aquifer in these areas occurs through the kame terraces at the valley sides. These lateral recharge areas produce downward gradients at the valley sides and upward gradients near the valley axis, resulting in the generalized ground-water flow depicted in figure 6.

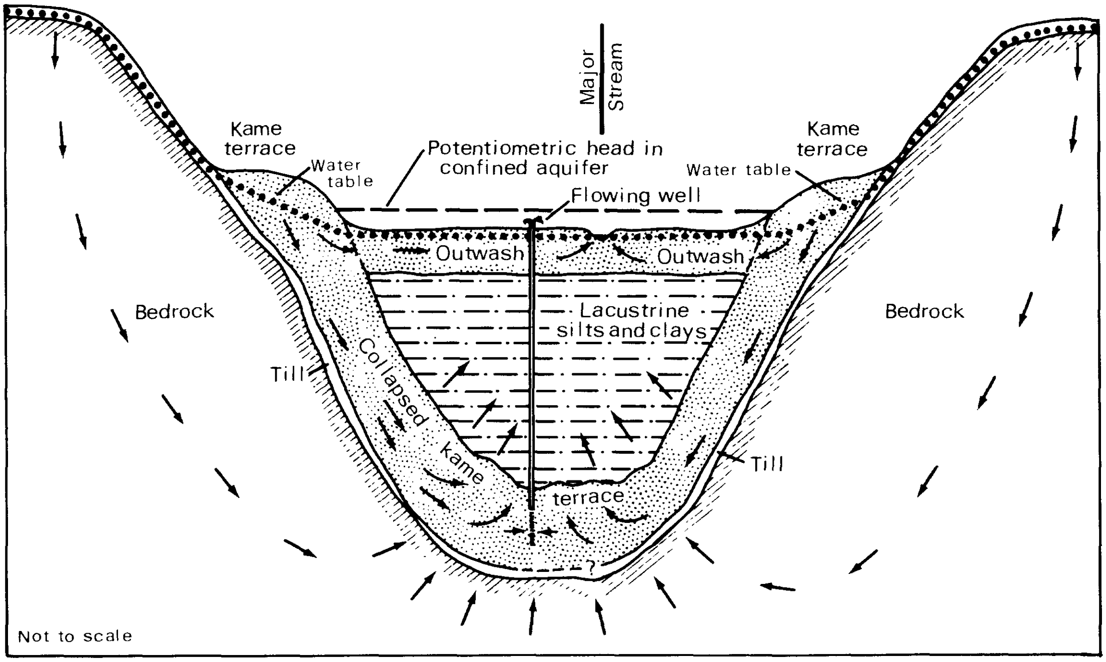


Figure 6.--Generalized hydrogeologic section showing ground-water flow paths in bedrock, water-table aquifer, and confined stratified-drift aquifer in a bedrock valley containing lacustrine deposits.

Ground-Water Movement

In valley aquifer systems such as this, ground water moves predominantly toward streams under a steep cross-valley gradient, with a lesser component of flow downvalley. Both downvalley and crossvalley gradients are largely controlled by the streambed gradient and local variations in recharge, saturated thickness, and aquifer permeability. The general directions of ground-water flow in the separated valley are shown in figure 7.

The west limb aquifer, which is generally more permeable than that in the east limb, has variations in saturated thickness (pl. 6) as a result of the undulating bedrock surface (pl. 2). The west limb displays steeper downvalley water-table gradients on the upvalley side of shallow bedrock shelves as a result of decreasing transmissivity in these areas (pl. 4). In contrast, the shallow surficial aquifer in the east limb has a relatively uniform saturated thickness as a result of the nearly flat underlying lacustrine sediments and thus displays more uniform downvalley gradients.

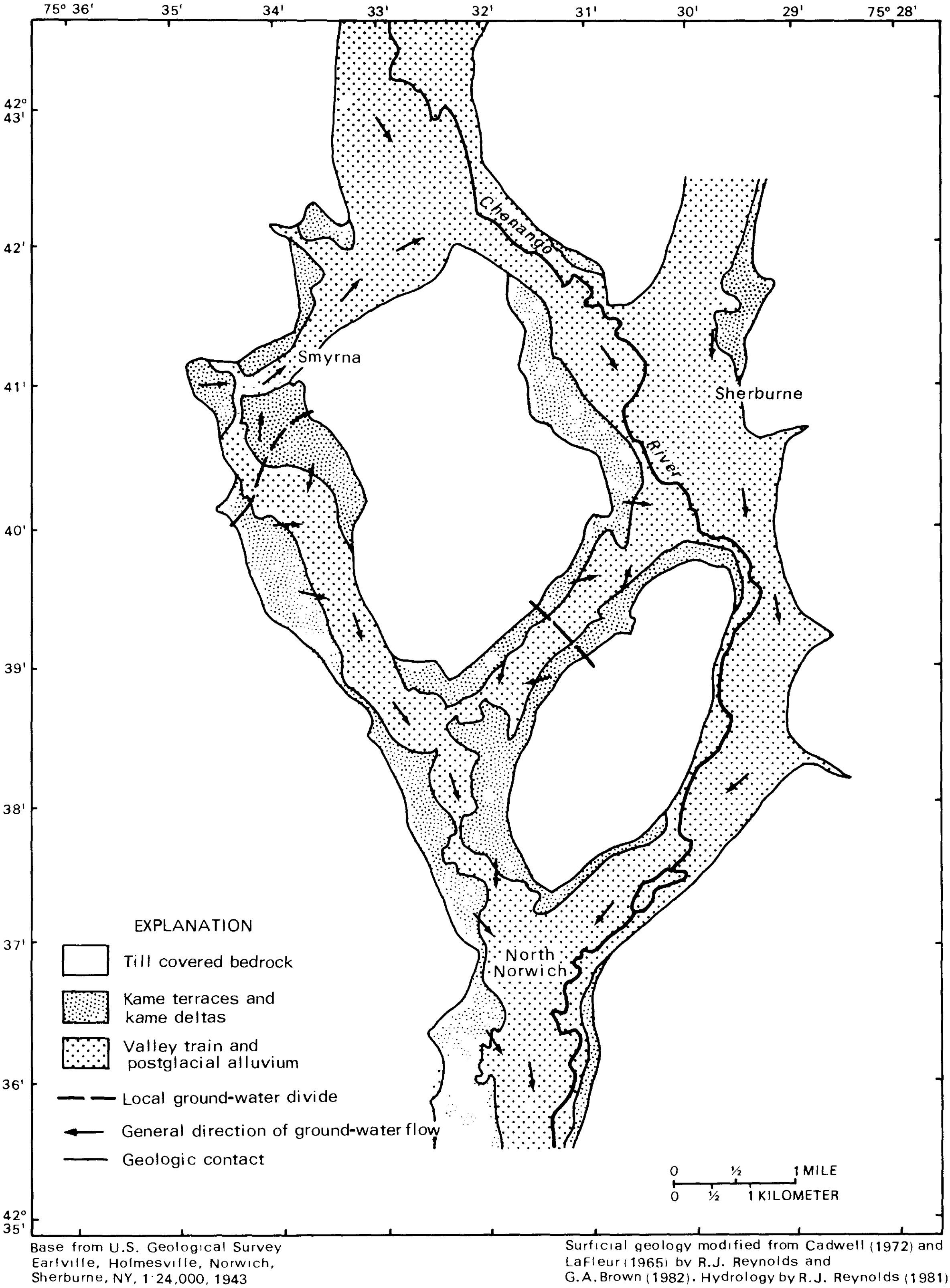
Most of the ground water within the separated valley discharges into the Chenango River valley (fig. 7 and pl. 4). A local ground-water divide bisects the west limb about 1 mi south of Smyrna, causing ground water north of the divide to flow northeastward toward the Chenango River and ground water south of the divide to flow southward, where it ultimately discharges into Fly Creek or the Chenango River at North Norwich (pl. 4). A local ground-water divide also bisects the east limb, so that about half the recharge to this branch moves northeastward to the Chenango River, while the remainder moves southwestward toward the central limb.

The local ground-water divides are caused by ground-water mounds that develop under small streams as a result of stream losses, and within large kame terraces, which have a lower permeability than the adjacent outwash. The divide in the west limb is probably caused by streambed infiltration (Randall, 1978) along Crooked Brook (pl. 4) and by the steeper gradient within the large kame terrace on the east side of the valley. During periods of high runoff, the ground-water divide runs more or less beneath Crooked Brook, but during dry periods it may migrate several hundred feet north to the topographic divide (pl. 4). The ground-water divide in the east limb, which is less clearly defined, may also migrate substantially during alternate wet and dry periods.

Well Yields

Bedrock Aquifer

Reported yields of 23 domestic wells tapping bedrock in the separated valley average 10.5 gal/min and range from 2 to 30 gal/min. Yield data for these wells are given in table 3. Most bedrock wells that were reported to yield less than 5 gal/min penetrate from 60 to 140 ft of bedrock, whereas the five wells with yields of 20 to 30 gal/min penetrate only 3 to 47 ft of bedrock. This inverse relationship between yield and depth of penetration reflects three factors:



Base from U.S. Geological Survey Earlville, Holmesville, Norwich, Sherburne, NY, 1:24,000, 1943

Surficial geology modified from Cadwell (1972) and LaFleur (1965) by R.J. Reynolds and G.A. Brown (1982). Hydrology by R.J. Reynolds (1981)

Figure 7.--Generalized surficial geology and direction of ground-water flow in the separated valley.

Table 3.--Selected statistics on domestic wells within the separated valley at Smyrna.

A. By aquifer

Aquifer material	Number of wells	Percentage of total number of wells	Average well depth (ft)	Average reported well yield (gal/min)	Range of well yields (gal/min)
Sand and gravel	57	61	48.1	39.3 (18 wells)	5 to 150
Bedrock	36	39	132.7	10.5 (23 wells)	2 to 30

B. By diameter

Well diameter (inches)	Number of wells	Percentage of total number of wells
Less than 3	27	26
4 to 8	72	69
Large-diameter dug wells up to 36	6	5

C. By construction method (sand and gravel wells)

Well-construction method	Number of wells	Average depth of well, (ft below land surface
Hand driven	27	18.2
Drilled	24	87.9

1) Drilling is ordinarily stopped when the well obtains ample water to meet the owner's needs. Wells that obtain little water near the top of bedrock are drilled deeper in hope of obtaining more.

2) Water in the bedrock of this region flows chiefly through numerous cracks or fractures in the otherwise nearly impermeable shale. The upper few feet of bedrock commonly contain larger and more numerous fractures than bedrock at depth as a result of postglacial rebound and weathering. LaSala (1968) described this phenomenon in relation to bedrock in western New York, and drillers in this region commonly report "broken rock" near the bedrock surface.

3) The hydraulic conductivity of the material directly overlying the bedrock is a principal factor controlling the yields of shallow bedrock wells. Because most of the water withdrawn from shallow bedrock wells comes from the overlying material, material of low hydraulic conductivity such as till or lacustrine silt and clay overlying the bedrock will contribute little or no additional water to that normally pumped from bedrock

fractures. Where more permeable sand and gravel overlie bedrock, however, water can move rapidly into the highly fractured upper rock surface under pumping conditions. As a result, yields of shallow bedrock wells can approach those of wells tapping sand and gravel. The thickness of the overlying saturated material is important to the long-term sustained yield of bedrock wells of this type. Thinly saturated sand and gravel would probably become dewatered under continuous pumping, such as for industrial use, and yields would soon diminish to levels considered normal for most bedrock wells. Pumping for domestic use, however, would probably not be sufficient to cause dewatering unless the water table declined naturally as the result of drought.

Sand and Gravel Aquifers

The reported yield of 18 wells tapping Pleistocene sand and gravel deposits in the separated valley averaged about 39 gal/min (table 3) and ranged from 5 to to 150 gal/min. Well diameters ranged from 1.25 inches (driven wells) to 3 ft (dug wells). Most private drilled wells tapping sand and gravel are 6 to 8 inches in diameter, and most are not screened but instead finished with open-ended casing. Thus, the only area through which water can enter the well is through the bottom. This, more than any other factor, limits the ability to obtain large well yields. Drillers' records for five such wells indicate that the wells were bailed at 30 to 40 gal/min, generally with negligible drawdown. By contrast, the 8-inch-diameter public-supply well for the village of Smyrna, finished with about 9 ft of screen exposed to the aquifer, yields 150 gal/min with only 2.5 ft of drawdown.

Maximum Potential Well Yields

Domestic and farm wells finished in sand and gravel yield only a small fraction of the maximum potential of ground water that could be obtained from larger wells finished with screens at the same locations. Screened wells for municipal or industrial use yielding at least 400 gal/min have been finished in sand and gravel in broad valleys similar to the Smyrna valley throughout the Susquehanna River basin (Randall, 1972; Buller and others, 1978; MacNish and Randall, 1982). Even these large-yield wells are commonly designed to meet only the owner's needs in a cost-effective manner and may not represent the maximum yields obtainable if longer screens, larger diameters, greater depths, or larger pumps had been selected. Hollyday (1969) presents an analysis of yields obtainable from wells designed for maximum potential in various types of aquifers throughout the Susquehanna basin.

An indication of maximum potential well yield was obtained by estimating transmissivity of the geologic sections penetrated by test wells in the area. First, the hydraulic conductivity of each lithologic unit was estimated from relationships between grain size and hydraulic-conductivity values tabulated by Randall (1977). The individual hydraulic-conductivity values were then multiplied by the respective bed thickness, and the products were summed to yield an estimated transmissivity for the entire saturated thickness. Where the geologic log showed an upper and lower aquifer separated by a lacustrine unit (as in the east and central limbs), transmissivities were estimated for each aquifer separately as well as for the entire section as a whole.

The estimated transmissivities were then substituted into the following equation (Walton, 1970), which expresses the theoretical specific capacity of a fully penetrating well discharging at a constant rate in a homogeneous, isotropic, nonleaky artesian aquifer of infinite areal extent:

$$Q/s = \frac{T}{264 \log \left(\frac{Tt}{(2693\ r_w^2 S)} \right) - 65.5} \qquad (1)$$

where: Q/s = specific capacity, in gallons per minute per foot of drawdown
Q = discharge, in gallons per minute
s = drawdown, in feet
T = transmissivity, in gallons per day per foot
S = storage coefficient, dimensionless
r_w = nominal radius of well, in feet
t = time after pumping started, in minutes

In estimating the maximum potential yield of a hypothetical well, a well diameter of 12 inches (r_w = 0.5 ft) was used because this represents a common casing size used in large-yield production wells. A specific yield of 0.15, an average value for unconfined aquifers, was used for water-table aquifers, and a storage coefficient of 0.005 was used for confined aquifers. The value of time, t, was 24 hours because many large municipal or industrial wells are pumped intermittently and because the purpose was to estimate the short-term yield of the well, rather than the yield of the aquifer, which is discussed later. The estimated aquifer transmissivity at selected test holes was substituted into the above equation with the assumed values of r_w, t, and S to arrive at a hypothetical Q/s. A maximum allowable drawdown of one-third the saturated thickness was used to estimate the maximum well yield for water-table aquifers and was then adjusted through Jacob's correction (Walton, 1970) for the decrease in transmissivity caused by pumping. The potentiometric head above the top of the aquifer was used as a maximum allowable drawdown for confined aquifers. Results for three sites in the separated valley are given in table 4.

The kame-terrace deposits that form the bulk of the aquifers within the area are, on the whole, fairly permeable but include lenses of very coarse, well-sorted sand and gravel that are highly permeable. To construct a well of maximum yield, it is necessary to locate one or more of these lenses, usually by drilling several test wells at various locations. Eight test wells were drilled in 1981 for the Village of Smyrna by a consulting engineer (appendix I and II), and the most promising site was selected for a production well (well 20-46, appendix I). An analysis of data from a pumping test run on that well by the consulting engineer yielded a hydraulic conductivity of 245 ft/d (appendix IV). This is probably an average value, however, because most of the nearby aquifer materials presumably have considerably lower or higher hydrualic conductivities.

Table 4.--Estimated transmissivity and maximum potential well yield at selected test-hole sites in the Smyrna valley.

[Test-hole locations shown on plate 1.]

Aquifer limb	Test-hole number	Type of aquifer	Saturated thickness of aquifer (ft)	Maximum drawdown selected (ft)	Estimated trans-missivity (ft^2/d)	Maximum potential well yield (gal/min)
Central	22-05	water table	58	19	21,000	1,550
East	25-59	water table	38	13	8,720	470
		confined	43	67	1,050	300
West	20-46	water table	51	17	11,100	760
	20-46*	water table	51	2.5	11,500	150

* Data from pumping test of 8-inch diameter municipal well at this site is shown for comparison.

Ground-Water Storage

All three valley limbs contain confined aquifers (units 4B, 4C, and 5 in pl. 5) and a water-table aquifer of varying thickness (units 3 and 4 in pl. 5). For purposes of storage calculation, the west limb was divided into northern and southern sections of approximately equal size; therefore storage estimates are presented for four sections of the valley.

Aquifer Distribution and Saturated Thickness

West Limb.--The primary aquifer in the west limb is essentially under water-table conditions and has an average staturated thickness of 60 ft (pl. 6). Where the aquifer overlies lacustrine sediments, its saturated thickness thins to about 10 ft. Northeast of Smyrna, a confined aquifer approximately 10 ft thick is inferred to underlie most of the lacustrine sediment.

Central Limb.--This limb has a water-table aquifer in which the saturated thickness averages 140 ft where lacustrine materials are absent and 20 ft where the aquifer is underlain by lacustrine silt and clay. This lacustrine unit is underlain by a confined aquifer approximately 40 ft thick.

East Limb.--Here the saturated thickness of the water-table aquifer averages 80 ft where the aquifer extends to bedrock and 40 ft where it is underlain by lacustrine material. A confined aquifer approximatly 35 ft thick underlies the lacustrine material.

Calculation of Storage

Surface areas of stratified-drift and lacustrine deposits in each limb were measured by digitizer on topographic maps. The area of lacustrine material was considered equivalent to the area of confined aquifer, although the actual area of the confined aquifers is probably somewhat smaller than the surface delineation of the lacustrine material. Estimates of available ground water in storage (table 5) were calculated from an estimated specific yield of 0.2, which is reasonable for silty sand and gravel and from the average saturated thickness of each of the aquifers.

As can be seen from table 5, the central limb has the greatest amount of storage, almost 40 percent more than the west limb, even though the surface area of stratified drift in the central limb is only half that in the west limb. This is because the central limb contains a thick water-table aquifer as well as a confined unit, whereas most of the aquifer material in the west limb is relatively thin, less than half the thickness of the water-table aquifer in the central limb. Table 5 also indicates that about 92 percent of the ground water in storage in the Smyrna valley is held in water-table aquifers.

Table 5.--Estimates of available ground-water storage in the separated valley at Smyrna.

[Storage is in billions of gallons.]

Subsection	Area of stratified drift, in mi^2	Storage in[1] water-table aquifer	Storage in[1] confined aquifer	Combined storage
West limb[2]				
north half	1.79	2.36	0.21	2.57
south half	1.86	2.99	--	2.99
Central limb	1.73	8.52	.53	9.05
East limb	1.54	4.13	.87	5.0
Totals	6.92	18.0	1.61	19.61

[1] Calculated from an estimated storage coefficient of 0.2 and an average saturated thickness for each aquifer according to the method outlined by MacNish and Randall (1982).

[2] For computational purposes the west limb is divided into northern and southern halves of nearly equal area.

Estimated Aquifer Yield

MacNish and Randall (1982) present a method for estimating maximum potential ground-water withdrawal from stratified-drift aquifers within the

New York part of the Susquehanna River basin. This method, suitable for reconnaissance studies such as this, estimates aquifer yield by applying average recharge rates derived from regional studies to the dimensions and other properties of local stratified-drift aquifers. The method separately accounts for each major source or component of recharge, including precipitation, runoff from adjacent till-mantled bedrock hills, and seepage from small streams crossing the valley floor, and also accounts for storage in the aquifer.

Information obtained during this study permits more precise estimates of aquifer dimensions than those compiled by MacNish and Randall (1982); therefore the recharge rates and computation techniques presented by MacNish and Randall were slightly modified when applied to the aquifer dimensions shown on plate 5.

For ease of computation, the area was arbitrarily divided into four sections--the west limb, which was separated into a northern and southern section of approximate equal area; the central limb, and the east limb. Calculations of recharge from various sources, and estimates of storage within each section, are presented in previous sections of this report.

Maximum Potential Aquifer Yield

Estimates of maximum long-term aquifer yield, sometimes termed "safe yield," are based on the effects of a drought similar in length and severity to that which occurred in the Northeast during the mid-1960's. Because the effects of such a drought are accounted for in estimating potential aquifer yield, the resulting maximum withdrawal rates presented here are considered to be conservative estimates.

During the drought of the 1960's, the cumulative deficiency in runoff in the Susquehanna River basin was equal to about 1.5 years of average runoff (Ku and others, 1975). In addition, local recharge during any single growing season could be nearly zero for as long as 6 months. Recharge to the study area, therefore, would be similarly deficient during such a drought. Accordingly, the volume of water needed from storage to sustain ground-water withdrawals at the average annual recharge rate during a drought of this severity would have to equal twice the volume of average annual recharge--1.5 volumes to meet the long-term deficiency caused by the drought, plus 0.5 volume needed to meet the normal seasonal deficiency.

The estimate of the amount of water stored in the aquifers within the separated valley was calculated on the principle that about 20 percent of the aquifer volume is drainable pore space. This value of specific yield (0.20) was applied to both surficial and confined aquifers in the Smyrna valley on the assumption that the aquifers are hydraulically connected through kame-terrace deposits along the valley sides. Thus, water pumped from the confined aquifer would induce recharge from the surficial aquifer through these kame deposits, with the confined aquifer, in effect, serving as a "sump." Pumping from the confined aquifer for an extended period, therefore, would actually remove water (under water-table conditions) from storage in the surficial aquifer. Only a fraction of this stored water can be withdrawn at a reasonable cost, however. The economic withdrawal of large volumes of water requires widely spaced, efficient, large-capacity wells and also requires that at least the lower part of the aquifer remain saturated at each well, with a greater saturated thickness away from each well to provide a sufficient gradient. MacNish and Randall (1982) suggest that approximately one-third of the available storage in an aquifer is the maximum that can be withdrawn without a costly and generally impractical network of small, closely spaced wells. This estimate was based on calculations with mathematical expressions for ground-water flow and simulations with a digital computer model of an idealized aquifer (MacNish and Randall, 1982).

Estimates of maximum sustained ground-water pumpage rates for each limb of the separated valley are presented in table 6. These rates are based on comparisons of volumes of water (pumped at the annual average recharge rate) needed to meet demand during a severe drought, allowing withdrawals of one-third of the storage actually available, as outlined by MacNish and Randall (1982).

Table 6.--Comparison of maximum sustained ground-water pumpage rates and average annual recharge rates.

[Values are in million gallons per day.]

Area	Maximum sustained ground-water pumpage rate	Average annual recharge rate
West limb		
north half	3.80	4.93
south half	3.04	4.00
Central limb	3.33	3.33
East limb	2.62	2.62
Total for separated valley	12.79	14.88

In the central and east limbs of the valley, storage is sufficient to permit maximum sustained pumpage equal to the average annual recharge rate. In the west limb, however, the lack of sufficient storage would permit a long-term pumping rate equal to only about 76 percent of the average annual recharge rate, or 6.84 Mgal/d.

These pumpage rates are conservative estimates of long-term maximum pumpage that could be sustained during a severe drought. During periods of above-normal recharge, pumpage rates could be somewhat higher without permanently depleting ground-water storage. The effects that individual pumping centers would have on ground-water levels in the area could be evaluated through digital modeling, but this would be inappropriate until extensive data on the water-level response to drought or heavy pumping become available.

AQUIFER-MANAGEMENT ALTERNATIVES

The valley configuration near Smyrna is atypical for New York in that its stratified-drift aquifers are largely separated from the major river by hills of relatively impermeable bedrock. Most other productive valley aquifers within the Susquehanna River basin and elsewhere in upstate New York are in direct hydraulic connection with streams or rivers, so that heavy pumping from the aquifers normally reduces streamflow by induced infiltration. This effect is especially important during seasonal low flows, when water demands are usually the highest. Reduction of streamflow by induced infiltration during summer may be unacceptable in some localities, especially if a given amount of flow must be maintained for downstream water supply, sewage dilution, or navigation. In addition, ground water derived from induced infiltration tends to approach the temperature of river water rather than the constant 50°F of ground water, which could be undesirable during warm summer months if the water were to be used for cooling.

Aquifers in separated valleys such as the one near Smyrna offer the advantage of having a greater hydraulic separation from nearby rivers, either because of distance to the river or because of the presence of impermeable boundaries. Thus, ground-water pumpage from an aquifer of this type would not affect streamflow to as great a degree as would be expected in a typical valley aquifer configuration. This affords several alternatives for ground-water management to meet specific objectives.

Regional Supply During Drought

From the amount of available water in storage, the aquifers in the separated valley contain sufficient water to supply a substantial population during a prolonged drought such as that of the mid-1960's. Water pumped during such a period would be from storage and would not induce infiltration from the Chenango River, whose stage would doubtless be critically low. Heaviest local demands on the separated aquifer could be made in the central limb, north of the limit of lacustrine sediments in the valley. (See fig. 5 and pl. 5.) Here, the large saturated thickness (up to 200 ft) could support large withdrawals of water that would otherwise naturally discharge to the Chenango River. The smaller saturated thickness in the west limb (up to 80 ft) would not support high-capacity wells but could support several closely spaced, low-capacity wells having small drawdowns.

Some variation in quality of water from confined aquifers can be expected with large-scale development. Water in confined aquifers is partly derived from upward seepage from the underlying shale bedrock and hence is commonly softer but more mineralized than in shallow aquifers and also may contain undesirable amounts of hydrogen sulfide (sulfur water) and (or) iron. Heavy pumping from these confined aquifers could accentuate these characteristics. Similarly, heavy pumping from shallow aquifers near swamps, which commonly produce reducing conditions, may also result in water-quality deterioration, especially through excessive iron.

Large-scale ground-water withdrawals, especially from the shallow water-table aquifer, would lower ground-water levels substantially and thereby dry up streambeds and swampy areas within the valley. Depending upon where pumping centers were located, varying numbers of shallow domestic wells would have to be deepened or the homes supplied with public water.

Cooling-Water Supply

Because of its hydraulic separation from the Chenango River, the aquifer system at Smyrna could support a variety of combinations of residential and (or) commercial development. Industries needing cooling water could obtain a year-round supply of water 50°F or less. During summer, wells situated a sufficient distance from the Chenango River (fig. 6) could supply cool ground water even though water in the Chenango River remained warm and the flow minimal. During winter, when streamflow is higher, cold water could be pumped from the river, or possibly from riverbank wells or infiltration galleries, without reducing streamflow to unacceptable levels. A dual-source pumping scheme of this type, although costly to initiate, would have less impact on river discharge and ground-water levels than year-round pumping of ground water only.

A similar dual-source pumping scheme could probably be carried out in the confined aquifer within the Chenango valley east and south of the separated valley. In this area, the thick lacustrine sediments overlying the aquifer would isolate the river from the effects of seasonal pumping. During the high-flow (cool) season, cooling water could be obtained from shallow wells dependent on induced infiltration, and during the low-flow (warm) season, cooling water could be obtained from deep wells tapping the confined aquifer.

Protection of Ground-Water Quality

Ground-water contamination in the Smyrna area is unlikely at present because the area is largely rural. Any large-scale residential or industrial development, however, could adversely affect the quality of the ground water unless the dynamics of the ground-water flow system are taken into account when land use and water-disposal plans are formulated.

If residential development with individual wells and septic-tank waste-disposal systems were to become extensive, water supplies would probably be ample, but water quality could deteriorate wherever shallow surficial aquifers were used for both water supply and waste disposal. Kame terraces along the valley sides provide a thick unsaturated zone through which wastes could be oxidized and adsorbed before reaching the water table, but even though this would minimize transmittal of bacteria and ammonia, it would do little to reduce the amount of nitrate and chloride loading to the ground-water body.

Confined aquifers beneath thick lacustrine sediments in the south-central and eastern parts of the separated valley are effectively protected from wastewater contamination originating in thin surficial aquifers. Even if large-scale industrial or agricultural pumpage were to reverse the upward gradient in these areas, the low hydraulic conductivity of the confining layers would greatly impede the flow of shallow ground water to the confined aquifer.

Surface contamination within kame terraces could be more serious and difficult to remedy than in shallow aquifers because these deposits transmit much of the recharge for both the surficial and confined aquifers in the area. This factor should be a major consideration in the selection of sites for landfills, salt-storage stockpiles, hydrocarbon fuel storage, chemical plants, and other facilities that have a high risk of contaminant leakage.

SUMMARY AND CONCLUSIONS

Water-table and confined aquifers within the Smyrna separated valley are, to a large extent, hydraulically separated from the nearby Chenango River and can therefore be developed without causing appreciable reduction in river discharge through induced infiltration. This hydraulic detachment from the river is an important consideration in ground-water-management planning to meet specific objectives such as use as a regional water supply or a year-round source of cooling water.

The Y-shaped valley aquifer system is estimated to contain 19.6 billion gallons of available ground water, approximately 92 percent of which is in water-table aquifers and the remaining 8 percent in confined aquifers of smaller extent. Although the west limb of the valley receives the greatest amount of recharge (60 percent of the valley's total), its smaller saturated thickness (60 ft) would support less pumpage than the central limb north of the lacustrine sediments, where the average saturated thickness is 140 ft.

An analysis of recharge to the valley from several sources indicates that approximately 56 percent of the recharge is from direct precipitation, 20 percent occurs as runoff from adjacent hillsides, and 24 percent is infiltration losses from small streams. Three of the four streams that recharge the area do so along the west limb, so that about 33 percent of the recharge to this part of the valley is derived from stream infiltration.

Kame-terrace material constitutes much of the water-table aquifers and all of the confined aquifers in the valley. Analysis of a pumping test at Smyrna indicates a hydraulic conductivity of 245 ft/d, which may be generally representative of the coarser fractions of kame-terrace material throughout the valley. Elsewhere, the kame-terrace material includes greater amounts of silty sand and gravel and is less permeable than at Smyrna.

Thick layers of lacustrine silt and clay occupy most of the central limb and half the east limb of the valley; therefore ground water in these sections occurs under both water-table and confined conditions. The west limb is essentially one large water-table aquifer with only minor discontinuous confining beds within the kame material and a thin sequence of lacustrine sediments at the north end.

The west, central, and east limbs could support long-term withdrawal rates of 6.8, 3.3, and 2.6 Mgal/d, respectively, during a prolonged drought similar to that of the mid-1960's. These figures are considered conservative, and higher rates of withdrawal would be possible during periods of higher-than-normal recharge or for short periods.

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APPENDICES

Appendix I: Records of Wells

Explanation of Column Headings

Location: Coordinates of latitude and longitude, in degrees, minutes, and seconds are shown for each well or test hole. Wells are listed from south to north by increasing 1-minute strips of latitude. Within each strip, wells are listed from east to west by increasing longitude in degrees, minutes, and seconds. Where two or more wells within a single strip of latitude have the same longitude, they are listed by increasing latitude, with the southernmost listed first. Latitude and longitude were measured from a 7 1/2-minute topographic map, scale 1:24,000, and each well location was plotted on the map after a field visit by a member of the U.S. Geological Survey or taken from large-scale engineering drawings. Locations of all wells listed are shown on plate 6 and are identified by a four-digit hyphenated number that represents the seconds of latitude and longitude written together. For example, a well with a latitude-longitude of 4236 56 7531 43 would appear on plate 1 with the number 56-43 adjacent to the well location.

Owner: Owner's name is listed. Some names are shortened or abbreviated. For example, U.S. Geological Survey appears as U.S.G.S., and Village of Smyrna is listed as Vill. of Smyrna.

Use: Categories include:

- A Agricultural--primarily dairy farming; generally also supplies domestic household water.
- C Commercial--small business or light industrial, for example, lumber processing.
- D Domestic--supplies household drinking water.
- M Municipal--public supply.
- O Observation--observation well used to monitor ground-water levels.
- T Test hole--drilled to obtain hydrogeologic information. Such holes were filled in soon after completion. Test holes that were converted to observation wells are so listed.
- U Unused--includes wells that had been abandoned or filled in because of poor yield or quality, and wells that were usable but not needed as of 1980.

Date drilled: Exact dates of well completion are listed if known; otherwise month and year, or year in which well was first drilled. Approximate dates are noted as "c" for "circa" or "b" for "before."

Method: Method of well construction

- B Bored or augered--generally with a hollow-stem auger that permits cores to be taken at selected depth intervals.
- C Cable tool--also termed "percussion drilling"
- D Dug well--generally stone curbed and of large diameter
- V Driven--commonly hand-driven shallow wells of small diameter (less than 3 in.) and equipped with a well point.
- R Rotary--either hydraulic or air rotary

Appendix I: Records of Wells

Explanation of Column Headings (Continued)

Well diam: Diameter of well casing or test hole (if no casing used), in inches. When more than two sizes of casing are used, the diameter of the upper section of casing is listed first.

Well depth: Numbers refer to depth below land surface. Where observation wells or production wells are installed in former test holes, depth refers to finished well depth; total depth of the test hole is listed under "Remarks" or in geologic log in appendix 1. Letters to right of depth column show source of information, as follows:

- D From driller's bill, log, or written records.
- E Estimated.
- M From memory of owner, driller, or some other person.
- S Measured by U.S. Geological Survey.
- ? Indicates questionable data from source listed.

Casing Depth: Numbers refer to depth of solid casing below land surface to shallowest point at which water can enter the well. Letters to right of depth column show source of information as explained under "Well Depth." A 2-ft drive point was assumed to be used in estimating the casing length for shallow driven wells in the absence of specific information. Question mark (?) in depth column indicates casing depth not known; when listed adjacent to a casing depth value, it indicates a questionable depth. Absence of entry in this column indicates no casing left in place; temporary test hole was held open with hollow-stem auger or casing that was later removed.

Depth to Bedrock: In absence of specific information, depth to bedrock was assumed to be approximately the same as casing depth for bedrock wells. Letters to right of Depth to Bedrock column show source of information as explained under "Well Depth." Question mark (?) in this column indicates depth to bedrock is unknown for wells known to terminate in bedrock or suspected to terminate in bedrock on the basis of other information. When listed adjacent to a depth value, it indicates a questionable depth.

Finish: Refers to character of openings that permit water to enter well, as follows:

- O Open end--cased to bottom of hole; all water enters through bottom.
- N None--test hole, filled after drilling.
- D Drive or sand point--assumed to be 2 ft in length unless otherwise known.
- S Screen--commercial well screen, developed without a gravel pack.
- W Walled--with open-jointed fieldstone, concrete blocks, tiles, stone curbing, or similar materials.
- X Open hole--no casing or other support opposite aquifer.
- ? Unknown.

Appendix I: Records of Wells

Explanation of Column Headings (Continued)

Aquifer: Indicates general geologic character of aquifer material tapped. Abbreviations include:

S&G	Sand and gravel
?	Aquifer identification questionable

Altitude: Altitude of land-surface datum above sea level at each well was estimated to the nearest foot from 7 1/2 min., 1:24,000 scale topographic maps having a contour interval of 20 ft. Altitudes shown to the nearest tenth of a foot were based on spirit levels by a consulting engineer.

Water level: Numbers show water level to nearest foot below land-surface datum under static (nonpumping) conditions except as noted under "Remarks." Water levels obtained by the U.S. Geological Survey were measured by wetted-tape method or electric water-level indicator and are reported to a tenth or hundredth of a foot. Dates of water-level measurements or approximate dates are shown. Letters to right of water-level column show source of the information, as explained under "Well Depth."

Remarks: Several symbols or expressions are used to abbreviate data:

crse	coarse
(D)	source of information is driller
DD	drawdown
(E)	estimated
fne	fine
GPM, gpm	gallons per minute
hdpn	hardpan
H_2S	hydrogen sulfide
LSD	land-surface datum
>LSD	above land-surface datum
<LSD	below land-surface datum
meas	measured
mg/L	milligrams per liter
MP	measuring point - top of the casing or vent hole in sanitary seal unless otherwise stated
neg	negligible
NO_3 as N	nitrate reported as nitrogen
(O)	source of information is owner
(?)	not verified
S&G	sand and gravel
sed	sediments
SWL	static water level
USGS	U.S. Geological Survey
w/	with

Example: 19 ft DD@ 36 GPM (D); MP 2 ft >LSD

Driller reported 19 feet of drawdown when well was pumped at 36 gallons per minute; measuring point is 2 ft above land-surface datum.

Appendix I: Records of Wells

No.	Location	Owner	Use	Date drilled	Method	Well diam (in)	Well depth (ft)		Casing depth (ft)		Depth to bedrock		Finish	Aquifer	Altitude
1	4237 00 7531 38	John Whaley	D	c.1900	V	1.25	20	M	18	E			D	S&G	1034
2	4236 56 7531 43	Truman Kellogg	D	1961	V	1.25	14	M	12	E			D	S&G	1030
3	4236 58 7531 43	Donald Frank	D	1950	V	1.5	16	M	14	E			D	sand	1031
4	4236 50 7531 52	J. Scheuerman	D	1976	V	1.5	12.5	M	10.5	E			D	sand	1025
5	4237 08 7531 15	Don Stanton	A	1948	C	6	308	M	300	M	300	E	X	bedrock	1038
6	4237 04 7531 32	Nellie Wright	D	1977	C	6,5	334	D	334	D			O	S&G	1035
7	4237 05 7531 34	William Labor	D	c.1960	V	1.25	21	M	19	E			D	S&G	1038
8	4237 00 7531 37	Albert Ebert	D	1945	V	1.25	12	M	10	E			D	gravel	1034
9	4237 11 7531 38	James Crandall	U	1979	C	6	202	M	202	M			O	silty sand	1045
10	4237 14 7531 42	Lloyd Moon	D	c.1950	C	6	219	M	200	M	200	E	X	bedrock	1035
11	4237 04 7531 44	Roger Pike	D	1967	V	1.25	18	M	16	M			D	sand	1038
12	4237 42 7531 49	Anthony Seibert	D	1967	C	6	119	M	119	?			O	S&G ?	1105
13	4237 03 7531 50	Barry Smith	D	1969	V	1.25	12	M	10	E			D	sand	1034
14	4237 04 7531 52	Leonard Jones	D	1979	V	1.25	16	M	14	E			D	sand	1033
15	4237 40 7531 56	John Meyers	D	8/1974	C	6	65	D	65	D			O	S&G	1065
16	4237 41 7531 56	Richard Decker	D	5/1977	C	6	66	M	66	M			O	S&G	1070
17	4237 11 7532 03	Town N. Norwich	D	?	C	6	85	M	85?	M			O	S&G ?	1035
18	4237 22 7532 05	U.S.G.S.	T	9/18/80	B	8	86.5	S			85.5	S	N	silty S&G	1050
19	4237 39 7532 09	Wm. Eggleston	D	?	V	1.5	20	M	18	E			D	sand	1045
20	4237 07 7532 09	Mitch Augustyn	D	c.1970	C	8	210	M	210?	M			O	S&G ?	1065
21	4237 38 7532 10	Robert Bates	U	1979	C	6	130	M	130	M			O	silt, sand	1030
22	4237 33 7532 11	U.S.G.S.	T	9/19/80	B	8	83	S					N	silty S&G	1050
23	4237 25 7532 27	Richard Brown	D	1971	C	5	151	M	100?	M	100?	E	X	bedrock	1110
24	4237 26 7532 28	C. VanSteinburg	D	c.1955	C	6	192	M	?		?		X	bedrock	1110
25	4237 29 7532 28	Robert Reese	D	1972	C	6	201	M	60	M	60	E	X	bedrock	1105
26	4237 57 7532 41	Barry Matteson	A	c.1945	C	6	172	M	?		?		X	bedrock	1100
27	4238 13 7531 49	Philip Pike	A	c.1939	C	6	90	M	90	M			O	S&G	1125
28	4238 49 7531 57	U.S.G.S.	O	11/1980	C	6	125	S	121		155	S	S	sand	1060
29	4238 56 7532 03	Donald Rabig	D	10/1977	C	6	125	D	58	D	58	D	X	bedrock	1108
30	4238 35 7532 15	U.S.G.S.	T	1/1981	C	6	104	S					N	silty S&G	1070
31	4238 56 7532 19	Robert Marks	D	c.1966	C	4	30?	M	30?	M			O	S&G ?	1150
32	4238 55 7532 36	Wagner Law	D	1945	C	6	161	M	?		?		X	bedrock	1100
33	4238 52 7532 36	Clifton Law	D	1971	C	6	62	M	62	M			O	gravel	1090
34	4238 54 7532 40	Betty Onyan	D	1979	C	6	80	D	76	D	75	D	X	bedrock	1098
35	4238 02 7532 46	John Homovich	U	c.1958	C	6	161	M	85?	E	85?	E	?	bedrock?	1105
36	4238 52 7532 46	Donald Cook	D	1939	V	1.25	18	M	16	E			D	S&G	1081
37	4238 49 7532 47	George Bullock	D	1952	C	6	39	M	39	M			O	S&G	1080
38	4239 00 7532 47	Richard Losee	D	1972	C	6	147	M	30	M	30	M	X	bedrock	1110
39	4238 29 7532 49	Richard Tarbell	D	1975	V	1.25	13	M	11	E			D	sand	1060
40	4238 51 7532 49	William Irwin	D	c.1950	V	1.5	25	M	23	E			D	sand	1079
41	4238 32 7532 52	Bruce Webster	D	1975	V	2	12	M	10	M			D	S&G	1055
42	4238 30 7532 53	Burt Landon	D	1978	V	1.25	30	M	28	E			D	sand	1070
43	4238 53 7533 07	Don Fairbanks	D	9/7/63	C	5	72	D	69	D	69	D	X	bedrock	1115
44	4238 53 7533 12	Glenn Treschow	D	c.1961	C	6	123	M	60	M	60	E	X	bedrock	1135
45	4238 58 7533 18	Gerald Parry	A	c.1968	C	6	60	M	40	M	40	E	X	bedrock	1115
46	4239 27 7530 20	Ralph Davenport	D	1975	C	6	150	M	150	M	?		X	bedrock	1205
47	4239 23 7530 44	Floyd Foster	D	1/1974	C	6	210	D	90	D	90	D	X	bedrock	1125
48	4239 25 7530 59	U.S.G.S.	T	11/20/80	C	6	137	S	137	S	133	S	N	silty S&G	1065
49	4239 25 7531 36	W. Palmiter	A	c.1965	C	6	229	M	21	M	21	E	X	bedrock	1150
50	4239 01 7531 58	Charles Boise	D	1974	C	6	105	D	58	D	58	D	X	bedrock	1110
51	4239 01 7533 15	Richard Lewis	D	b.1960	C	8	23	M	23	M			O	gravel	1120
52	4239 04 7533 17	Gerald Parry	D	?	C	6	60	M	60	M			O	S&G	1130

Appendix I: Records of Wells (Continued)

No.	Water level (ft)		Water level Date	Yield (gpm)		Remarks
1						Suction pump; private lab QW analysis-2/75; NO_3 as N-4.2 mg/L, chloride-17 mg/L.
2	9	M	6/61			Well in basement; supply adequate.
3	4	M	1950			Well in basement; hard water; log (owner): sand 0-7 ft/gravel/fine sand.
4	10	M	1976			Hard water; owner reports "quicksand" at 18-20 ft, pulled back to 12.5 ft.
5	20	M				Hard water; supplies 3 families, 150 cattle; log (O): 300 ft "hardpan," 8 ft rock.
6	8	D	1977	30+	D	Supplies adult home; 6" casing to 297 ft, 5" casing to 334 ft; H_2S odor; neg. DD.
7	14	M				Hard water; owner replaces well point annually due to plugging.
8	9	M				Hard water; calcium deposits; log (owner): sand to 8 ft, then coarse gravel.
9	14.31	S	6/3/80			Abandoned; poor yield; penetrates and ends in silty sand; MP is 1.6 ft above LSD.
10						Well supplies 2 homes; slight H_2S odor.
11	12	M				Hard water; owner reports well has never failed.
12	25	M				Hard water; slight H_2S odor; S&G aquifer?
13	3	M	1969			Suction pump; hard water; log (owner): 0-12 ft sand, clay below 12 ft.
14	8	M	1979			Suction pump; fairly soft water (tested); log (O): sand, fine gravel to 16 ft.
15	18	D	8/74	30	D	Hard water; bailed to bottom at 30 GPM (D); drillers log: S&G to 65 ft.
16	15	M	5/77			Hard water; some iron; owner reports negligible DD with continuous bailing.
17	7.48	S	6/5/80			Once supplied canning factory; poor yield; unused for drinking; MP 1.8 ft > LSD.
18	23	S	9/18/80			U.S.G.S. augered test hole; log in Appendix 1.
19						Suction pump; hard water; adequate supply.
20						Slightly hard water; H_2S odor, taste.
21	1.74	S	5/29/80			Abandoned well; casing at LSD; poor yield; penetrates and ends in lacustrine sed?
22	20	S	9/19/80			U.S.G.S. augered test hole; penetrates lacustrine sed.; log in Appendix 1.
23				10	M	Depth to bedrock questionable based on nearby data.
24	40	M				Hard water; slight H_2S taste; depth to rock unknown; neg DD when bailed (owner).
25				13	M	Slightly hard water; trace of H_2S odor.
26	15-20	M				Depth to rock unknown; owner reports H_2S odor in last 5 yrs.
27	75	M		50	M	Supplies home and 40 cattle; 137 mg/L hardness reported.
28	10.6	S	1/27/81	30	E	U.S.G.S. test hole; log in Appendix 1; hole depth 164 ft; screened 121-125 ft.
29	35	D	10/77	10	D	Adequate supply; driller reports water enters at 83 ft.
30	37	S	1/81			U.S.G.S. test hole; log in Appendix 1.
31	28	S	5/28/80			Water level measured through vent pipe 3 ft above LSD.
32						H_2S odor and taste.
33				20+	M	Hard water; well has supplied 2 homes and barn in the past.
34	45	D	10/79	8-9	D	Driller's log in Appendix 1.
35				4	M	Abandoned, buried; aquifer uncertain; household uses spring for supply.
36						Supplies house, barn; 308 mg/L hardness reported by owner.
37	12	M		50	M	Owner reports sand and gravel, 0-39 ft.
38				3.5	M	H_2S odor, taste; owner uses activated carbon-chlorine treatment.
39	5	M				Hard water; owner reports several feet of clay near surface.
40						Very hard water; suction pump; formerly 23 ft deep-failed during the 1960's drought.
41						Owner reports soft water; 2 ft well point; well has never failed.
42	12	M				Owner reports clay 0-11 ft, gravel 11-27 ft, black sand 27-30 ft.
43	23	D	9/7/63	25	D	Hard water.
44				8	M	Owner reports sand and gravel 0-21 ft, then some gray clay.
45	20	M	3/80			Supplies house, farm; owner measured water level when pump was removed 3/80.
46				20	M	Owner reports soft water, iron.
47	45	D	1/74	6	D	Driller's bail tests: 105 ft-water to drill with, 186 ft-5 GPM, 210 ft-6GPM.
48	14.6	S	11/20/80			U.S.G.S. test hole; log shown in Appendix 1; SWL 14.6 ft with well cased to 32 ft.
49						Supplies house and barn.
50				30+	D	Driller reports sand and gravel 0-58 ft, shale 58-105 ft.
51	7	M				Suction pump; owner reports well ends in gravel; pumped at 60+ GPM (E) w/2 ft DD.
52	20	M		12	M	Owner reports slight H_2S odor, taste.

Appendix I: Records of Wells (Continued)

No.	Location	Owner	Use	Date drilled	Method	Well diam (in)	Well depth (ft)		Casing depth (ft)		Depth to bedrock		Finish	Aquifer	Altitude
53	4239 07 7533 20	Clarence Brooks	D	1968	C	6	52	M	52	M			S	S&G ?	1130
54	4239 14 7533 21	U.S.G.S.	T	9/17/80	B	8	31	S			29	S	N	silty S&G	1133
55	4239 08 7533 23	Robert Maynard	D	c.1974	R	6	38	M	38	M			O	S&G	1140
56	4239 13 7533 23	Rupert Alderman	D	1980	V	1	23	M	21	E			D	S&G	1132
57	4239 21 7533 30	Kent Blanchard	A	?	C	6	55	M	55	M			O	S&G	1150
58	4239 56 7533 50	William Stevens	D	?	C	6	32	M	?				S	S&G	1170
59	4239 43 7533 53	Gerald Nelson	D	1978	C	6	135	D	112	D	111	E	X	bedrock	1250
60	4239 37 7533 56	Robert Lloyd	D	1956	C	6	97	M	44	M	44	E	X	bedrock	1230
61	4239 26 7534 06	Gary Graham	D	1973	C	6	170	D	30	D	30	D	X	bedrock	1295
62	4240 03 7530 44	Harold Bundy	D	1945	C	6	185	M	85	M	85	M	X	bedrock	1100
63	4240 04 7531 19	Robert Covell	D	1969	C	6	168	M	28	M	28	M	X	bedrock	1260
64	4240 43 7533 34	Paul Hunsicker	A	c.1940	C	6	180	M	?		?		X	bedrock	1305
65	4240 27 7533 43	Carl Manwarren	D	1975	C	6	96	M	96	M			O	S&G	1210
66	4240 08 7533 51	Art Bennett	D	1972	V	1.25	20	M	18	M			D	S&G	1165
67	4240 10 7533 51	George Baker	D	1965	C	5	29	M	29	M			O	S&G	1165
68	4240 14 7533 51	Dan DuBois	D	c.1978	V	2.5	20	M	18	E			D	S&G	1165
69	4240 20 7533 51	Don Brokaw	D	?	V	.75	15	S	13	S			D	S&G	1165
70	4240 01 7533 52	Gordon Monroe	D	1967	C	6	110	M	28	M	28	M	X	bedrock	1175
71	4240 22 7533 52	Joseph Pinckney	D	1978	V	1.25	16.5	M	14	M			D	S&G	1165
72	4240 25 7533 52	Leo. Blackman	D	1978	V	2	20	M	19.5	M			D	S&G	1167
73	4240 02 7533 53	Raymond Monroe	D	c.1975	C	5	29	M	29	M			O	S&G	1175
74	4240 03 7533 54	Albert Monroe	D	1969	V	1.25	22	M	20	E			D	S&G	1175
75	4240 09 7533 54	Chas. Thompson	D	1975	C	6	52	M	38	E	38	M	X	bedrock	1165
76	4240 08 7533 55	Kirk McKee	D	1976	C	6	48	D	31	D	31	D	X	bedrock	1170
77	4240 27 7533 56	Harry Shortway	D	1978	V	2	12	M	10	E			D	S&G	1172
78	4240 04 7533 57	Ralph Simons	D	1975	C	6	39	D	26	D	26	D	X	bedrock	1170
79	4240 06 7534 03	Gene Nelson	U	b.1900	D	42	35	M	?	M			W	S&G	1195
80	4240 12 7534 05	John Maynard	D	b.1960	D	36	25	M	?	M			W	S&G	1180
81	4240 14 7534 07	Marvin Tefft	D	1963	D	-	9	E	?				W	S&G	1180
82	4240 21 7534 18	Galen Barnes	D	1964	C	6	118	M	24?		24	M	X	bedrock	1185
83	4240 22 7534 18	Barney Hubbell	D	5/1980	C	6	100	D	20.5	D	20	D	X	bedrock	1190
84	4240 30 7534 22	Smyrna Lumber	C	c.1970	V	1.25	20	M	18	E			D	S&G	1180
85	4240 39 7534 28	Leon Brown	D	?	D	36	20	M	?	M			W	S&G	1170
86	4240 58 7534 30	Lee Schwarting	D	b.1900	D	36	17	M	?	M			W	S&G	1195
87	4240 49 7534 33	Aubrey Fuller	D	c.1956	C	4	50	M	30	E	30	M	X	bedrock	1195
88	4241 37 7532 42	John Lawrence	D	1955	C	6	120	M	60	M	60	M	X	bedrock	1127
89	4241 39 7532 42	Bruce Blanchard	U	1979	C	6	98	S	56	S	56	E	X	bedrock	1110
90	4241 39 7533 04	Lok-N-Logs	C	?	C	6	90	M	75	M	75	E	X	bedrock	1095
91	4241 35 7533 19	Robert Wright	A	?	V	1.5	15	M	13	E			D	S&G	1103
92	4241 50 7533 24	Henry Drexler	A	11/1978	C	6	56	D	56	D			O	S&G	1105
93	4241 27 7533 32	Vill. of Smyrna	T	4/7/81	B	6	31.5	D					N	fine sand	1119
94	4241 29 7533 34	Vill. of Smyrna	T	3/6/81	B	6	61.2	D					N	S&G	1122
95	4241 28 7533 36	Vill. of Smyrna	T	4/6/81	B	6	59.5	D					N	S&G	1120
96	4241 21 7533 39	Vill. of Smyrna	T	4/7/81	B	6	56.5	D					N	S&G	1123
97	4241 27 7533 39	Vill. of Smyrna	T	4/3/81	B	6	47.5	D			47.5	D	N	S&G	1127
98	4241 25 7533 41	Vill. of Smyrna	T	4/2/81	B	6	44	D					N	gravel	1130
99	4241 20 7533 46	Vill. of Smyrna	M	4/29/81	C	8	56	D	47	D			S	S&G	1127.2
100	4241 19 7533 47	Vill. of Smyrna	U	4/20/81	B	6	101	D	62	D	58.6	D	X	bedrock	1127.5
101	4241 09 7533 59	Baillie Lumber	C	c.1970	V	1.5	28	M	26	E			D	S&G	1137
102	4241 10 7533 59	Baillie Lumber	C	c.1970	V	2	21	M	19	E			D	S&G	1137
103	4241 05 7534 01	Baillie Lumber	C	1977	C	6	75	D	52	D	52	D	X	bedrock	1140
104	4241 08 7534 05	Vill. of Smyrna	M	c.1901	D	120	30	S	?	S			W	S&G	1145
105	4241 02 7534 23	Bruce Blanchard	A	c.1963	C	6	127	D	24	D	24	D	X	bedrock	1160

Appendix I: Records of Wells (Continued)

No.	Water level (ft)		Date	Yield (gpm)		Remarks
53	6	M				Hard water; water softener used.
54	25	E	9/17/80			U.S.G.S. augered test hole; log shown in Appendix 1.
55	14.75	S	5/21/80	8	M	Slightly hard water; MP is vent hole in top of casing, 1.4 ft above LSD.
56	7	M				Suction pump; slightly hard; owner reports nearby 19 ft well failed August, 1980.
57	10	M				Supplies 3 homes and 75 cattle.
58				17	M	Suction pump; screen size unknown; log (O): S&G 0-6 ft, hdpn 6-12 ft, S&G 12-32 ft.
59	88.1	S	5/9/80	20	D	Driller reports: hole dry to rock, neg DD at 20 GPM; MP is 1.5 ft above LSD.
60	20	M		10	M	Very hard water; owner reports gravel 0-14 ft, hard clay 14-44 ft (till?).
61	35.9	S	5/20/80	3	D	Driller reports hardpan over gravel 0-30 ft; MP is 1.1 ft above LSD.
62						Owner reports sand and gravel 0-85 ft.
63				10	M	
64	40	M				Supplies home, 200 cattle; H_2S odor; depth to rock unknown (suspect shallow rock).
65	71	M		100	M	Owner reports hard water sand and gravel 0-96 ft.
66	15	M		30	M	Suction pump; 2 ft drive point; hard water; can pump 30 GPM for short periods (O).
67	10	M		40+	M	Owner reports yield greater than 40 GPM when drilled.
68						Suction pump; owner reports well has never failed.
69	8.3	S	5/7/80			Suction pump; MP is top of 3/4" pipe-1 ft above basement floor, 3 ft below LSD.
70	28	M		3.5	M	Trace H_2S, iron; owner chlorinates occasionally for iron bacteria; S&G 0-28 ft (O).
71	10	M		5	M	Owner reports 18" drive point; hard water.
72	9	M				Suction pump; 6" drive point; owner reports recent H_2S; well has never failed.
73	12	M				Owner reports: S&G 0-29 ft, cobbles near surface; well can supply 3-4 homes.
74						Owner reports well occasionally fails during droughts.
75	16	M				Owner reports well has never failed; suction pump.
76	15.5	S	5/6/80	12	D	Log in Appendix 1; water enters at 36 ft (D); MP is 1.2 ft >LSD.
77						Owner reports well occasionally fails during late summer.
78	7.9	S	5/7/80	8	D	Driller reports: S&G 0-26 ft; MP is top of casing, 0.9 ft above LSD.
79	27.3	S	5/6/80			Owner reports very hard water, low yield; uses spring; MP-top stone curb at LSD.
80	9.05	S	5/6/80			Owner reports well has never failed; MP is top of stone curbing at LSD.
81	7	M				Hard water; well is 2 x 4 ft rectangular pit in basement floor; fails occasionally.
82				3	M	Owner reports S&G 0-24 ft.
83	11	D	5/2/80	4	D	Driller reports: loam 0-8 ft, S&G 8-20 ft; bail test-4 GPM with approx. 85 ft DD.
84						Owner reports well has never failed.
85	3	M				Suction pump; owner reports well fails occasionally during droughts.
86	16.1	S	5/5/80	10+	M	Suction pump; owner can pump 10 GPM for 40 min w/neg DD; MP is top curb at LSD.
87						Well depth approximate.
88	40	M		2	M	Owner reports S&G 0-60 ft, bottom few feet is "quicksand" - cased off to rock.
89	13.61	S	5/20/80	8	M	Well to supply dairy farm at future date; MP-top of casing, 1.2 ft above LSD.
90	4.21	S	5/9/80			MP is top of reducer at vent hole, 2.3 ft above LSD.
91						Suction pump; drive point; supplies 90 cattle.
92	9.02	S	5/20/80	36	D	Hard water; fne Sw/G 0-40 ft, crse S&G 40-56 ft, 19 ft DD @ 36 GPM (D); MP-2 ft >LSD.
93	7	D	4/7/81			Test boring No. 6 for Village of Smyrna; log in Appendix 1.
94	10	D	3/6/81			Test boring No. 4 for Village of Smyrna; log in Appendix 1.
95	7	D	4/6/81			Test boring No. 3 for Village of Smyrna; log in Appendix 1.
96	7	D	4/7/81			Test boring No. 5 for Village of Smyrna; log in Appendix 1.
97	9	D	4/3/81			Test boring No. 2 for Village of Smyrna; log in Appendix 1.
98	10	D	4/2/81			Test boring No. 1 for Village of Smyrna; log in Appendix 1.
99	5.37	D	7/2/81	150	D	Future supply well; 2.5 ft DD @ 150 GPM after 24 hrs; log in Appendix 1.
100	4	D	4/20/81	100	D	Future supply well (?); silt, S&G 0-58 ft, 60 ft DD @ 100 GPM after 2.5 hrs (D).
101						Supplies washroom; occasionally fails during late summer.
102	15	M				Used for log washing; occasionally fails during late summer.
103	10.4	S	5/7/80	30	D	Boiler feed water; softener used; MP is 1.1 ft >LSD; log in Appendix 1.
104	14.9	S	5/7/80	100	D	Municipal supply; MP is 5 ft <LSD; SWL in nearby rock well 11.1 ft <LSD (S-5/7/80).
105	17.0	S	5/20/80	10	D	Hard water; MP 1.6 ft >LSD; meas during recovery; SWL 13 ft <LSD, 1/64 (D).

Appendix II: Selected Well and Test-Boring Logs

[Locations shown on plate 1.]

Wells and test borings are identified on plate 1 by a hyphenated, four-digit number representing the location of the well or test boring in seconds of latitude and longitude. For example, the test boring at 42°37'22" latitude 75°32'05" longitude is shown as test boring 22-05 on plate 1.

Colors referred to in sample descriptions and shown in parenthesis, for example (10YR 4/2), are taken from the Rock-Color Chart (Goddard and others, 1970) distributed by the Geological Society of America. Abbreviations are explained in "Remarks" on page 37.

U.S. Geological Survey Test Boring at Location 4237 22 7532 05

Drilled with U.S. Geological Survey hollow-stem auger rig 9/18/80. Log based on field examination of drill cuttings and cores by G. A. Brown. Depths are in feet below land surface. Land-surface datum approximately 1,050 ft above sea level.

Depth interval	Materials penetrated
0 - 2 ft	Soil, fill
2 - 6 ft	Gravel - 1/4" to 1"
6 - 26 ft	Interbedded sand and gravel, brown, poorly to fairly sorted, gravel up to 2" diam. Water table at 23 ft.
26 - 31 ft	Sand, dark brown, medium to coarse
31 - 36 ft	Sand, with gravel up to 1/2" diam.
36 - 41 ft	Sand, with gravel up to 1" diam.
41 - 46 ft	Interbedded fine sand, medium to very coarse sand, and sand and gravel up to 1"
46 - 46.5 ft	Hard drilling, boulder?
46.5- 50 ft	Easier drilling
50 - 51 ft	Hard drilling, boulder
51 - 52 ft	Sand and gravel, gravel to 1/2"
52 - 56 ft	Clayey silt, medium yellowish brown
56 - 58 ft	Sand and gravel. Sand, medium to very coarse, gravel up to 1", predominantly local shale material
58 - 61 ft	Medium sand and gravel up to 1/2", interbedded with yellowish brown very fine to fine sand, shale cobbles, and gravelly clay.
61 - 71 ft	Interbedded sandy gravel and sand. Sandy gravel is medium sand to 1/2" gravel. Sand lenses are very fine to medium with some silt, poorly sorted.
71 - 76 ft	Silty sand and gravel and silt, interbedded. Sand and gravel is dark yellowish brown, fine sand to 1/2" gravel, silty, poorly sorted. Silt is mottled gray and yellowish brown with pebbles.
76 - 81 ft	Interbedded fine sand, clayey gravelly sand, and shale cobble zones, diameters to 1 1/2".
81 - 85.5 ft	Till - dry near bottom, mixture of clay, silt, sand, and cobbles to 1 1/2". Pebbles and cobbles are quartz and shale.
85.5- 86.5 ft	Bedrock, shale - driller reports refusal.

Appendix II. Selected Well and Test-Boring Logs (Continued)

U.S. Geological Survey Test Boring at Location 4237 33 7532 11

Drilled with U.S. Geological Survey hollow-stem auger rig 9/19/80. Log based on field examination of drill cuttings and cores by G. A. Brown. Depths are in feet below land surface. Land-surface datum approximately 1,050 ft above sea level.

Depth interval	Materials penetrated
0 - 16 ft	Sand and gravel fill for railroad grade
16 - 21 ft	Sandy silt, medium yellowish brown. Water table at aproximately 20 ft.
21 - 31 ft	Interbedded well sorted sands and sandy silt beds. Sand is fine to medium, well sorted. Silt is slightly sandy, yellowish brown.
31 - 37 ft	Interbedded sand and gravel to 1/8", poorly sorted silty gravelly sand, and very fine silty sand.
37 - 83 ft	Lacustrine sediments--variably clayey silt, varved in sections, grayish-brown, occasional pebbles. Also, thinly interbedded layers of sandy silt, clayey sand, sandy clay, and clean well-sorted sand. Silt-bound layers are grayish-brown, sand is fine to medium. Occasional beds of clayey gravelly sand, dark yellowish brown.

U.S. Geological Survey Test Boring at Location 4238 49 7531 57

Drilled with cable tool rig 10/23-11/7/80. Log based on field examination of cuttings by G. A. Brown. Depths are in feet below land surface. Land-surface datum approximately 1,060 ft above sea level. Finished 6" diam. observation well screened 121-125 ft with 5-inch x 5-ft-long PVC slotted screen, 0.016 inch slots. MP is top of coupling, 4 ft above land-surface datum. Well bailed at 30-40 GPM with negligible drawdown, static level 15 ft below land-surface datum.

Depth interval	Materials penetrated
0 - 12 ft	Silty sand and gravel up to 1 1/2", approximately 50 percent silt and/or clay; occasional cobbles.
12 - 20 ft	Silty sand and gravel up to 1/2", tan to brown, sand medium to coarse.
20 - 26 ft	Sand and gravel, dark gray, gravel up to 3/4" interbedded with thin beds of bright yellow-brown silt. Silt washes out easily, saturated material. Material heaves into casing.
26 - 35 ft	Silty sand and gravel, dark gray. Sand size ranges to very coarse, gravel to 1/4". Material heaves into casing.
35 - 44 ft	Sand and gravel, very little silt or clay, gravel up to 1" diam., yields some water.
44 - 52 ft	Sand and gravel; predominantly coarse to very coarse sand to 1/8" gravel, with much gravel to 1/2," some cemented gravel, with well cased to 48 ft, water level rose to 12 ft below LSD; bailed at 10-20 gpm.

U.S. Geological Survey Test Boring at Location 4238 49 7531 57 (cont.)

Depth interval	Materials penetrated
52 - 55 ft	Slightly silty sand and gravel, sand medium to very coarse, gravel to 1 1/2", not yielding as much water.
55 - 57 ft	Hard drilling, hard coarse gravel.
57 - 63 ft	Sand and gravel, slightly silty. Sand medium to very coarse, some light grayish brown sandy silt, gravel to 1/4". Well bailed with casing at 63 ft; SWL was 45 ft below LSD 20 min. after bailing.
63 - 67 ft	Sand and gravel with interbedded sandy silt; medium to very coarse sand, gravel up to 1/4" - 1/2", mineralogy predominantly black and dark gray shale; tan, buff and red sandstone, and quartz. Sandy silt is grayish brown with very fine to fine sand. Yields little or no water.
67 - 73 ft	Sand, very fine to very coarse, predominant size is very fine to medium, some fine gravel, slightly silty, becoming coarser with depth. Coarser fraction predominantly black shale, fine fraction predominantly quartz. Driller can drill about 1 ft ahead of casing before material caves.
73 - 80 ft	Sand, coarse, with fine gravel to 1/8", silty, with interbedded silty sand. Driller able to drill several feet ahead of casing; not yielding water. With casing at 79 ft, static water level after 40 hours was 11 ft below LSD.
80 - 94 ft	Sand and gravel, variably silty, interbedded with sandy silt. Sand predominantly coarse sand with gravel to 1/4". Sandy silt is grayish brown, compact; hole stays open ahead of casing, yields little or no water, boulder or large cobbles of black siltstone at 90-91 ft. With casing at 94 ft, overnight static water level is 80 ft below LSD.
94 - 95.5 ft	Siltstone boulder.
95.5-121 ft	Silty sand and gravel, sand up to very coarse with very fine gravel to 1/8", rare gravel to 1/4". Silt matrix is grayish brown. Yields little or no water.
121 -131 ft	Sand, predominantly fine to medium with some coarse sand and fine gravel, material coarser with depth, slightly silty. Well bailed to develop formation, water level recovered to within 20 ft of LSD.
131 -138 ft	Interbedded silty sand with gravel and silty sandy clay. Sand and gravel very silty, sand size ranges to very coarse, gravel up to 3/4".
138 -150 ft	Fine silty sand grading downward into silty sand and gravel, sand ranges to very coarse, gravel up to 1 1/2".
150 -155 ft	Clayey silt, gray, bedrock at 155 ft.
155 -158 ft	Siltstone, soft, dark gray to black.
158 -164 ft	Siltstone, hard, bottom of test hole.

U.S. Geological Survey Test Boring at Location 4238 35 7532 15

Drilled with cable tool rig 1/26-1/29/81. Log based on field examination of cuttings by R. J. Reynolds. Depths are in feet below land surface. Land-surface datum approximately 1,070 ft above sea level.

Appendix II. Selected Well and Test-Boring Logs (Continued)

U.S. Geological Survey Test Boring at Location 4238 55 7532 15

Depth interval	Materials penetrated
0 - 15 ft	Sand and gravel, with many cobbles and 15-30 percent clayey silt. Sand is very coarse, gravel is very fine, cobbles to 6", clayey silt matrix is dark yellowish brown (10 yr 4/2). Material becomes siltier with depth. Grass and plant roots inbedded in material at 15 ft suggests upper 15 ft may be fill.
15 - 30 ft	Very coarse sand to very fine gravel in a silty clay matrix. Silty clay comprises 40-50 percent of sample. Particles of subangular to angular shale, red and tan sandstone, green siltstone.
30 - 55 ft	Very coarse sand to very fine gravel with very fine sand, and silty clay. Silty clay comprises 30-50 percent of sample. Occasional pebbles and subrounded stones to 2". Material gets saturated near 40 ft.
55 - 70 ft	Well sorted fine to medium sand with less than 5 percent silt and clay. Clay is dark yellowish brown.
70 - 80 ft	Fine to coarse sand, small amounts of fine gravel, silt and clay content less than 5 percent. Not as well sorted as material at 55-70 ft. With well cased to 70 ft, overnight static water level was 37 ft below LSD. Material heaves into casing.
80 - 90 ft	Coarse to very coarse sand, fairly well sorted with some medium sand. Approximately 10-15 percent silty clay. Material heaves into casing.
90 -100 ft	Fine to very fine sand with 15-20 percent silty clay. Clay is light olive gray (5 yr 5/2). Also minor amounts of medium coarse sand and very coarse sand to fine gravel.
100 -103.5 ft	Well sorted medium sand with minor amounts of fine sand. Clay silt content less than 5 percent. Color is dark yellowish brown (10 yr 4/2).

Driller's Log of Wells at Location 4238 54 7532 40

Depths are in feet below land surface. Log by Sergi's Well Drilling, Greene, N.Y. Land-surface datum is approximately 1,098 ft above sea level.

Depth interval	Materials penetrated
0 - 20 ft	Gravel
20 - 30 ft	Hardpan
30 - 37 ft	Large gravel, baseball-size cobbles.
37 - 55 ft	Hardpan, gray.
55 - 68 ft	Bedrock "ledge" (boulder?)
68 - 75 ft	Hardpan
75 - 80 ft	Bedrock, shale.

Appendix II. Selected Well and Test-Boring Logs (Continued)

U.S. Geological Survey Test Boring at Location 4239 25 7530 59

Drilled with cable tool rig from 11/19-11/25/81. Log based on field examination of drill cuttings by G. A. Brown. Depths are in feet below land surface. Land-surface datum is approximataely 1,065 ft above sea level.

Depth interval	Materials penetrated
0 - 15 ft	Sand, slightly silty, dry.
15 - 25 ft	Sand and gravel, silty to slightly silty, gravel to 3/4". Water table approximately 18 ft, yielding water at 21 ft.
25 - 32 ft	Sand and gravel, very silty, predominantly medium to very coarse sand with gravel up to 1/8". Silt matrix is yellowish brown. Mineralogy is predominantly black and dark gray siltstone; red, tan, sandstone, some quartz. With casing at 32 ft, overnight SWL was 14.6 ft below LSD.
32 - 56 ft	Sand and gravel, very to slightly silty, sand up to very coarse with gravel up to 1/4", some gravel to 3/4".
56 - 70 ft	Lacustrine material-silt and clay, ranges from silty clay to clayey silt, dark gray to brownish gray, ocasionally interbedded with thin layers of very fine sand or dark brown layers of silt. Yields no water, material heaves 20 ft into casing.
70 - 90 ft	Sandy silt, grayish brown, approximately 50 percent silt, 50 percent very fine sand, occasionally interbedded with dark brown silt beds. Occasional rounded siltstone fragments to 1" diam. (ice-rafted stones?). Material still heaves about 20 ft into casing.
90 -106 ft	Gravelly silt. Could be collapsed kame terrace material. Predominantly silt and very fine sand with some interbedded very coarse sand and gravel to 1/2". Yields some water on bailing. Also interbeds of silt or clayey silt, especially near bottom. Formation heaved 45 ft up into casing during weekend. Static water level at 15 ft below LSD.
106 -118 ft	Predominantly silt and fine sandy silt, interbedded with thin layers of very fine sand, and occasional silty gravel up to 2 1/2".
118 -133 ft	Silty sand and gravel ranging to gravelly silt. Very silty, interbedded with gravel up to 1/4", occasional gravel to 2". Mineralogy is black siltstone, red and tan sandstone. Yields some water; with casing at 132 ft, bailed to within a few feet of bottom. Static water level about 40 ft below LSD with casing at 128 ft.
133 -137 ft	Bedrock-black siltstone.

U.S. Geological Survey Test Boring at Location 4239 14 7533 21

Drilled with U.S. Geological Survey hollow-stem auger rig on 9/17/80. Log based on field examination of drill cuttings and cores by G. A. Brown. Depths are in feet below land surface. Land-surface datum is approximately 1,133 ft above sea level.

U.S. Geological Survey Test Boring at Location 4239 14 7533 21 (cont.)

Depth interval	Materials penetrated
0 - 13 ft	Gravel, predominantly 2-3" diam., well sorted.
13 - 17 ft	Fine gravel, becoming finer with depth, ranging from 1/4 to 1/2" diam.
17 - 25 ft	Gravel, up to 3" diam.
25 - 29 ft	Till, with angular fragments and some rotten granite stones. Hole dry above till, till was wet, suggesting water table near top of till.
29 - 31 ft	Bedrock-shale.

Driller's Log of Wells at Location 4240 08 7533 55

Depths are in feet below land surface. Log by McLean Well Drilling, Greene, N.Y. Land-surface datum is approximately 1,170 ft above sea level.

Depth interval	Materials penetrated
0 - 3 ft	Abandoned railroad bed, gravel, cinders.
3 - 25 ft	Gravel with boulders (cobbles? - RJR)
25 - 31 ft	Clay-like material (till? - RJR)
31 - 48 ft	Bedrock, shale, water enters at 36 ft.

Log of Test Boring at Location 4241 27 7533 32

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna on 4/7/81. Log by soils technician. Depths are in feet below land surface. Land-surface datum is approximately 1,119 ft above sea level.

Depth interval	Materials penetrated
0 - 5 ft	Coarse to fine sand, little fine gravel, trace to little silt. Moist, brown.
5 - 10 ft	Medium to fine gravel, brown, wet, little silt and sand.
10 - 15 ft	Medium to fine sand, saturated, brown, trace of fine gravel, coarse sand, silt.
15 - 31.5 ft	Fine sand, saturated, brown, trace to little silt. Boring terminated at 31.5 ft. Water table approximately 7 ft below land surface.

Log of Test Boring at Location 4241 29 7533 34

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna on 3/6/81. Log by soils technician. Depths are in feet below land surface. Land-surface datum is approximately 1,122 ft above sea level.

Log of Test Boring at Location 4241 29 7533 34 (cont.)

Depth interval	Materials penetrated
0 - 10 ft	Sand and gravel, brown, moist to wet, trace to little silt.
10 - 13 ft	Coarse to fine gravel, brown, wet, little coarse to fine sand, trace to little silt.
13 - 55.5 ft	Silt, saturated, trace of clay, with varying amounts of fine sand.
55.5- 61.2 ft	Coarse to fine gravel, little coarse to fine sand, trace to little silt. Boring terminated at 61.2 ft. Water table approximately 10 ft below land surface.

Log of Test Boring at Location 4241 28 7533 36

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna 4/6/81. Log by soils technician. Depths are in feet below land surface. Land-surface datum is approximately 1,120 ft above sea level.

Depth interval	Materials penetrated
0 - 10 ft	Coarse to fine sand, moist, brown, little silt, trace of fine gravel.
10 - 20 ft	Medium to fine gravel, brown, saturated, little coarse to fine sand, trace of silt.
20 - 45 ft	Fine to very fine sand, little silt, brown, saturated.
45 - 59 ft	Medium to fine sand with traces of fine gravel and coarse sand, trace to little silt.
59 - 59.5 ft	Medium to fine gravel, some coarse to fine sand, little silt. Boring terminated at 59.5 ft. Water table approximately 7 ft below land surface.

Log of Test Boring at Location 4241 21 7533 39

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna 4/7/81. Log by soils technician. Depths are in feet below land surface. Land-surface datum is approximately 1,123 ft above sea level.

Depth interval	Materials penetrated
0 - 7 ft	Silt, brown, moist, trace of sand and gravel.
7 - 15 ft	Coarse to fine gravel, saturated, little coarse to fine sand, trace to little silt.
15 - 49 ft	Predominantly fine to very fine sand, little silt, interbedded with some medium sand.
49 - 56.5 ft	Coarse to fine gravel, little coarse to fine sand, trace of silt. Boring terminated at 56.5 ft. Water table approximately 7 ft below land surface.

Appendix II. Selected Wells and Test-Boring Logs (Continued)

Log of Test Boring at Location 4241 27 7533 39

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna 4/3/81. Log by soils technician. Depths are in feet below land surface. Land-surface datum is approximately 1,127 ft above sea level.

Depth interval	Materials penetrated
0 - 17 ft	Predominantly coarse to fine gravel, some coarse to fine sand, some to little silt.
17 - 35 ft	Very fine to fine sand, traces of silt (interbedded), occasional traces of coarse to medium sand, saturated.
35 - 47.5 ft	Medium to fine sand, traces of fine gravel, coarse sand, and silt.
47.5 ft	Bedrock (refusal). Water table approximately 9 ft below land surface.

Log of Test Boring at Location 4241 25 7533 41

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna 4/2/81. Log by soils technician. Depths are in feet below land surface. Land-surface datum is approximately 1,130 ft above sea level.

Depth interval	Materials penetrated
0 - 10 ft	Coarse to fine sand, little fine gravel, trace to little silt.
10 - 42 ft	Predominantly very fine sand and silt, traces of medium to fine sand, saturated. (Lacustrine materials - RJR)
42 - 44 ft	Coarse to fine gravel, little sand and silt - brown to gray. Boring terminated at 44 ft. Water table approximately 10 ft below land surface.

Log of Test Boring at Location 4241 20 7533 46

Drilled by Catoh Environmental Companies, Inc., with hollow-stem auger rig for Village of Smyrna 4/29/81. Log by soils technician and driller. Public-supply well installed. Screened from 47 to 56 ft below land surface. Static water level (7/2/81) is 5.37 ft below land surface. Depths are in feet below land surface. Land surface is 1,127.2 ft above sea level (levelled). Two PVC observation wells located nearby.

Depth interval	Materials penetrated
0 - 7 ft	Sand and silt, moist, brown.
7 - 15 ft	Sand and gravel, wet to saturated.
15 - 25 ft	Silty sand and gravel, saturated, brown.
25 - 27 ft	Cobbles and boulders.
27 - 46 ft	Silty sand and gravel, brown.
46 - 54 ft	Predominantly alternating beds of coarse to fine gravel and coarse to fine sand, brown, with traces of silt.
54 - 57 ft	Alternating thin beds of coarse to fine sand and coarse to fine gravel, gray, with traces of silt. Boring terminated at 57 ft.

Appendix III: Seismic Refraction Profiles

Two seismic-refraction profiles across the east and west limbs of the valley (pls. 1 and 2) in November 1980 were analyzed by a computer program that interprets seismic-refraction data. The computer program (Scott and others, 1972) generates a two-dimensional model that represents a layered-earth depth interpretation based on the input data. Seismic-wave traveltimes are identified on the seismic records by the geophysicist, and these data, together with shot-point and geophone locations and refraction layer control information, are submitted as input data to the program.

A first approximation of each refracting horizon is obtained by a computer adaptation of the delay-time method. The approximation is then tested and improved by the computer through a ray-tracing procedure in which ray traveltimes are computed for the model and compared against the actual data. The model is subsequently adjusted in an iterative manner to minimize the discrepancy between computed and measured traveltimes.

Certain simplifying assumptions are made that affect the operation of the program and may, therefore, affect the accuracy of the final interpretation. Layer velocities are assumed to increase with layer depth; that is, the uppermost layer has the lowest velocity, and the deepest layer has the highest velocity. This assumption is fundamental to the seismic refraction theory, and most geologic situations encountered in valley aquifer investigations in New York, such as the Smyrna valley, generally meet this assumption. Refracted rays are assumed to represent minimum traveltime paths of compressional seismic waves. The deepest layer is assumed to extend to an infinite depth, and the deepest rays that are considered are those that refract along its upper surface. Finally, each layer of each geophone spread is assumed to be characterized by a constant horizontal velocity along its upper surface and a constant vertical velocity for rays traveling through the layer. This last assumption can cause problems in interpretation, especially if large changes in horizontal velocity occur within a given geophone spread.

The two seismic-refraction profiles of the west limb (fig. 8A) and the east limb (fig. 8B) show the approximate configurations of the water table and the bedrock/till surface. These profiles are based predominantly on the computer-interpreted profile with minor modifications based on water-level and bedrock control data. The computerized profiles, in each case, were in good agreement with test-hole and water-level data.

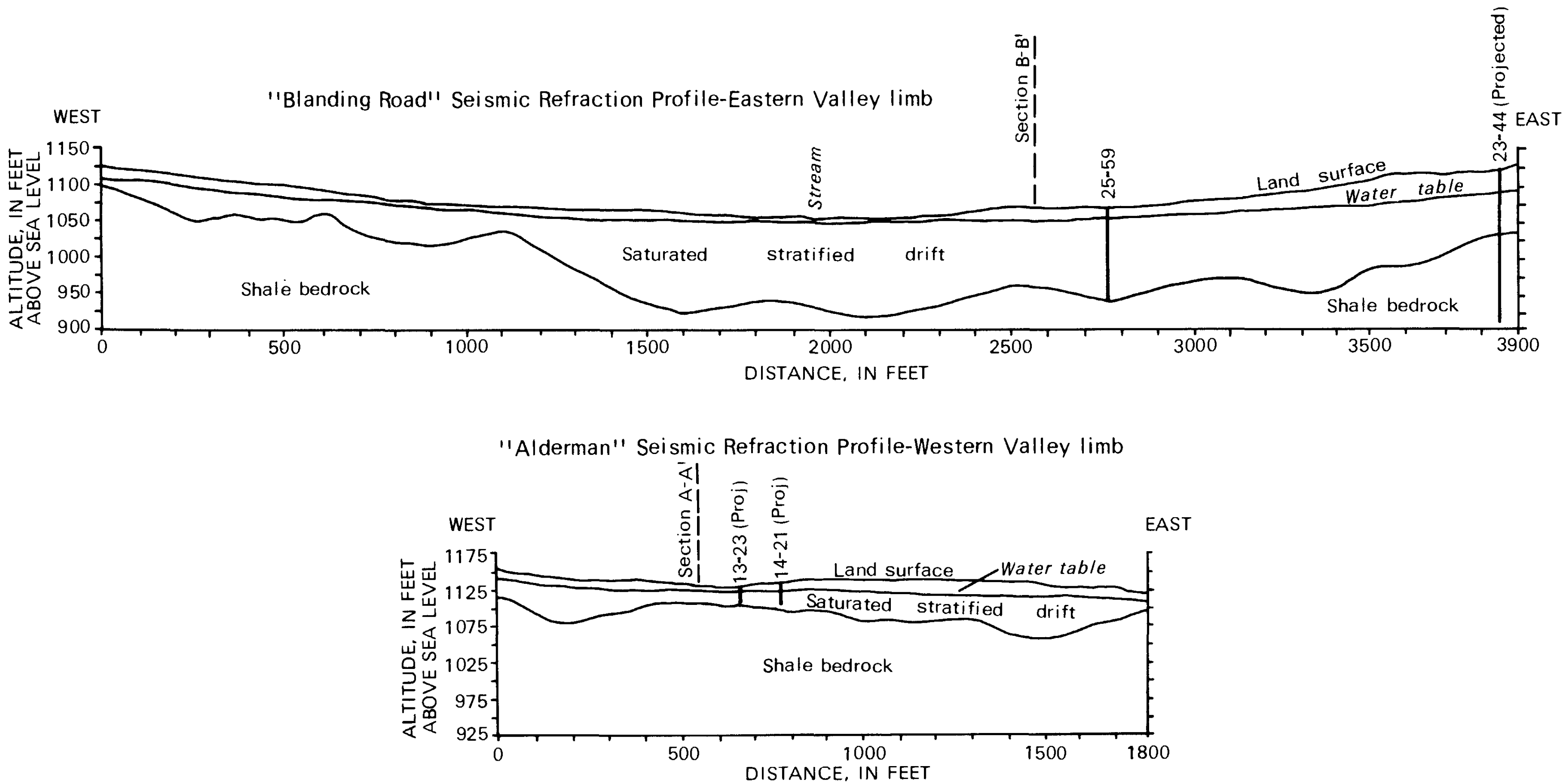

Figure 8.--Seismic-refraction profiles across the limbs of the separated valley.
(Locations are shown in plate 1.)
A. West limb - Alderman line
B. East limb - Blanding Rd. line

Appendix IV: Analysis of Pumping Test

A pumping test conducted by a private consultant for the Village of Smyrna in June 1981 consisted of pumping, in two steps, an 8-inch-diameter well screened in gravel (MacNeil, J. S. Jr., 1981). The well was drilled at the edge of the kame delta near the Village of Smyrna and was equipped with 9 ft of 100-slot well screen exposed to the aquifer. The saturated thickness of materials at this site was 47 ft; two observation wells were installed 12 ft and 62 ft from the pumped well and screened at approximately the same interval as the pumped well. The production well was first pumped for 4 hours at 50 gal/min, which resulted in a drawdown of 0.6 ft in the well after 4 hours. The pumping rate was then increased to 150 gal/min and held there for 44 hours. At the end of the 48-hour test, drawdown in the production well was 2.5 ft. Both observation wells responded rapidly to the pumping-rate change, which would seem to indicate locally semiconfined conditions.

The increase in pumping rate posed an obstacle to conventional analysis, therefore trends of drawdown at the two observation wells at the 50 gal/min rate were extrapolated to the end of the test. The extrapolated drawdowns were then subtracted from the actual observed drawdowns resulting from pumping at 150 gal/min to yield drawdowns for a 44-hour, 100 gal/min test. Resulting data were used in a semilog, time-drawdown plot (Lohman, 1972) to calculate transmissivity and storage coefficient. The data indicated extreme heterogeneity in the aquifer material and numerous localized boundary conditions, as seen in changes of drawdown rate with time throughout the test. The closer of the two observation wells seemed to respond somewhat slower to the boundary effects, which suggests:

1) The closer well was screened in a slightly different zone than the production well screen, whereas the distant well was in approximately the same zone as the production well, or

2) A localized boundary, presumably a silty zone of low hydraulic conductivity as compared to the gravel in the screen zone, is near the distant observation well. Therefore the distant well would have responded to the boundary for some time before its effects reached the closer well.

On a semilog plot of time versus drawdown for the distant observation well, a straight line was fitted to the latest segment of the data before the entrance of the boundary. Substitution of values into an equation by Lohman (1972, p. 21, eq. 56) yielded a transmissivity of approximately 11,500 ft^2/d with a hydraulic conductivity of 245 ft/d. These figures are considered reasonable for the poorly sorted, silty gravel in the screen zone (Randall and others, 1966). Data were not corrected for partial penetration (Jacob, 1963) because the correction factor was found to be negligible. The straight line fitted to the later time-drawdown curve was extended back to the point of zero drawdown, and an estimate of storage coefficient was made through the following equation from Lohman (1972, p. 21, eq. 56):

Appendix IV. Analysis of Pumping Test (Continued)

$$S = 2.25T \left(\frac{t}{r^2}\right) \text{ at zero drawdown}$$

where:
- S = storage coefficient (unitless)
- T = transmissivity, in feet squared per day
- t = time, in days, at point of zero-drawdown
- r^2 = distance from observation point to pumping well, squared

A storage coefficient (S) of 0.021 was calculated and is considered reasonable for the semiconfined conditions expected in such heterogeneous, silty material.

Attempts to use log-log, time-drawdown plots and curve matching techniques to Boulton's delay curves (Prickett, 1965) for water-table conditions (Lohman, 1972) did not result in reasonable values for either T or S.

An attempt to correlate the T value obtained with the plot of time-drawdown data from the distant observation well with a T estimate based on specific capacity of the pumped well gave equivocal results. If it is assumed that the aquifer consists of the entire thickness of stratified drift from the water table to the bottom of the well, then the observed drawdown is corrected for partial penetration (Turcan, 1963), and a 24-hour specific-capacity graph by Walton (1970, p. 318) is applied to yield a transmissivity of 26,700 ft^2/d, a little more than twice that obtained by the semilog time-drawdown analysis. However, the upper part of the stratified section is probably not as permeable as the screened interval (see log of test hole 20-46, appendix I). Therefore, if one assumes that the aquifer consists only of the screened interval, no correction for partial penetration is needed, and Waltons' (1970) graph of specific capacity for 24 hours yields a transmissivity of 12,032 ft^2/d, which is very close to the 11,550 ft^2/d obtained by the semilog plot. Because the T from the latter specific-capacity calculation is close to that of the semilog time-drawdown method, the aquifer may be inferred to be a confined or partially confined localized system in which the pumping well and the distant observation well are screened in approximately the same unit, whereas the closer observation well is not. This would explain why changes in pumping rate affect the distant observation well before it affects the closer observation well. Although the test results show that the aquifer is locally confined, the valley-train and kame-terrace aquifer in the west limb (where the test was conducted) are generally unconfined.

The hydraulic conductivity thus calculated is probably a good estimate for the slightly silty sand and gravel beds and represents average values when compared to the range of values commonly seen in kame terraces and deltas. This value cannot be used for the study area as a whole, however, nor for the kame terrace as a whole, because of the heterogeneous nature of their geologic structure.