GEOLOGY FOR ENVIRONMENTAL PLANNING IN THE BRATTLEBORO-WINDSOR REGION, VERMONT

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VERMONT GEOLOGICAL SURVEY
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(In Pocket)

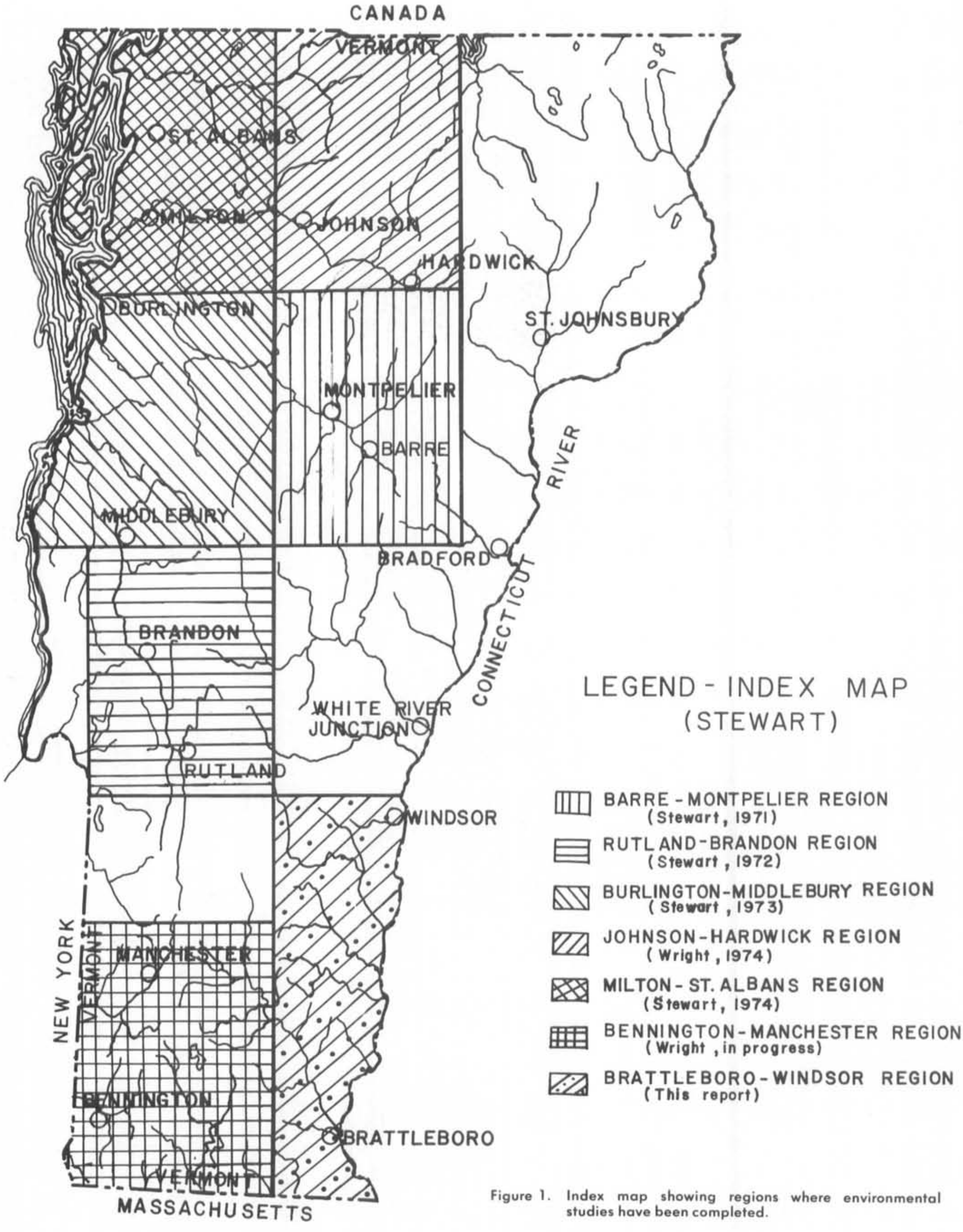

Figure 1. Index map showing regions where environmental studies have been completed.

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INTRODUCTION

The Vermont General Assembly in 1970 approved *Public Act No. 250, An Act to Create an Environmental Board and District Environmental Commissions*, and the State of Vermont was thus committed to a program for the conservation, protection and improvement of the environment. The law, better known simply as Act 250, was a major commitment by a small and essentially rural state to regulate to a significant degree selective activities, such as the use of land, water and air, that have a direct influence on environmental quality. Act 250, at the time of its enactment, was a progressive model for environmental planning inasmuch as the extent of its coverage, the commitment of the state government and its provisions for enforcement surpassed the laws of all other states with the possible exception of Hawaii and California. The law is predicated on the supposition that the right of a citizen to "do as he pleases" is limited by the necessity to legislate for the common good.

Act 250 created an Environmental Board and required the board to establish a state capability and development plan, a state land use plan, and provide guidelines for land use and development. The requirements of this law were acted upon with little delay and a Land Capability Plan, which included general land use, was completed in 1972. A land use and development law, *The Capability and Development Plan, (Public Act No. 85)*, was enacted by the General Assembly in 1973 in accordance with the guidelines submitted by the Environmental Board.

In spite of the enthusiasm for Act 250 by the state and local governments, there has been much opposition to the environmental emphasis by certain segments of the population. The law has inhibited and slowed down real estate development, has required the approval of several agencies for all types of land use, has restricted the construction of such facilities as ski resorts, and has limited the use for which farm land can be bought and sold. Those that oppose the law have not been, to date, successful in their efforts to have it modified or appealed. The adversaries, however, are becoming increasingly better organized, and it remains to be seen whether or not pressure will force the General Assembly to ease the restrictive sections of Act 250 and Act 85. It seems assured, however, that the state government's commitment to a program for environmental quality will continue into the foreseeable future.

Environmental quality is a matter of choice. There are those who insist that the freedoms enjoyed by the people of this country should not be limited at any cost. Others, particularly those concerned about the environment, believe that restrictions are necessary to maintain the quality of the land, water and air; to prevent the exhaustion of natural resources including the soil; and to halt the general degradation of the landscape. In Vermont, this conflict is chiefly concerned with controlled vs. uncontrolled development, preservation of natural beauty, pollution of land, water and air, and the inherent problems of a rugged terrain.

This report is the seventh of a series that have resulted from studies sponsored by the Vermont Geological Survey to supply the geologic information

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necessary for certain aspects of environmental planning. The purpose of these reports is to present this information in a condensed and modified form so that it can be used by environmental planners. The present report attempts to describe and explain the geologic conditions of the Brattleboro-Windsor region, and to outline and summarize these conditions on a series of large-scale maps. The field investigations for this study were completed by the writer, assisted by David Scanlon and James E. Miller, during the summer of 1974. The work was under the direct supervision of Dr. Charles G. Doll, State Geologist.

The accumulation of geologic data is an essential prerequisite to many facets of environmental planning. All environmental problems that involve the movement of water, the supply of ground water, the strength of earth materials and the reserves of earth resources are related to the geology of the subsurface. These factors, in turn, are controlled by the texture of rock and soil, the degree of metamorphic change, the fractures in the rock, the ability of earth materials to hold and transmit water, and the plasticity of the unconsolidated sediment above bedrock. The availability of water and the pollution of water supplies are related to the movement of liquids. The thickness, strength and stability of surficial material determines their suitability for foundations for heavy construction. In addition, special consideration must be given to the location of economically important geologic resources when planning for land use. It is the intent of this report to explain how these specific factors are influenced by the geologic conditions of the Brattleboro-Windsor region and how they relate to the environmental problems of that area.

The environmental geology program has been in progress for five years. The regions that have been studied to date have been selected because of the estimated potential growth of those regions. The initial study was completed in the Barre-Montpelier region (Stewart, 1971), the second in the Rutland-Brandon region (Stewart, 1972), and the third in the Burlington-Middlebury region (Stewart, 1973). Frank M. Wright, III, joined the program in the summer of 1973. During that field season, studies were completed in the Johnson-Hardwick region (Wright, 1974) and the Milton-St. Albans region (Stewart, 1974). In 1974, Wright studied the Bennington-Manchester region and the writer, the Brattleboro-Windsor region (this report). The two reports are scheduled for publication in 1975 (Figure 1).

The region about which this report is concerned is in the extreme southeastern corner of the state. The area is a long, relatively narrow strip that extends north and south along the west side of the Connecticut River from the Massachusetts border to

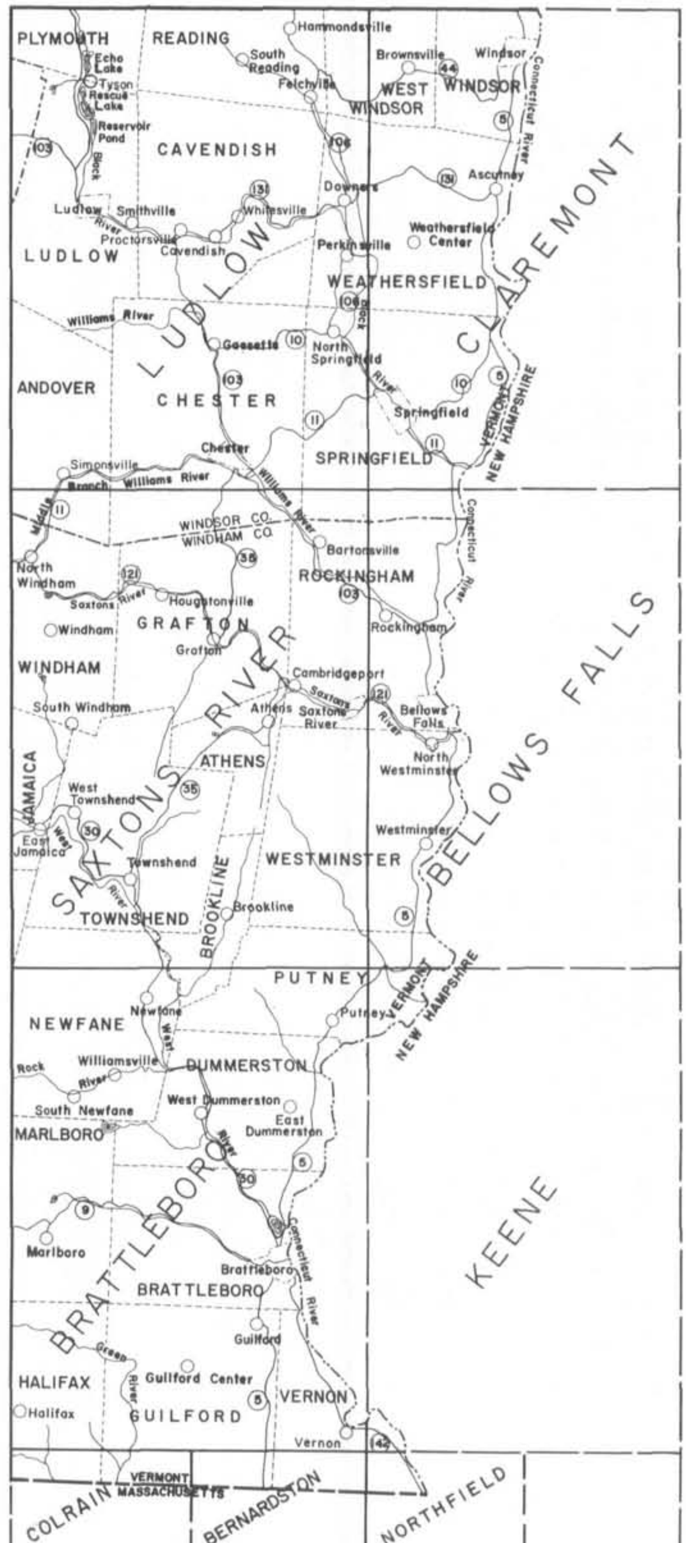

Figure 2. Index map showing the location of quadrangles, townships, cities and villages of the Brattleboro-Windsor region.

the vicinity of Windsor, a distance of approximately 55 miles (Figure 1). In an east-west direction the region lies between the Connecticut River and the line marking the longitude 72° 45′ (west). The width is 15 miles at the Massachusetts line, narrows to 10 miles at Brattleboro, widens again north of Brattleboro and is 19 miles at Windsor. Included in this region are the Ludlow and Saxtons River quadrangles, the Brattleboro quadrangle except for a small area in New Hampshire, the Vermont sections of the Bellows Falls and Claremont quadrangles and small areas of the Keene quadrangle to the east and the Colrain, Bernardston and Northfield (seven and one-half minute) quadrangles along the southern border (Figure 2). The region has a predominantly rugged topography inasmuch as it includes portions of the Green Mountain and the New England Upland geomorphic provinces and elevations range from very low (200 to 400 feet) along the major streams to relatively high (2000 to 3000 feet) on the mountain crests.

Development and growth in the Brattleboro-Windsor region has not been excessive in recent years. Growth that has occurred has been mostly rural. Whereas the population of Windham and Windsor counties has increased more or less steadily over the past twenty years, the population of all of the villages with populations of over 1,000 have decreased in the past decade (Vermont Secretary of State, 1970). The recent rural trend is interestingly illustrated by the water-wells drilled in the region. Records for approximately 2,500 water-wells drilled in this region have been filed with the Vermont Department of Water Resources since 1967. A plot of the well locations shows that the water-wells are fairly evenly distributed over the whole region with the greatest concentrations being in the stream valleys and least in areas of more rugged terrain.

The Vermont Secretary of State population report of 1970 lists Brattleboro and Springfield, both unincorporated villages, as two of the ten urban areas of the state with population in excess of 5,000. The term "urban area" may seem to be a misnomer in this case since both villages had populations of less than 10,000 (Brattleboro, 9,005; Springfield, 5,632) in 1970 and both are located in counties with total populations of less than 50,000 (Windham, 33,476; Windsor, 44,082). Urbanization has definitely started in these centers, however, and it seems inevitable that they will develop as bonafide urban centers. The Bellows Falls, Chester and Ludlow sections are also developing and will probably become urban centers in the not too distant future. Shopping centers, eating and lodging accommodations, real estate development and a few new industrial plants are already appearing in all of these areas at a slow but definite rate.

As the Brattleboro urban area grows, this development will extend to include Vernon to the south and Putney to the north and up the West River to Townshend and Jamaica. The Springfield area will expand up and down the Black River to include North Springfield and Perkinsville and northeastward to the Connecticut River. The development in the Ludlow area is already concentrated along the Black River from Cavendish to Plymouth and as expansion continues it will be in the directions away from the river, particularly southward. The Bellows Falls and Chester areas will probably merge into a single urbanized region inasmuch as growth will concentrate along the Williams River. Expansion from Bellows Falls is also progressing up the Saxtons River and will soon include the village of Saxtons River.

Growth in the Windsor area has been spotty. The village of Windsor and its environs have not experienced the growth of most sections. There has been growth, however, in the Ascutney Village area to the south of Windsor Village and around the villages of Brownsville and Feltchville to the west of it. The pattern of the development around Mt. Ascutney is not yet apparent. It is probably, however, that this section will eventually develop into one or more small population centers. There has been much rural development in the Westminster area and this section will probably remain more or less rural until it gradually merges with the Brattleboro Urban Center to the south and the Bellows Falls area to the north.

Interstate Highway (I-91) crosses the Brattleboro-Windsor region in a north-south direction following closely the Connecticut River. The highway route passes near Brattleboro, Bellows Falls, Springfield and Windsor and is therefore quite accessible to all areas of the region. When completed, this highway will extend from the Canadian border at Derby Line to New Haven, Connecticut on Long Island Sound. As a result, the Brattleboro-Windsor region is in easy access to the urban centers to the south in Massachusetts, Rhode Island and Connecticut, and New York City is no more than a six hour drive away. It could be said that Brattleboro is now in commuting distance of Boston and Springfield, Massachusetts, and Hartford, Connecticut. The area to the south in Massachusetts and Connecticut is becoming more and more urbanized as expansion away from the cities continues at an ever increasing rate. At the present time, the southern, eastern and central sections of Massachusetts have already developed to the point that urban characteristics are common all over these areas. As this expansion continues, mostly northward, it will eventually extend into southern Vermont. Many would say, and no doubt rightly so, that the migration into southern Vermont, and into the Brattleboro-Windsor region in particular, has already begun.

It seems a foregone conclusion, therefore, that this region will grow and develop at an increasing rate. Environmental planning is therefore advisable. Planning is not to impede the development, but to assure that it takes place in an orderly manner and to insure adequate facilities for such growth.

EXPLANATION OF THE PLANNING MAPS

The planning maps (Plates I through VII) in the pocket at the end of this report summarize in simplified form the investigations made during this study. It is intended that the maps constitute a major portion of this report and that the chief purpose of the text is to explain the geology and the principles on which the mapping was completed. The maps show the classification of the surface material, the kinds of bedrock, the ground water potential, the suitability of various sections for specific uses and the distribution of sand and gravel deposits. The color legend of certain maps (Plates III through VI) using green for go, yellow for caution, and red for stop is a modification of a color-scheme developed by the Illinois Geological Survey (Hackett and McConas, 1963; Jacobs, 1971). The areas shown in green on the maps are interpreted as offering minor problems and minimum limitations. Sections shown in yellow have moderately complex problems and fairly severe limitations, but the problems are, as a general rule, controllable. These areas require detailed study to ascertain the limitations and to determine the required controls. Areas legened in red have severe limitations and many problems that are impractical to overcome. These areas should be avoided in most cases. Where two or more symbols are used for the same color, y-1 and y-2 for example, it is to show different conditions with different problems, but not necessarily more, or less, limitations. The maps of necessity are quite generalized and do not eliminate the need for detailed study of each locality as development is anticipated.

The maps of the surficial material (Plate I) and the bedrock map (Plate II) show the distribution of the various kinds of surficial material and bedrock. Certain materials, such as sand and gravel, have been combined inasmuch as they have similar characteristics insofar as environmental problems are concerned. Each kind of surface material and bedrock, as legened on the maps, has particular characteristics that need emphasis for planning.

The planning maps for solid waste, septic tanks and general construction conditions are, of course, based on the most up-to-date concepts as viewed by this survey at this particular time. It must be admitted, however, that there is debate among authoritative sources as to the correct environmental interpretation of the geology in each of these cases. Different geologists and planners have conflicting views on many aspects of these environmental problems, and undoubtedly many concepts will change in the future. For these reasons, the boundaries of the different units on each of the maps are, in most cases, essentially the same as the boundaries between the different kinds of material. In addition, the explanations of the map describe the characteristics of the surficial material used for interpretation. The purpose of this method of classification, plus the inclusion of a surficial material and a bedrock map, is to make the maps usable for planning by those that prefer an interpretation based on different concepts.

GEOLOGIC SETTING

The major portion of the Brattleboro-Windsor region lies within the New England Upland geomorphic subdivision of the Appalachian Highlands as defined by Fenneman (1938, p. 358) and Thornbury (1965, p. 161), and Jacobs (1950, p. 79), in his physiographic description of the state, designated this section the Vermont Piedmont. The eastern slopes of the Green Mountain geomorphic subdivision, nevertheless, do extend into the region along the northern two-thirds of the western border (Figure 3). Tectonically, the entire region is located in the Crystalline Appalachian Province as delineated by King (1959, p. 47). The boundary between the New England Uplands and the Green Mountains, as described in this report (Figure 3), is based on the rock structures and the tectonic subdivisions of the Centennial Geologic Map of Vermont (Doll, Cady, Thompson and Billings, 1961) rather than on the topography and other geomorphic features as was done by Jacobs (1950).

The boundary between the Green Mountains and the New England Uplands in this region is not conspicuous at the surface, except in the Ludlow section, inasmuch as the bedrock in both subdivisions is very complex, the topography is quite rugged, and the elevations on the higher crests of the uplands are almost as high as the eastern crests of the mountains. Jacobs (1957, p. 73) stated that the Green Mountains extend almost to the Connecticut River in the extreme eastern part of the state, and if only the topography and elevations are considered, this is not an unreasonable statement. In this report and on the geomorphic map (Figure 3), the higher, more rugged segments of the uplands, bordering the Green Mountains on the east, are designated the Green Mountain foothills to emphasize their rugged character. This is strictly a geomorphic subdivision since the structure and bedrock of the Green Mountain foothills is exactly the same as the remainder of the New England Upland.

Figure 3. Geomorphic subdivisions and major topographic features of the Brattleboro-Windsor region.

New England Upland

The New England Upland, including the Green Mountain foothills, is a plateau-like region that has been dissected by streams and crossed by several invasions of continental glaciers. Because of the stream dissection, the topography is in many places quite irregular and often rugged. This is particularly true in the Brattleboro-Windsor region. The rocks of the uplands were originally stratified sedimentary and volcanic but they have subsequently been folded, faulted and metamorphosed. In addition, the metamorphic rocks have been intruded by numerous plutons composed of both light and dark colored igneous rock. The topography of the uplands is predominantly erosional, and the resulting surface reflects such varying geologic factors as the differential hardness of the rock, the courses of the streams, and the rock structure. Mt. Ascutney and Little Ascutney mountains, for example, are high and rugged because they are composed of more resistant, intrusive igneous rock (Figure 4). Putney and Windmill mountains are composed of resistant, steeply dipping quartzite. Hawks Mountain, however, located south of the Black River between Perkinsville and Cavendish, seems to have remained high chiefly because the major drainage of the area has not, as yet, greatly affected it. This is partly due to the drainage pattern and partly the result of recent drainage changes that are discussed later in this report. Glaciation has also helped to shape the land surface, but glacial erosion, as a general rule, tended to smooth out the topography rather than make it more rugged.

The Connecticut River, along the eastern border of the region, has cut a valley into the New England Upland that shows little influence of the structure of the bedrock. In most sections, the river valley is narrow attesting to the fact that downcutting by the river into the complex bedrock has been a very slow process and that the river is still in the downcutting stage. The tributary streams have kept pace with the Connecticut River in the downcutting of their valleys, at least in their lower reaches, and therefore the stream gradients, in general, are low near the confluence with the master stream. The tributary valleys, nonetheless, have steep sides and rugged topography adjacent to them. The upper reaches of the tributary streams have steep gradients as they flow from the Green Mountains or the foothills on the east side of the mountains.

Structurally, the New England Upland in southern Vermont is a portion of a large structural depression that lies between the Green Mountains uplift on the west and the Bronson Hill-Boundary Mountain uplift of New Hampshire. This downwarped structure, that parallels the eastern flank of the Green Mountains throughout its length, is named the

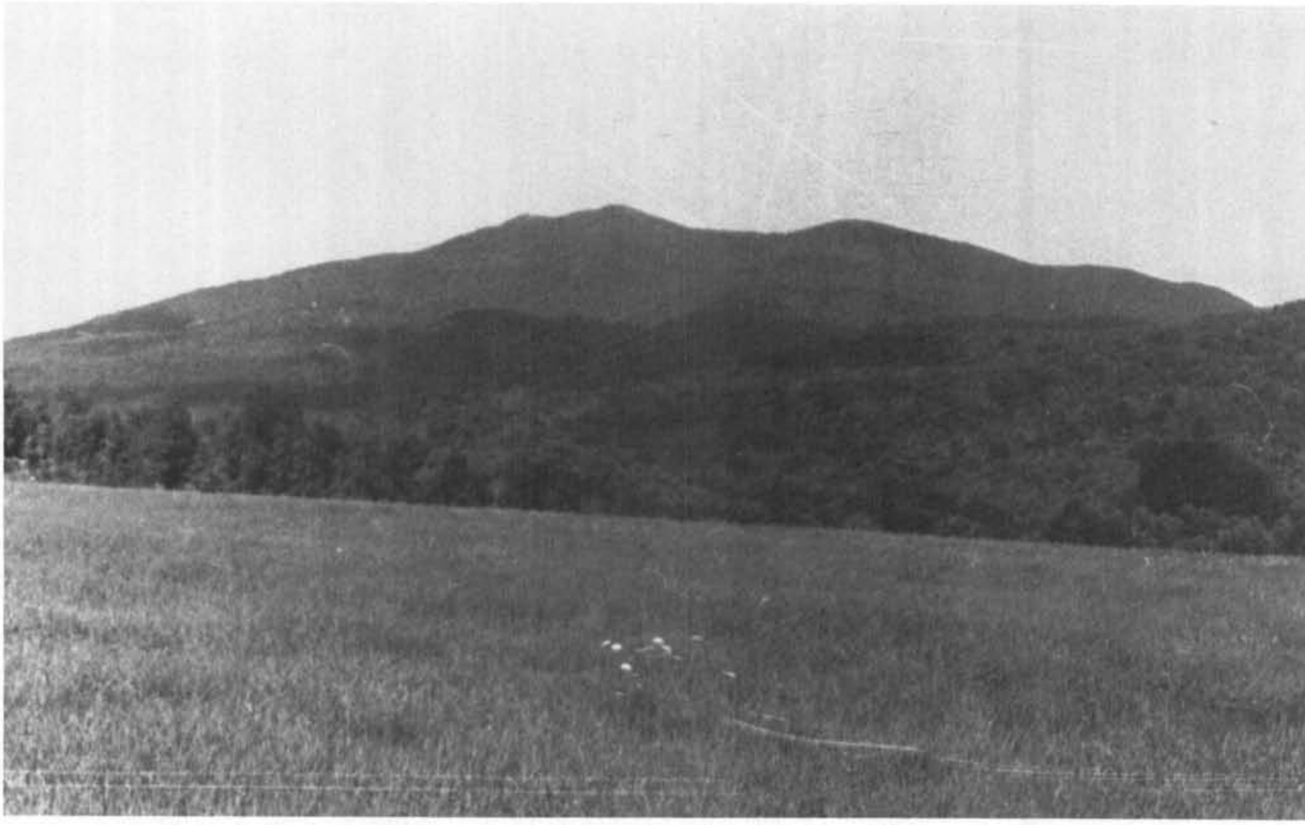

Figure 4. Mt. Ascutney. Picture taken looking northwest from State Route 131 two miles east of Amsden.

Connecticut-Gaspe synclinorium. It is called a synclinorium because it is not a simple downfold but instead it is made up of a series of upfolds and downfolds that are superimposed upon it. In the Brattleboro-Windsor region these structures include two downfolds or synclines separated by uplifts in the form of domes (Figure 5). The Townshend-Browington syncline (downfold) follows the eastern base of the Green Mountains the entire length of Vermont. In the southern two-thirds of the Brattleboro Quadrangle, the axis of this structure lies to the west of the region, but it enters near Newfane Village and follows the base of the mountains northward (Figure 5). The Brattleboro syncline (downfold) parallels the Connecticut River in the eastern part of the region. This structure is similar to the downfold to the west and extends along the Connecticut River from the Massachusetts line south of Guilford Village to the northern border of the region just west of the village of Windsor (Figure 5). Three domes, called the Chester, Athens and Guilford domes, occupy the upfolded section of the region between the two downfolds. The Chester Dome is the largest of these structures, and it extends from the northern border of the region southward to the vicinity of Grafton. The dome was formed by an uplift of the basement rock that underlies the whole region, and erosion has subsequently exposed this ancient, complex rock. The Athens Dome is a southward continuation of the same structure that forms the Chester Dome. The basement complex is exposed in the crest of this structure that trends south-southwest from near Grafton to Newfane Hill. In the extreme southern part of the region, the Brattleboro syncline is bordered on the east by the Vernon Dome that lies mostly in New Hampshire and the Guilford Dome to the west. The Guilford Dome, situated between the two synclines, is the smallest of the domes in the region (Figure 5).

Green Mountains

The size of the area covered by the Green Mountains in the Brattleboro-Windsor region is so small that they hardly merit discussion in this report. The influence of the mountains, however, on several aspects of the environment, particularly the runoff, is so important that some consideration of them is deemed necessary. The Green Mountains are the most conspicuous element of the topography throughout Vermont and occupy a major portion of the southern part of the state. The mountains have the highest elevations, the most rugged terrain, and the greatest influences on the drainage than any other

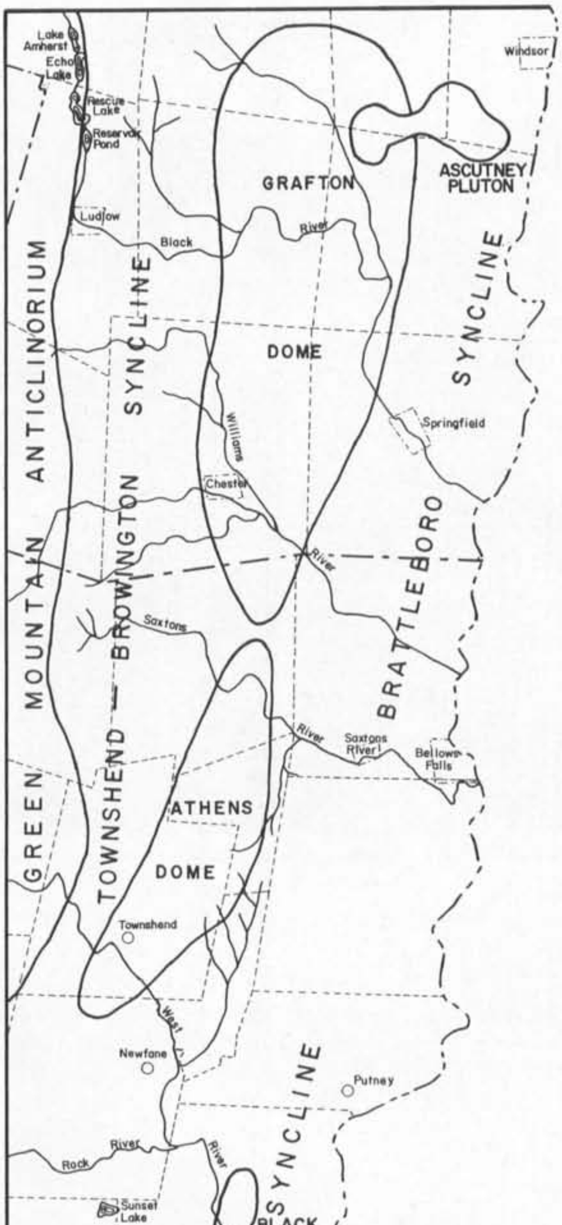

Figure 5. The generalized structures of the bedrock in the Brattleboro-Windsor region.

feature of the state. Structurally the mountains are a huge, complex anticlinorium composed of highly metamorphosed rock. The uplift is called an anticlinorium because the great arch has a series of upfolds and downfolds superimposed upon it. Only the eastern limb of this structure is found in the region of this report.

In the Brattleboro-Windsor region, the highest elevations are on Ludlow Mountain, west of Ludlow village, where the summit of the eastern range of the mountains rises above the 3300-foot contour. Tiny Mountain, west of Echo Lake, has a crest elevation above 2800 feet. South Mountain, southwest of Ludlow village is slightly more than 2700 feet high, Terrible Mountain 2900, and Turkey Mountain, north of West Townshend, 2100 (Figure 4).

Environmental Significance of Structure

The above short discussion of the geologic structures of the New England Upland and the Green Mountains attests to the fact that the whole region has been exposed to multiple episodes of mountain building causing the rocks to have been folded, faulted, jointed, crushed and broken. Since the rocks are metamorphosed, they do not contain pore space between the grains in which water can be held or through which water can move. Water can only be held in the rock fractures of various kinds and can move only through these fractures. This is important as it relates to the ground water supply. Equally important, however, is the fact that water is not filtered as it moves through the fractures in the rock adding to the gravity of the pollution problems posed by solid waste and septic tank installations. These aspects of the rock properties and their bearing on environmental planning will be treated at length in later sections of this report.

DRAINAGE

The Brattleboro-Windsor region is located between the Connecticut River that borders it on the east and the Green Mountains to the west. Therefore all of the streams of the region flow in a generally eastward direction and are tributaries of the Connecticut. The larger streams, as a rule, head on the eastern slopes of the mountains or in the foothills and, as a result, they usually have a steep gradient at least in their headwaters. The drainages are none-the-less quite complicated and present problems in most areas that must be reckoned with in environmental planning.

The drainage in the northeastern corner of the region is complicated by the steep slopes of Mt. Ascutney and Little Ascutney Mountain. According to the topographic map, two separate streams drain the north and south slopes of the Ascutney uplift and both of the streams are named Mill Brook, Jacobs (1950, p. 133) stated that there are at least eight Mill Brooks in Vermont and there are probably more inasmuch as there are five streams bearing that name in the Brattleboro-Windsor region. To avoid confusion, the two streams north and south of Mt. Ascutney are designated Mill Brook (North) and Mill Brook (South) as shown on the map of the drainage basins (Figure 6). The other Mill Brooks have the name of the townships in which they occur in parenthesis, Mill Brook (Townshend) for example.

Mill Brook (North) enters the region about a mile north of Hammondsville and flows in a southeasterly direction to the foot of Little Ascutney Mountain and then eastward along the northern base of Mt. Ascutney. One mile south of the village of Windsor, the stream turns north and flows through a gorge, called the narrows, to Mill Pond at Windsor village. From Mill Pond the stream flows east to the Connecticut River. Mill Brook (North) therefore drains the section east of Hammondsville and north of the crests of Little Ascutney Mountain and Mt. Ascutney (Figure 6). Mill Brook (South) is a very short stream that heads high on the south slope of Mt. Ascutney, just below the lookout tower, and drains the southern slopes of the mountain and a small area south of it that extends to the vicinity of Weathersfield.

The Black River, a major drainage system of the Brattleboro-Windsor region, heads in Woodward Reservoir about five miles north-northwest of the point where it enters the region near Lake Amherst. It flows southward through Amherst, Echo, and Rescue lakes and Reservoir Pond to the village of Ludlow where it turns east and flows through Smithville, Proctorsville and Cavendish villages and then east-northeast to the vicinity of Downers. The river valley from the mouth of Elm Brook, two miles north-northeast of Cavendish village, is steep and narrow indicating that this section of the valley is more recent than the valley from the headwaters to Cavendish. The River at some former time must have flowed through Proctorsville Gulf, and possibly through Duttonsville Gulf, and then southward via the present course of the Williams River. From Downers, the Black River flows south to Perkinsville, then east for a mile and one-half, and southward again to North Springfield. Then the river flows southeast through Springfield village to the Connecticut River. Major tributaries of the Black River include: Bryant Branch that flows off the Green Mountain slopes and enters the river two miles north of Ludlow village; Twentymile Stream that drains the uplands north of Proctorsville and Cavendish villages; and the North Branch of the Black River that heads in the town of

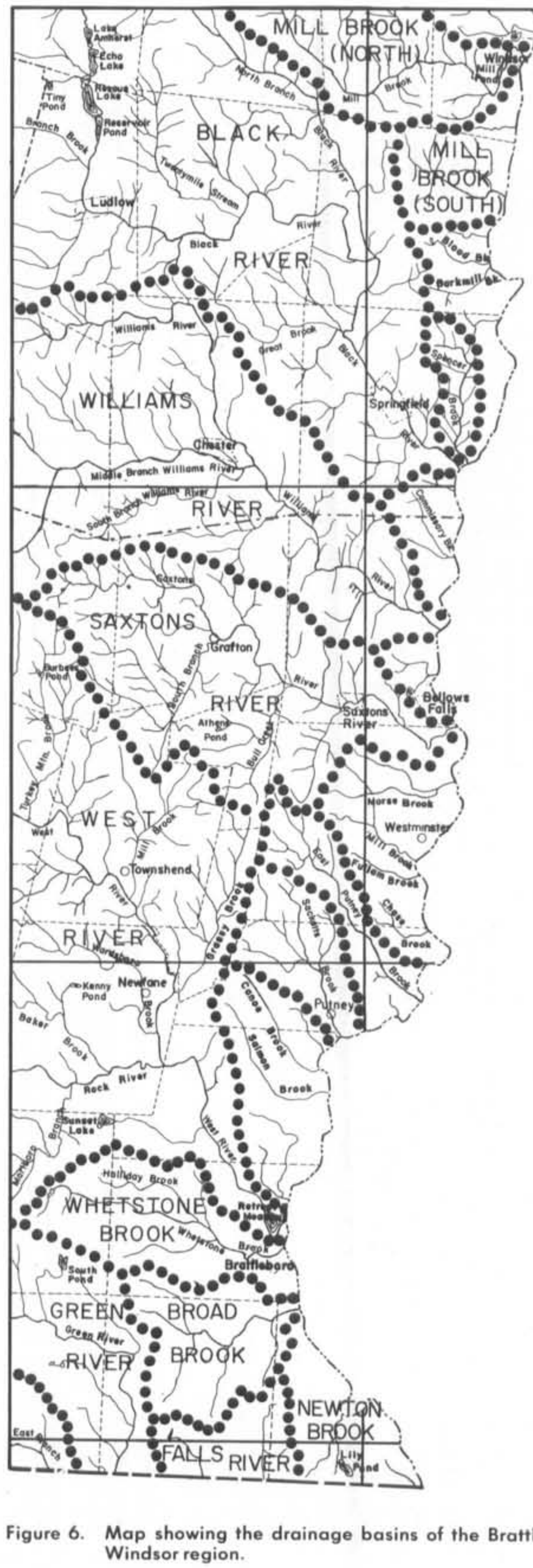

Figure 6. Map showing the drainage basins of the Brattleboro-Windsor region.

Reading and flows southeastward through the villages of South Reading, Feltchville and Amsden to enter the master stream one mile east of Perkinsville (Figure 6). The North Branch was the major drainage system east of Cavendish prior to the rerouting of the Black River through Hawks Mountain. The Black River valley downstream from Downers was undoubtedly cut by North Branch during that phase of the drainage history.

The Black River thus drains the eastern slopes of the Green Mountains north of Bear Hill (three miles south of Ludlow village) and all of the northwestern part of the Brattleboro-Windsor region north of Bald Hill (two miles south of Proctorsville) and west of Little Ascutney Mountain. From Bald Hill, the divide between the Black River basin and the drainage basin to the south trends southeastward to the crest of Litchfield Hill (three miles southwest of Springfield) and then northeast to near the mouth of the river (Figure 6).

The drainage basin of the Williams River lies immediately to the south of the Black River basin and as explained above, they were probably at one time parts of the same basin. Like the Black River, the Williams River heads in the Green Mountains and flows across the total width of the Brattleboro-Windsor region. The main branch heads on the slopes of Terrible Mountain along the western border of the region and flows generally eastward through the Green Mountain foothills to the vicinity of Gassetts. At Gassetts, the stream turns south and flows through the village of Chester and then southeastward to enter the Connecticut River three miles north of Bellows Falls. The Middle Branch of the Williams River heads in the town of Londonderry east of North Windham. It flows in a northward direction from North Windham to Simonsville and then eastward to join the main branch immediately east of Chester. The South Branch heads one-half mile southeast of North Windham and flows generally east-northeast for approximately seven miles to flow into Middle Branch one mile southeast of Chester village. The topography of the sections drained by the headwaters of the main branch west of Gassetts and the total length of the Middle and South branches is quite rugged inasmuch as they flow through the Green Mountain foothills. As stated earlier, the boundary between the uplands and the mountains in this area is not conspicuous because of the height and ruggedness of the uplands along the mountain front.

Saxtons River is a relatively short stream and its drainage basin lies wholly within the Brattleboro-Windsor region (Figure 6). The stream heads in the hilly terrain between the villages of Windham and North Windham. From its headwaters, the river flows eastward through Houghtonville, but two miles east of the village it turns to the southeast and flows through the villages of Grafton, Cambridgeport, Saxtons River, and North Westminster and joins the Connecticut River in the southern part of Bellows Falls village. Two major tributaries, South Branch and Bull Creek drain the sections south of Grafton and Cambridgeport respectively. The gradient of the river is high in the headwaters, dropping approximately 1000 feet before it reaches Grafton. Between Grafton and Saxtons River, however, the gradient is much lower but it steepens again near Bellows Falls. Most of the latter drop is southeast of Bellows Falls where the stream plunges over a falls held up by the resistant strata that form Oak Hill north of the river and Bald Hill to the south of it (Figure 7).

A more or less continuous ridge that trends north from Black Mountain through Putney and Windmill mountains to the Saxtons River divide northwest of Westminster West forms a divide that separates the West River drainage basin from a section drained by several small streams that flow into the Connecticut River (Figure 6). The eastern slopes of this divide are drained chiefly by Morse, Mill (Westminster) East Putney, Sacketts, Mill (Putney), Canoe, and Salmon Brooks.

The West River is the largest tributary of the Connecticut River in southeastern Vermont. According to Jacobs (1950, p. 160) the river rises in the town of Mt. Holly, has a total length of 40 miles, and flows through Londonderry and Jamaica townships before it enters the Brattleboro-Windsor region a mile west-northwest of the village of East Jamaica. From East Jamaica the river flows northeast for two miles to West Townshend where it turns to the southeast and follows that general course to the Connecticut River at Brattleboro. Drainage of the Brattleboro-Windsor region by the West River is mostly due to the tributary streams that flow into it from the north and south. Turkey Mountain and Tannery brooks drain the section north of East Jamaica and West Townshend. Turkey Mountain Brook heads in the vicinity of Windham and flows south through South Windham, draining the west slopes of Turkey Mountain, and enters the West River one-half mile west of East Jamaica. Mill Brook (Townshend) drains the area north of the village of Townshend. Grassy Brook heads in Hedgehog Gulf (three and one-half miles north of Brookline village) and flows southward through a deep valley between Putney Mountain on the east and Crane Mountain on the west and joins the West River one and one-half miles east of Newfane village. Several small streams drain the south side of the West River between West Townshend and Newfane village. The largest of these is Wardsboro Brook that flows out of the mountains north of Newfane Hill, joins Smith Brook north of Newfane vil-

Figure 7. Falls of the Saxtons River one mile south-southeast of Bellows Falls.

lage, and flows into West River two miles south of the village.

The Rock River is a major tributary of the West River that enters the region from the west two and one-half miles west of South Newfane and joins the West River two and one-half miles south of Newfane village. The total length of the Rock River in this region is about six miles, but two tributaries are major drainages of that section. Baker Brook, that flows into the Rock River from the northwest at Williamsville, drains the south slope of Newfane Hill and the north slope of Oregon Mountain. Marlboro Branch of the Rock River drains the section south of South Newfane.

The Green Mountain foothills west of Brattleboro village are drained by Whetstone Brook that heads a mile west of Marlboro village and flows east-southeast to Brattleboro. In Guilford Township, the Green Mountain foothills are drained by Broad Brook that starts on the west side of Governors Mountain and flows eastward through the village of Guilford to the Connecticut River.

The southern margin of the region is drained by streams that flow south into Massachusetts. East Branch of North River flows across the extreme southwestern corner of the region (Figure 6). The Green River drains a large area in Halifax and Guilford townships. Drainage at the southern border of Guilford township flows into the headwaters of the Falls River, and the drainage of the southwestern corner of Vernon township flows into the Connecticut River via Newton Brook.

SURFICIAL MATERIAL

The surficial material of the Brattleboro-Windsor region was deposited during and immediately following the Great Ice Age. These materials include unsorted debris that was deposited directly from the ice, stratified sands and gravels transported and deposited by meltwater streams flowing from the melting glaciers, and sediments deposited in lakes that were formed because glacial deposits dammed the Connecticut River valley to the south. It is believed that most of the surficial materials were deposited during the Shelburne Stade of the Wisconsin Glacial Stage that preceded the last Wisconsin Glaciation in Vermont. Deposits of the earlier Bennington Stade, however, are present in the southern part of the region (Stewart and MacClintock, 1969, p. 47-58; 1970).

Figure 8. Stratified outwash sand and gravel exposed in a pit one and three-fourths miles north of Ascutney village.

The lake deposits were made in Lake Hitchcock that occupied the Connecticut River valley and the tributary valleys during and after the recession of the Shelburne glacier. A morainal deposit across the valley in the vicinity of Middletown, Connecticut, formed the dam that blocked the drainage.

The surface material with the largest areal extent in the region is glacial till, an unsorted glacial debris deposited directly from melting ice. Because till is unsorted, it is composed of particles of all sizes ranging from clay to large boulders. There are two different kinds of till in the Brattleboro-Windsor region. Much of the surface is covered by a loose, sandy till, but in some areas the till is dense and compact. The loose till is more sandy than the dense till but, in general, both contain a higher percentage of sand and a lower content of clay than do the average tills found elsewhere. Tills usually have a very low permeability because they are unsorted and contain much fine-grained material, but the sand content of the tills in this region, particularly the loose till, allows them to transmit liquids at a slow to moderate rate. The till cover on the uplands is usually thin, less than 10 feet, and large areas of bedrock are exposed at the surface. It may be much thicker in the valleys.

Outwash is stratified glacial drift that was deposited by meltwater streams. It contains a high content of well sorted sands and gravels (Figure 8). Outwash has a high permeability and is a good water-bearing material. Kame terraces are outwash deposits that form along a valley wall or along a mountain slope. The deposits have a terrace form with a relatively flat top. The terraces were deposited in contact with ice on their outer side and they can usually be identified by the slumping structures that developed as the ice melted. Kames are rounded hills of outwash that were also deposited in contact with ice. A valley train is a deposit of outwash on the floor of a stream valley. These deposits are usually horizontally bedded and do not contain ice contact structures.

Lake sands and gravels, including beach and delta gravel, are shallow water deposits that are generally well sorted. These sands and gravels have good permeability, but the permeability varies depending on the amount of silt and/or clay contained in them. Ordinarily, the gravel is at the top and is much thinner than the sand underlying it, and both the sand and gravel occur above silts and clays. In the Brattleboro-Windsor region, lake sands and gravels, par-

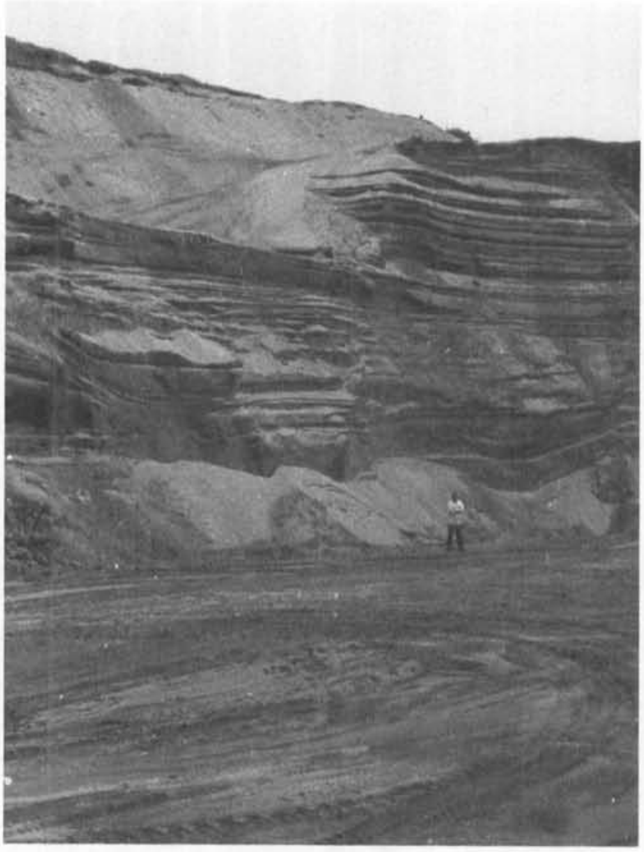

Figure 9. Stratified lake sand exposed in a pit three miles southwest of Springfield village.

ticularily sands, are the most common surface material in the larger stream valleys (Figure 9).

Lake silts and clays are fine textured bottom sediment. These materials have a relatively high porosity and have the capacity to hold large quantities of water. They are so fine grained, however, that the permeability is low and they do not yield the water contained in them. Lake silts and clays are exposed at the surface in only a few small areas of the Brattleboro-Windsor region, but they commonly occur below lake sands and gravels in the stream valleys and are exposed in most of the small stream valleys that flow into the Connecticut River (Figure 10).

Recent alluvium is a post-glacial deposit deposited by streams. It usually forms a layer on the surface of the valley floor that ranges from 5 to 25 feet in thickness. It may be composed of fine, silty sediment with varying amounts of clay or it may be predominantly sand. Alluvium is a low-strength material that must be removed to have a satisfactory foundation for heavy construction.

Peat and muck are deposits made in swamps and other poorly drained areas. They are composed of a high percentage of organic material. Most of these in the Brattleboro-Windsor region are in small, isolated swamps occupying small depressions in the surficial material or bedrock.

Figure 10. Lake clay exposed in the valley of Mill Brook (Putney) one mile south of Putney village.

BEDROCK

As has already been stated in this report, all of the rocks, except some of the igneous intrusions, of the Brattleboro-Windsor region are quite complex and highly metamorphosed (Figure 11). The metamorphism of the rocks resulted from the several episodes of mountain building and igneous intrusion that formed the geologic structures. All such rocks are complicated and confused by the fact that new minerals are formed and recrystallization occurs during the metamorphic process. The number and kind of different minerals formed is dependent upon the composition of the original rock, new substances added by gases and solutions, the intensity of the pressures, and the temperatures generated by the great stresses. It is assumed that the metamorphism of the rocks was caused by regional stresses inasmuch as the more intense metamorphic zones parallel the Green Mountain anticlinorium and the Connecticut River-Gaspe synclinorium. Most of the metamorphic

Figure 11. Folded and faulted schistose bedrock. Exposed in a road cut along State Route 30 one mile northwest of Brattleboro village.

rocks are foliated since recrystallization formed platy and elongate minerals that were aligned parallel to the bedding of the original rock by movement along the bedding planes.

The bedrock map prepared for this report (Plate II) is not a geologic map in the usual sense of the word, because it does not use formation names, geologic sequences, or age relationships. This survey believes that these aspects of a geologic map are not of significant importance to planning and that they are too technical for use by the personnel of most planning agencies. The bedrock map of this report (Plate II), therefore, shows the lithologies of the rocks, their physical description, and their significant chemical properties. These are the rock characteristics that are most applicable to environmental planning. It is believed that the map, modified from the Centennial Geologic Map of Vermont (Doll, Cady, Thompson and Billings, 1961) will prove to be more practical for planning use. If more detailed geologic information is desired, it is available on the Centennial map.

The oldest rocks of the Brattleboro-Windsor region are those that make up the basement complex that is exposed along the Green Mountain front and in the Grafton and Athens domes. These ancient, complex rocks, that are assumed to underlie most of New England, were uplifted with the mountains and domes to form the cores of these structures. Many geologists now believe that these rocks are the same as those that occur in the Adirondack Mountain region of New York State and known to geologists as the Grenville Series. The basal complex is an intricate mixture of schists and gneisses with large amounts of quartzite and small amounts of limestone and dolomite marble. The mineralogy is complicated by the large number of minerals that were formed as a result of several different intervals of metamorphism.

Quartzite is a very hard, massive rock formed by the metamorphism of sandstone. It has been changed to the degree that the quartz (silica) has recrystallized but no new minerals have formed. The rock is composed predominantly of quartz and is therefore very resistant to both chemical and physical weathering and erosion. For these reasons, it often forms the crests of the hills and mountains. Quartzite is often highly fractured in the Brattleboro-Windsor region and usually occurs interbedded with less resistant, foliated rock.

Dolomite marble (designated dolomite on the bedrock map) is a carbonate rock containing magnesium in addition to calcium. The magnesium in the composition of dolomite marble makes it somewhat harder, more resistant to physical weathering and erosion, and less susceptible to chemical decomposition than limestone marble. Dolomite marble is, however, slowly dissolved by acid waters. The occurrence of dolomite marble in the Brattleboro-Windsor region is in short, narrow bands in a few small localities.

The other metamorphic rocks of the region are foliated and composed of varying amounts of slate, phyllite, schist, gneiss and greenstone. The chief differences among these rocks are the degree of metamorphism, the texture, the thickness of the foliation, and the mineral composition. Slates and phyllites are very fine textured and finely foliated (Figure 12). Since both are formed by the metamorphism of shale, they contain mostly clay-type minerals. The physical and chemical characteristics of these two kinds of rocks are so similar that they do not need to be separated for environmental consideration. Schist has a texture and foliation almost as fine as phyllite but the composition is quite different. The common platy and elongate minerals in the schists of this region, that produce the foliation, are the dark-colored micas, amphiboles and pyroxenes. Gneiss has a composition similar to schist except that it contains a higher proportion of minerals that are massive (not platy or elongate) and therefore it has a coarser foliation (Figure 13). Amphibolite has the physical characteristics of schist but it is composed predominantly of the mineral amphibole (hornblende). Greenstone is composed largely of the mineral chlorite that gives it a green color and a foliation similar to schist.

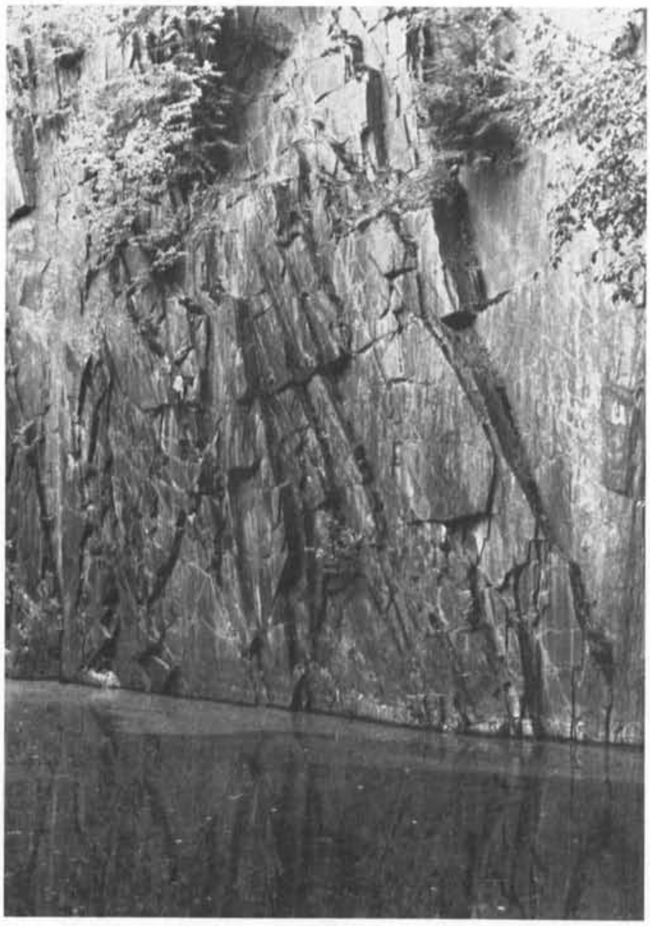

Figure 12. Slate exposed in an old abandoned quarry in Dummerston State Park. One-half mile south of Brattleboro village.

The rock legended calcareous schist on the bedrock map contains such a high calcium carbonate content that it is designated a limestone on the Centennial Geologic Map of Vermont. The rock, however, has physical characteristics that are more like schist than limestone and these were thought to be more significant to the environment. The fact that the rock contains much calcium carbonate and biotite, both very susceptible to chemical decomposition, make the rock one of the least resistant to chemical weathering and erosion.

In general, the foliated metamorphic rocks of the Brattleboro-Windsor region are very difficult to differentiate by visual inspection or in the field because they appear to be so similar. These rocks have similar characteristics insofar as their reaction to weathering and erosion except that the slates and phyllites are more resistant to chemical decomposition than the other rocks.

Igneous rocks occur in isolated localities throughout the region. These have been formed by igneous intrusions at various times throughout geologic history. The igneous rocks occur in structures that differ in size from small tabular-shaped bodies that invaded the rock fractures to large plutonic masses such as those forming Black Mountain and Mt. Ascutney (Figures 14 and 15). Some of the igneous rocks are light-colored whereas others are the dark varieties.

SURFACE WATER

The surface water potential of the Brattleboro-Windsor region is limited inasmuch as there are few lakes and ponds of sufficient size to supply large quantities of water and the Connecticut River and the lower reaches of the major tributaries are too polluted at this time to be considered as possible water supplies. State governmental agencies do have an ambitious program under way to decrease stream pollution, and it does seem that some progress is being made. But, progress is slow, opposition to re-

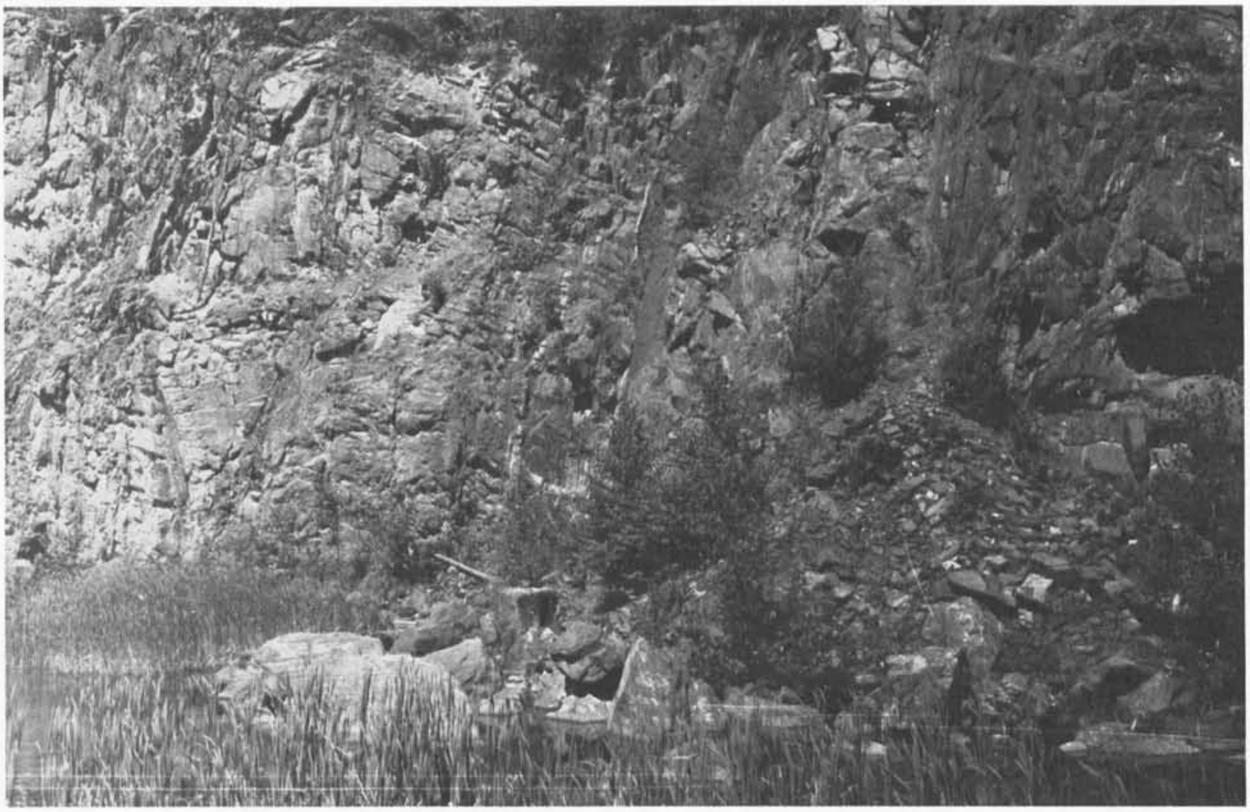

Figure 13. Complex gneiss bedrock exposed in a quarry one mile southeast of East Dummerston.

Figure 14. Light-colored, tabular-shaped igneous intrusions into gneiss bedrock. Exposed along State Route 30 four miles north-northwest of Brattleboro village.

Figure 15. Massive granite intrusion exposed in a quarry on the west slope of Black Mountain across the West River from West Dummerston.

striction is increasing and there is such a long way to go that this survey could not make a reliable projection concerning future possibilities.

The lakes with the greatest water potential are those in the Black River valley north of Ludlow. The river, as already stated, flows through Amherst, Echo and Rescue lakes and Reservoir Pond and a few small streams also flow into these bodies of water. The source of the water, therefore, is mostly surface drainage rather than ground water springs. These lakes have a high water potential, in case the water is ever needed, but planning should start immediately if this water is to be reserved for future use. The land surrounding the lakes is mostly privately owned and there has been considerable development along the shores. This survey does not know the present classification of the water, but it is assumed that pollution has already begun. To assure a clean water supply in future years, modifications of the present practices would have to be enacted to clean up the water and future development would have to be restricted to keep it clean. The streams that flow into these lakes, the upper Black River plus Buffalo, Patch and Kingdom brooks would also have to have restricted development. Other lakes and ponds of the region are quite small, but some might have good possibilities as water supplies. These are: Tiny Pond, west of Tyson; Burbees Pond, south of the village of Windham; Athens Pond, southwest of Athens village; Kenny Pond, northwest of Newfane Hill; and South Pond, south of Marlboro village.

The headwaters of the streams that have sources in the Green Mountains or in the Green Mountain foothills are also possible sources of surface water. These streams include: Branch Brook, west of Ludlow village; headwaters of the three branches of the Williams; the Saxtons River, west of Grafton; Turkey Mountain Brook, north of East Jamaica; Wardsboro Brook, northwest of Newfane village; Baker Brook northwest of Williamsville; Marlboro Branch, north of Marlboro village; Halladay and Whetstone brooks, northwest of Brattleboro village; Broad Brook, southwest of the village of Guilford; and the headwaters of the Green River in Guilford and Halifax townships. Since most of these streams are in the western, more rugged, part of the Brattleboro-Windsor region, the demand for water has not been great and they have never been considered as possible water sources. As the region develops, however, these sources may be needed. To have these waters available for future use,

Figure 16. Minards Pond, water supply for the town of Bellows Falls. One mile northwest of Bellows Falls village.

it will be necessary to reserve the water by restricting development along the watersheds of the streams.

The development of the surface water on the Green Mountain and the foothill slopes would mean a relatively expensive initial investment inasmuch as it is assumed that the demand for water will be mostly in the Connecticut River valley and the lower valleys of the major tributaries. The development of the surface water would involve the acquisition of land, the construction of water catchment and water storage facilities, and the laying of pipeline to carry the water to the area of use. After the initial cost, however, the maintenance of such a system would be less than other types of water supplies. A detailed study of the projected water needs and the advisability of reserving certain streams for future water supply is needed in this region.

The towns of Bellows Falls and Brattleboro have water systems that exemplify the possibilities of surface water. Minards Pond has been the water supply for Bellows Falls for the past 103 years (Figure 16). The pond has an area of 475 acres and a maximum depth of 54 feet. Over the years the town has purchased land that includes the watersheds of the surface drainage that supplies the pond. The town now owns 1,000 acres, mostly north of the pond, and the present capacity of the system is over 200 million gallons per day, about four times the present demand. The town of Brattleboro has used the Pleasant Valley Reservoir for many years as a water supply. The reservoir, located three miles northwest of Brattleboro village, has a forested watershed that is owned and maintained by the town. Recently, the town has acquired Sunset Lake, located four miles northwest of the reservoir, as an additional supply. As needed, the water is diverted to the reservoir, partly by way of the natural outlet Stickney Brook. These two systems, that have consistently kept pace with increased demands, demonstrate how a surface water system can be efficiently maintained.

GROUND WATER

In an effort to ascertain the ground water potential of the Brattleboro-Windsor region, data were collected, evaluated and assimilated from many different sources. The most useful information used for this purpose came from water-well records, seismic investigations, field observations and the *Ground Water Favorability Map* of the river basins (Hodges and

Butterfield, 1968a and 1968b).

Water-well records have been required of all drillers in Vermont since 1966. These records are on open file at the Vermont Department of Water Resources, and they are available to planners. The well records supply information concerning the depth to bedrock, the depth of each well, the material (sediment or bedrock) that yields the water, and the amount of water produced at each location. The water-well data also assists in the location of buried valleys, the selection of suitable locations for seismic studies, and in ascertaining, in a general way, the regional water-bearing characteristics of the bedrock and surficial material.

Eleven locations were selected for seismic investigations where well-log and field data indicated good ground water potential and where additional information was desired. Seismic information is useful in that it delineates the width, depth, and shape of the valleys, the location of buried valleys, the depth of the water table and the generalized sequence of the surficial material above bedrock. In this region, the seismic studies were designed to specifically ascertain some of the significant characteristics of the unconsolidated sediment in the stream and buried valleys. Using seismic data alone, material may be placed into broad classifications based on the velocities of the seismic wave transmitted through them. Each velocity does not, however, have a unique material classification, but most unsaturated sediment and bedrock has a definite velocity range. Most saturated sediment and bedrock, regardless of texture, have the same velocity range. For these reasons, it is advantageous to have records of water-wells located nearby for correlation with the seismic data. Certain seismic profiles made during these investigations are difficult to interpret because there are no records of wells located in the vicinity. In these cases, test drilling is recommended for more reliable results.

Most bedrock has a seismic velocity above 12,000 feet/second and this is considered high because it is much higher than any unconsolidated sediment. Compact, dense glacial till may have a velocity as high as 8,000 feet/second, but most Vermont tills have a lower range. Alluvium, stream sediment on the valley floor, has seismic velocities ranging between 800 and 2,000 feet/second. Unconsolidated sediment that is saturated with water, regardless of the texture, usually has a seismic velocity range between 4,000 and 5,500 feet/second. Velocities between 4,800 and 5,300 feet/second is the usual range for unconsolidated sediment containing ground water in quantities large enough for a municipal water supply. The seismic work completed during this survey was done by the Weston Geophysical Engineers, Inc. of Westboro, Massachusetts, under the direct supervision of Mr. Thomas Sexton and Mr. David Ross. The Weston Geophysical Engineers also supplied the seismic profiles reproduced in this report. The exact location of each seismic profile is shown on the maps in Appendix A of this report.

The available ground water data prior to 1966 and the interpretation of that data was obtained from the *Ground Water Favorability Map* of each stream system prepared by Hodges and Butterfield (1968a and 1968b). These maps show the most favorable areas for ground water based on the best information available at the time. They also show the location of high yield wells and specify the type of water aquifer for each. Highway Department drill-hole records are also located and described. It is not intended that the Ground Water Potential Map of this report (Plate III) will supersede the favorability maps. The favorability maps have been most useful to this study and the data they contain are quite accurate.

There are two modes of occurrence of ground water in the Brattleboro-Windsor region. These are the water contained in the fractures in the bedrock and the water in the unconsolidated sediment in the stream and buried valleys. The most important of these is undoubtedly the unconsolidated sediment although the yield of most of the wells in the sediment for which records are available is not much greater than those in the bedrock. It is the contention of this report that the water-wells in the unconsolidated sediment of the valleys could have a much higher yield if different methods, such as surging and screening, were used in the well. Most wells drilled thus far have been for domestic use and the yield has been adequate. But, if more water is required, it is believed the yield can be greatly increased by more up-to-date methods.

As has already been stated in this report, the rocks of the Green Mountains and the New England Upland are metamorphosed and recrystallized and they contain little or no pore space between the mineral grains that would give the rocks a capacity to hold or transmit water. It follows, therefore, that these rocks would produce little or no water if they were not fractured. The fractures are open at the surface and water can readily pass through them. The width of the fractures decreases downward, however, and at a depth of 300 to 400 feet most of them are usually so tight that they either do not contain water, or the water is held by capillary action. The fractures trend in all directions and intersect at different depths, and for this reason the water they contain is commonly under hydrostatic pressure and rises in the well and occasionally overflows. Water-wells producing from fractures, as a general rule, have very low yields that range from 2 to 15 gallons of water per minute with an occasional well with a yield as high as 50 to 60 gallons per minute. The mountains and uplands of the region, except for the valleys, have bedrock exposed at the surface or the bedrock cover is a thin layer of glacial till with low permeability and therefore the fractures in the rock are the only source of ground water. Some of the valleys even have till or low permeability lake clay and silt covering the valley floors or the bedrock is barren of sediment, and bedrock is the only source of ground water. Enough water can usually be obtained from the bedrock to supply a one-family home, a farm or a small business, but rarely will the yield be enough for even a very small community.

Ground water that occurs in rock fractures is most susceptible to contamination. Water filtering a short distance through unconsolidated sediment or rock will usually filter out any organic pollution contained in it. But the same water may travel for miles through the fractures in the rock without any purification. There is little or no filtering action as the water moves through the fractures. Equally important is the fact that, once contamination occurs, there is no filtering action to remove the contaminants and therefore control and abatement are most difficult. For these reasons, one of the most important aspects of environmental planning is to prevent pollutants from ever entering the rock fractures. The bedrock is by no means impervious.

The ground water potential in the Connecticut River valley of the region is, in general, a hit and miss proposition. The valley usually has a sedimentary fill that ranges in thickness from zero in some areas to over 300 feet in others. The depths are unpredictable since they change rapidly from place to place. The sediment in the valley is predominantly lake sediment and, in spite of the wide occurrence of sand and gravel at the surface, the bulk of the sediment below surface is lake clay and silt. Gravel, however, commonly occurs above bedrock and below the lake clays and silts in the valley. Well record studies show that the gravel may not occur at all or that it may be as much as 30 feet in thickness. Near Westminster Station, for example, a driller's log reports 8 feet of gravel at the surface, 150 feet of clay below the surficial gravel and 12 feet of gravel below the clay. The well did not penetrate bedrock so the total thickness of the gravel is not known. The yield of this well is 11 gallons per minute. Another well in the same section penetrates 305 feet of lake clay and then 3 feet of gravel and yields 40 gallons of water per minute. This is a common occurrence along the river the length of the Brattleboro-Windsor region. The genetic classification of the gravel in the bottom of the valley is not understood, but it seems logical to assume that it is at least in part outwash that was deposited as the ice melted in the valley. This is the reason that the valley deposits are all shown on the ground water map in yellow, except for patches of green, even in areas where lake clay is exposed at the surface (Plate III).

There are areas along the Connecticut River where the sedimentary fill in the valley is chiefly sand and gravel. These sections are shown in green on the ground water map (Plate III). In the Windsor section of the valley, the terrace on which Mill Pond is located is composed of sand and gravel that has a thickness in excess of 90 feet. The town of Windsor has a water-well just north of Mill Pond that is 90 feet deep, bottoms in sand and gravel and yields 1140 gallons of water per minute (Hodges and Butterfield, 1968a). Insofar as yield is concerned, this is the best well in the whole region, and it illustrates the water-producing possibilities of the valley sediment. In the Ascutney section, the sediment is predominantly sand and some wells penetrate as much as 165 feet of this unconsolidated sediment.

South of the Williams River in the town of Rockingham, the sand and gravel in the Connecticut River valley is up to 165 feet in thickness. At the village of Bellows Falls, according to Hodges and Butterfield (1968a) the village has a well 70 feet deep in sand and gravel that yields 500 gallons per minute. The sediment in the vicinity of Westminster Station, as stated earlier, is an interesting mixture of lake clay and gravel. There is a narrow strip along the river, however, that well records show to be gravel over 40 feet in thickness. Another narrow strip along the river just north of the mouth of West River has a sand and gravel fill that is as thick as 158 feet.

The section along the Connecticut River that has the greatest water potential is in Vernon Township. Well records in this area, that extends northward from the Massachusetts line to a point three and one-half miles upstream from Vernon village, show the unconsolidated sediment to be sand and gravel that varies from 25 to 100 feet in thickness. The wells do not have high yield, but it is believed that there is a very good water potential in this section.

The Black River valley north of Tyson, at the south end of Echo Lake, is shallow and filled with non-permeable sediment. South of Echo Lake, however, the valley is quite deep and the sediment in the valley, according to driller's reports, is mostly gravel. One well on the west side of Rescue Lake penetrates 237 feet of gravel and does not reach bedrock. East of Reservoir Pond, south of Rescue Lake, wells that do not reach bedrock are bottomed in gravel at depths up to 160 feet. These wells yield 10 to 75 gallons per minute. A well near the mouth of Branch Brook shows gravel to a depth of 180 feet. These data show a very good ground water potential in the Black River

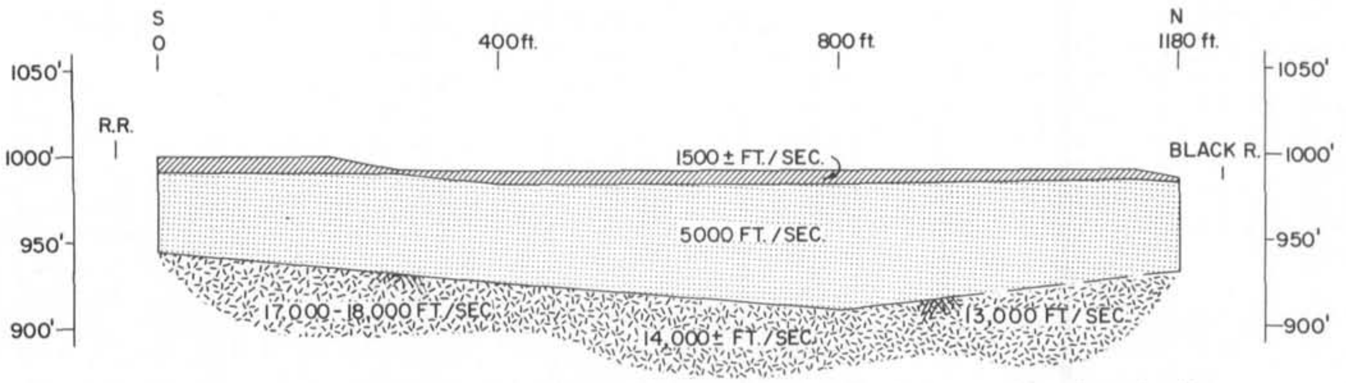

Figure 17. North-south seismic profile across the Black River valley. One-fourth mile east of the village of Ludlow.

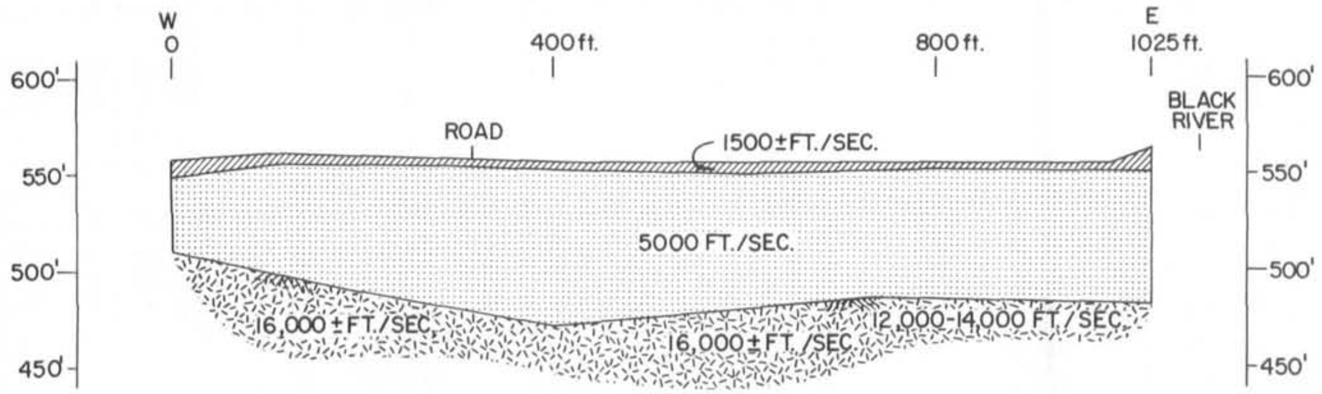

Figure 18. East-west seismic profile across the Black River valley. One-half mile south of Downers.

valley between Ludlow village and Tyson. Between the village of Ludlow and Cavendish village the well-record data is incomplete since there have been only a few wells drilled in this stretch of the valley. Available records of two wells in the vicinity of Smithville show gravel to a depth of 60 feet. A seismic profile across the valley a quarter of a mile east of the Ludlow village limit, however, indicates a wide, shallow valley with a maximum depth of 80 feet (Figure 17). The surface of the valley sediment is composed of 10 to 20 feet of alluvium overlying saturated sediment with a seismic velocity of 5,000 feet/second. Since wells just east of this traverse have gravel, it is assumed by this survey that the material at Ludlow is also gravel.

East of Cavendish, the Black River, as noted earlier, flows through a narrow, steep valley that is younger than the valley upstream. In some of this distance, the river is on bedrock and in other section till. There does not seem to be any sediment in this part of the valley that would contain water in large quantities. At Downers, the river joins the former valley of North Branch and again has characteristics of an older stream. A seismic profile across the valley one-half mile south of Downers shows the maximum depth of the buried valley to be 90 feet and the sediment below 10 to 15 feet of low velocity alluvium to be saturated sediment assumed to be sand and gravel (Figure 18).

South of Perkinsville the data concerning the sediment in the valley are scattered. According to Hodges and Butterfield (1968a), 120 feet of sand and gravel fill the valley at North Springfield. The town of Springfield has two well fields in the valley one mile downstream from North Springfield and the wells here produce large quantities of water from gravel at depths ranging from 20 to 60 feet. Downstream from Springfield the valley fill is shallow and mostly fine grained.

The headwater of the Williams River, west of Gassetts, is in rugged terrain and the stream is still downcutting. The valley is therefore steep and narrow with bedrock exposed along much of the channel. Between Gassetts and North Chester the valley is much wider but it is still quite shallow and the valley fill is mostly fine textured. At North Chester, according to well-data, the valley is 45 to 50 feet deep and filled with gravel which extends down valley to the rapids in the river near the mouth of Hall Brook, two and one-half miles southeast of Chester Depot. A seismic profile across the valley two miles southeast of Chester village shows a wide valley with maximum depths of over 65 feet (Figure 19). It is assumed that the valley fill at this location, with seismic velocity of 5,500 feet/second, is sand and gravel. There are no wells in this vicinity with which to correlate, however, and a test well is needed along the traverse to definitely ascertain the texture of the unconsolidated sediment.

A short section of the river valley in the vicinity of Bartonsville is filled with sandy sediment and is believed to have good water potential. Downstream from Bartonsville the valley is filled with lake silts and clay below a thin veneer of sand and gravel.

The middle branch of the Williams River south of the Windsor-Windham county line, a mile north of North Windham, is shallow in most sections and filled with till in others. North of the county line, however, the valley deepens to over 100 feet and is filled with gravel. In the vicinity of Simonsville, the valley is over 160 feet deep. A seismic profile one and a half miles east of Simonsville indicates a valley over 80 feet deep with sediment having seismic velocity of 5,500 feet/second (Figure 20). It is believed this area has a good water potential. The South Branch of the Williams river flows through rugged terrain and has a narrow, steep valley with little or no valley fill. It has a low ground water potential.

The headwaters of the Saxtons River west of Grafton flow mostly over bedrock except in a few places where till fills a shallow valley. West of Grafton, therefore, the groundwater potential of the valley is quite low. At Grafton, well records indicate that a considerable thickness of sand and gravel fill the river valley and that the fill extends a mile or two southward down the valley of South Branch. It is the conclusion of this survey that there are good ground water possibilities in this vicinity, but test drilling will be necessary to establish the extent and depth of the sand and gravel.

Between Grafton and Cambridgeport the Saxtons River valley seems to be shallow over most of the distance, but well record data are inclusive. At Cambridgeport, the river valley again deepens and sand and gravel occurs up to depths of 80 feet. The valley of Bull Creek, south of Cambridgeport, probably has the best ground water potential of this section inasmuch as well records show sand in the valley

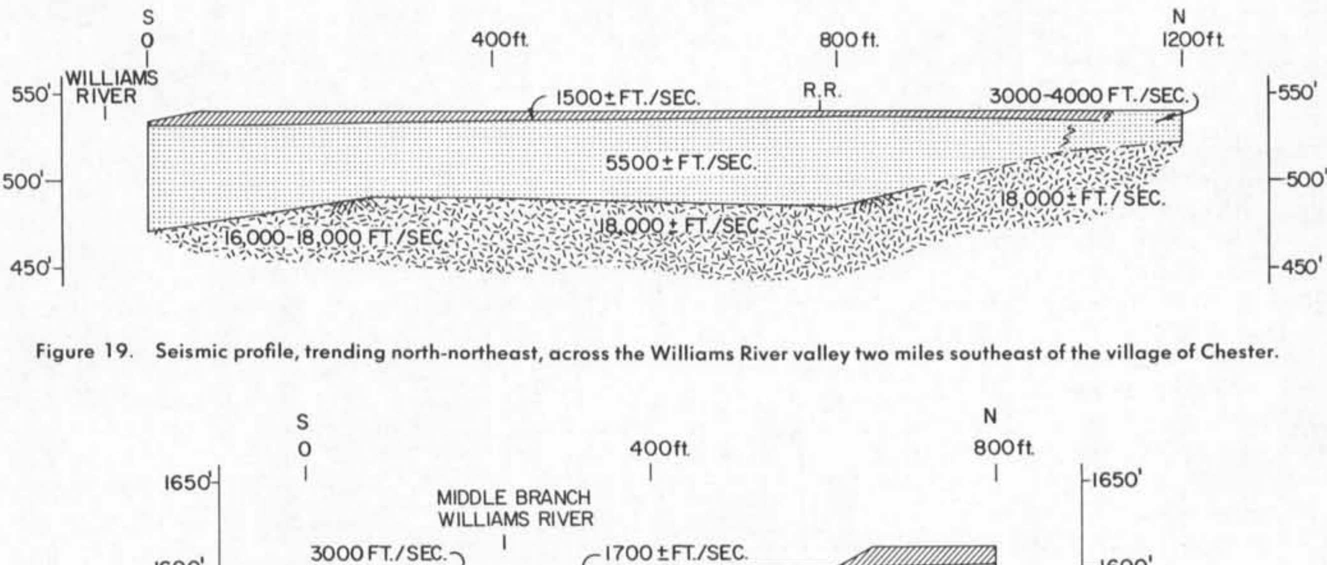

Figure 19. Seismic profile, trending north-northeast, across the Williams River valley two miles southeast of the village of Chester.

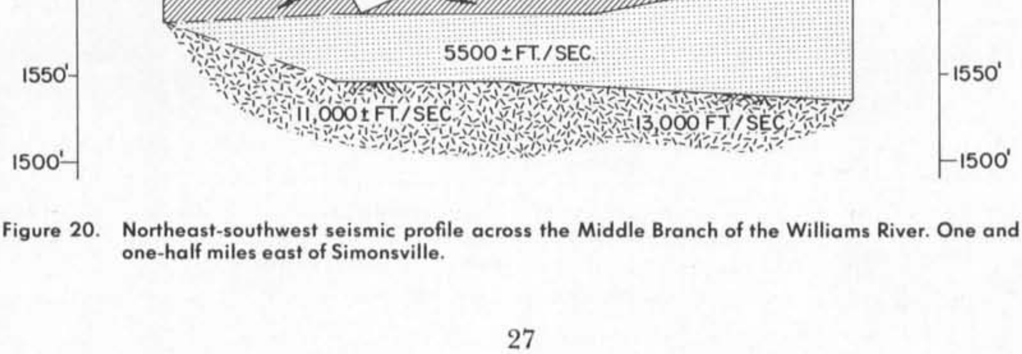

Figure 20. Northeast-southwest seismic profile across the Middle Branch of the Williams River. One and one-half miles east of Simonsville.

as far south as the village of Athens. A seismic profile across Bull Creek valley one mile south of Cambridgeport indicates a maximum depth of the buried valley is 85 feet (Figure 21). Except for the top 5 to 10 feet, the valley fill has a velocity of 5,000 feet/second, is saturated with water and is assumed to be mostly sand.

The Saxtons River valley between Cambridgeport and the village of Saxtons River is again shallow and the few well records in this stretch of the valley indicate a low water potential. At Saxtons River village, however, the valley deepens and fine-grained lake sediment fills the buried valley in the western part of the village. On the eastern side of the village, in contrast, water-wells, according to the drillers' logs, penetrate as much as 90 feet of sand and gravel. The sand and gravel continues downstream in the river valley to the falls south of North Westminster. Some well records, however, show a considerable thickness of lake clay below a few feet of gravel at the surface and above gravel in the bottom of the valley. One and one-half miles downstream from Saxtons River village a seismic profile across the valley made during these investigations shows that there is a buried valley 25 to 50 feet deep filled with saturated sediment (Figure 21). The log of a water-well just upstream from this profile records 10 feet of sand and gravel at the surface, above 70 feet of silt and clay and 14 feet of gravel below the clay. There is a possibility, therefore, that a clay and gravel sequence occurs below the depth of the seismic profile. Records of wells downstream from the profile show up to 150 feet of sand and gravel with no clay. These facts at any rate, suggest a high ground water potential for this section of the valley.

This survey rates Sacketts Brook north and south of the village of Putney with a high ground water potential. Records of wells south of the village show gravel filling a buried valley from 40 to over 150 feet deep. Upstream from the village the valley fill is over 130 feet in thickness. The only well record in this section shows clay or till at the top of the valley fill with gravel below. The seismic survey made during this survey, however, shows 65 feet of saturated sediment, probably sand and gravel, below 15 feet of stream deposited alluvium (Figure 23).

Indications of a high ground water potential were found all along the West River from its point of entry into the region near East Jamaica downstream to Newfane township. Water-well logs indicate sand and

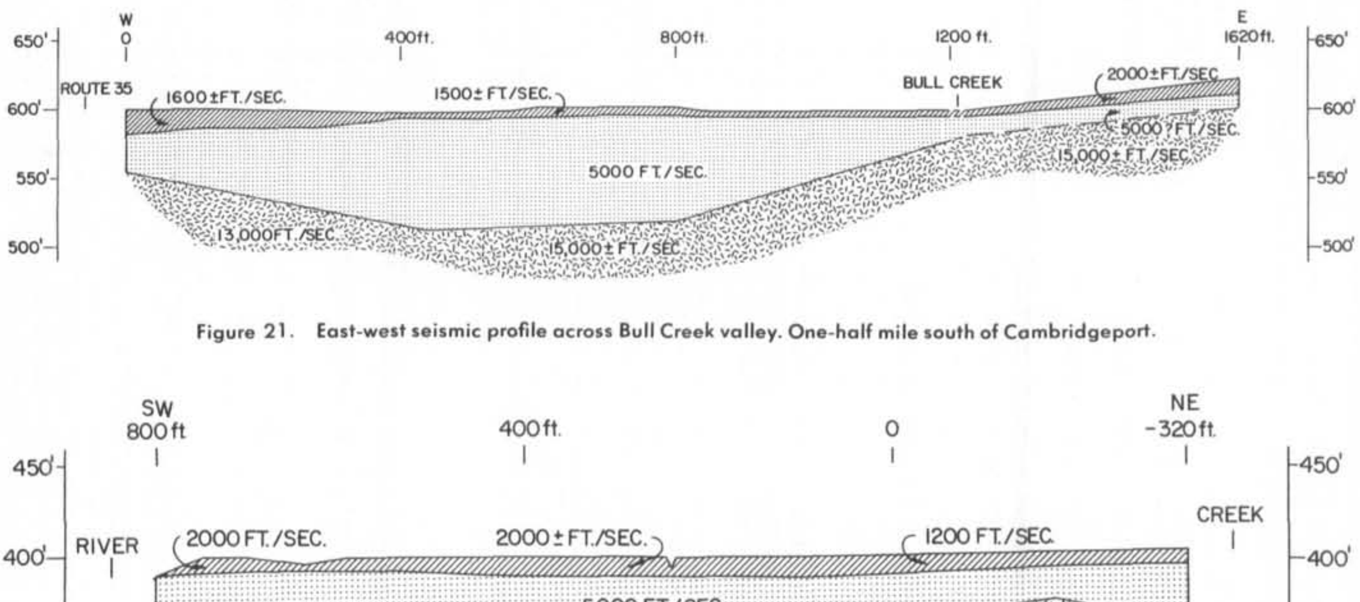

Figure 21. East-west seismic profile across Bull Creek valley. One-half mile south of Cambridgeport.

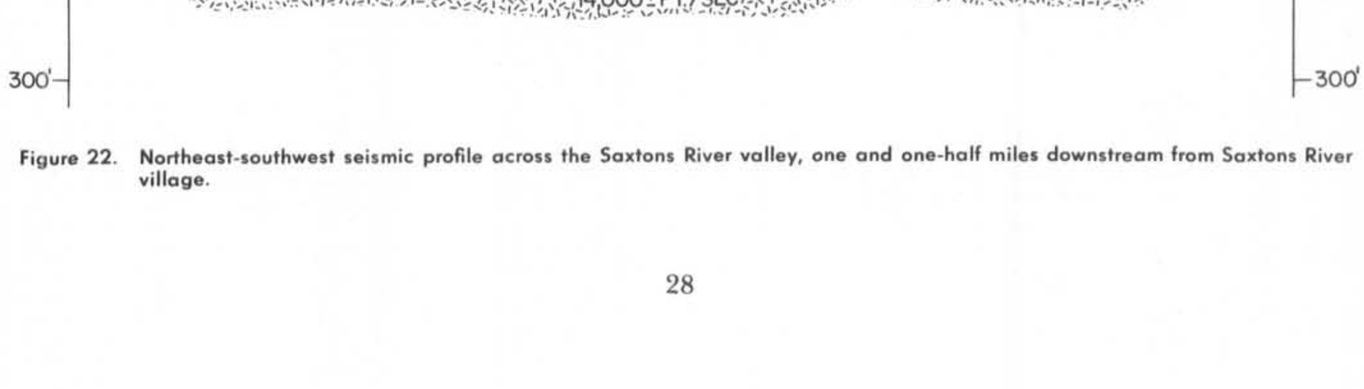

Figure 22. Northeast-southwest seismic profile across the Saxtons River valley, one and one-half miles downstream from Saxtons River village.

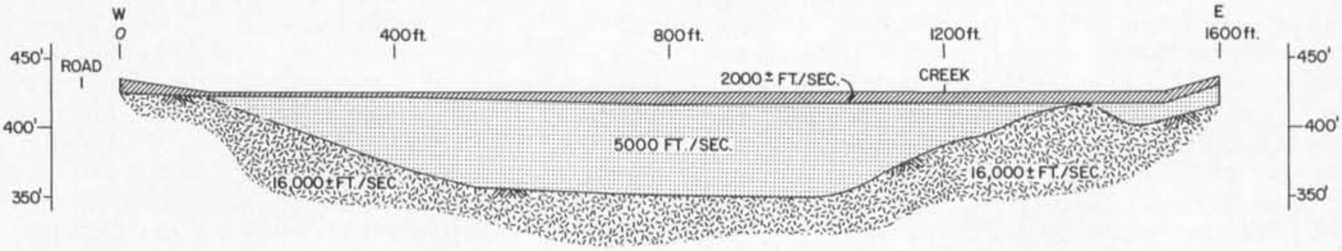

Figure 23. East-west seismic profile across Sacketts Brook valley one and one-half miles north-northwest of Putney village.

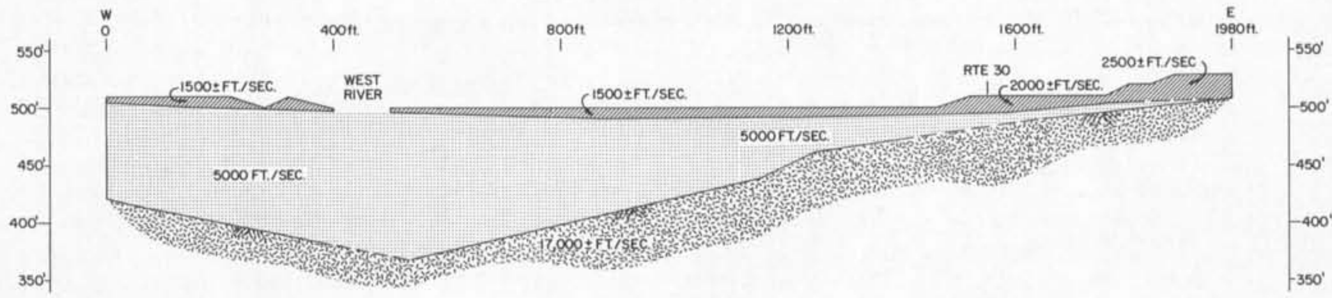

Figure 24. East-west seismic profile across West River valley one and one-half miles south of West Townshend.

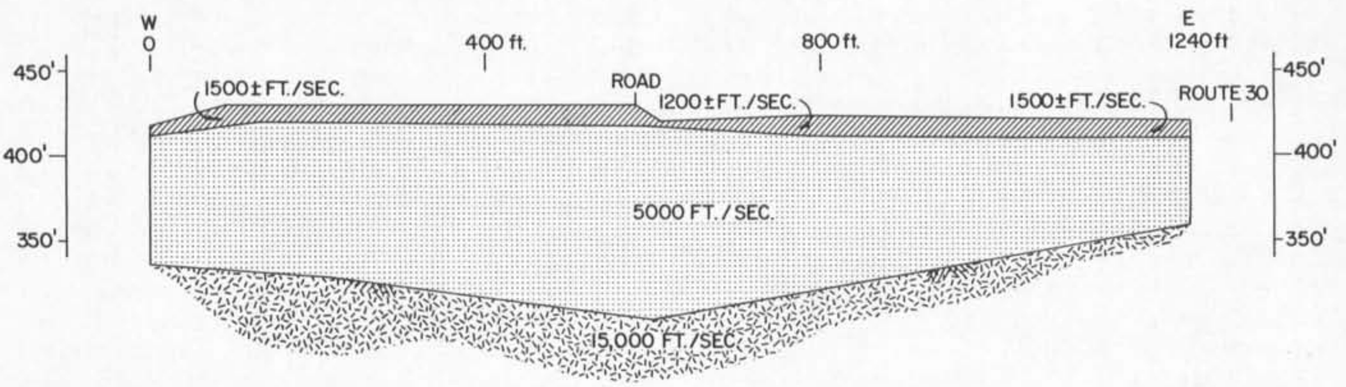

Figure 25. East-west seismic profile across the West River valley one mile south of Harmonyville.

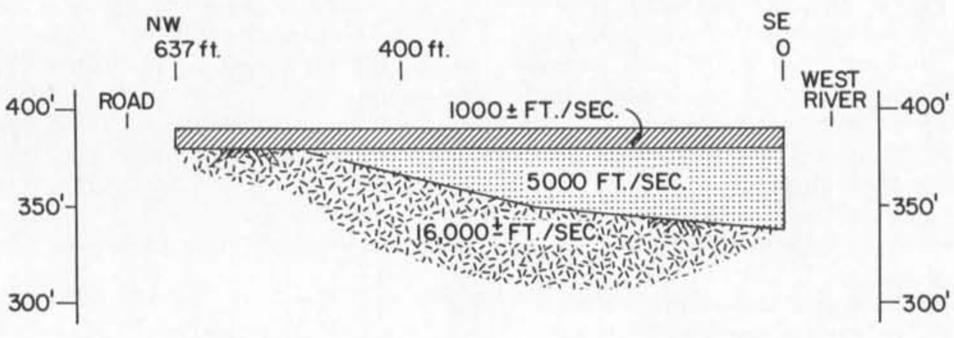

Figure 26. Northwest-southeast seismic profile across the West River valley one mile east of Newfane village.

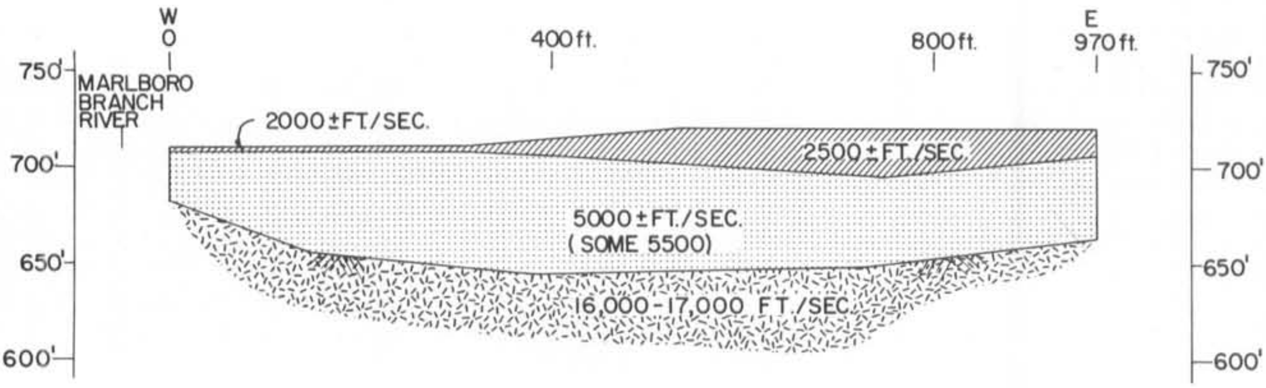

Figure 27. East-west seismic profile across Marlboro Branch valley one mile south of South Newfane.

gravel 40 to 80 feet deep, both in the river valley and in the terraces along the sides, in the East Jamaica-West Townshend section. A seismic profile one and one-half miles south of West Townshend shows the valley depth 130 feet at the deepest point (Figure 24). The sediment in the profile with seismic velocity 5,000 feet is believed to be saturated sand and gravel, but there is no record of a well in the vicinity with which to correlate. This survey, nonetheless, believes this part of the valley has a high ground water potential. There is only one well record for the valley sediment between West Townshend and Townshend village, but the one record and surface observations indicate a high potential. Records of several wells in the vicinity of Harmonyville show gravel in the river valley and up Mill Brook (Townshend) valley for at least a mile and a half. A seismic profile across the valley one mile south of Harmonyville measures the deepest part of the valley at 125 feet (Figure 25). Records of wells in this vicinity prove the fill to be saturated gravel and therefore this section has a high ground water potential.

Northeast of Newfane village the West River swings eastward and crosses a series of rapids where bedrock is exposed in the channel. South of the mouth of Grassy Brook, however, the valley widens and one mile east of Newfane village a seismic profile that partially crosses the valley shows fill over 50 feet deep with a seismic velocity of 5,000 feet/second (Figure 26). Although there are no wells in this section for correlation, this survey interprets the ground water potential as good. Newfane is located in a valley that well records indicate is filled with gravel 25 to 50 feet deep. This area should have a good ground water potential.

The Rock River and one of the tributaries, Marlboro Branch, have very good possibilities for ground water. West of South Newfane, the Rock River has gravel filling a buried valley to depths of over 95 feet. At South Newfane and for two miles downstream to Williamsville, well records show gravel in the valley from 50 to 100 feet deep and east of Williamsville the valley fill is mostly sand 25 to 50 feet in thickness. The Marlboro Branch valley south of South Newfane has a single well record located one and one-half miles south of the Rock River that records 70 feet of gravel. A seismic profile across the valley one mile south of South Newfane describes a wide valley with a maximum depth of 75 feet (Figure 27). As much as 25 feet of low velocity stream sediment occurs at the top of the valley fill, but the remainder of the sediment, with seismic velocity of 5,000 feet/second, is correlated as a saturated gravel.

Downstream from the mouth of the Rock River, the West River has a shallow valley in most sections. A small area on the east side of the valley a mile north of West Dummerston seems to be an exception inasmuch as drillers' logs record up to 100 feet of gravel. On the west side of the valley between Brattleboro and West Dummerston a terrace composed primarily of lake sand and gravel extends up and down the valley for approximately four miles. The terrace gravel, according to well records, varies in thickness from one locality to the next, but some logs indicate thicknesses of 50 to 200 feet. In other places, however, the depth to bedrock is only 15 to 25 feet. It is believed that the ground water potential in the terrace is good, but test drilling is recommended.

The tributary streams of the Connecticut River south of the West River do not have ground water potentials that can be classified. There are few places where permeable sediment has been reported, except in occasional small isolated localities.

HIGHWAY SALT

One of the problems of water pollution that has not, as yet, been given adequate consideration is the use of salt on roads and highways. The problem includes both the use of sodium chloride for ice removal in winter and calcium chloride for dust control in the summer. The two salts are easily soluble; they are transported by both surface and subsurface water, and once they enter a water supply their removal is most difficult. This is a form of chemical pollution and the pollutant is not removed by filtering through sediment or rock.

Calcium chloride is applied to dusty, gravel roads since it absorbs water from the atmosphere, making a damp surface which lays the dust. It is preferred to a water spray inasmuch as water evaporates rapidly whereas the water absorbed by the calcium chloride remains for several days or even weeks. The number of miles of unpaved roads diminishes all the time and therefore use of calcium chloride for dust control likewise decreases. But, there is still much calcium salt used for this purpose.

Sodium chloride is applied to icy, snowy roads and highways to melt the ice and snow. The amount of salt used for this purpose has increased rapidly over the past few years because of the increased mileage of paved roads and the building of four-lane highways such as the interstates. The salt melts the snow and ice and traffic is maintained at normal speeds.

When these salts are applied to a highway, they are dissolved by the water of the next precipitation and carried away in solution. Fortunately, the design of modern highways is such that most of the runoff from the roadway enters the drainage system and is carried into surface streams. A portion of the salt, nonetheless, is carried onto the adjacent land where it sinks into the ground. Most secondary roads are not so well drained and a larger portion of the salt is transported to adjacent land. Evidence of this is apparent along the highways where grasses, plants, bushes and even trees have been affected by the salt. In areas of porous, permeable surficial sediment, the flow of this polluted water into the subsurface and downward to the water table is quite rapid.

Probably the most serious practice in regard to the salt concerns the storage of the salt by local, township and state agencies. It is common practice to stockpile a winter salt supply during the summer months. The salt is stored in all kinds of places under all kinds of conditions. Some storage is in properly sheltered, dry facilities, whereas other supplies are dumped on the ground with little or no cover. A favorite location seems to be in abandoned gravel pits where the surface material has a very high permeability. This report suggests that salt storage should be considered a serious environmental problem and that facilities for storage should be dry and the floor should be impermeable, preferably four to six inches of cement. The location of the facility should be in a section where the surface material is of low permeability such as till or lake clay and silt. The salt spilled during loading and unloading may be hazardous in areas of sand and gravel.

A few states have reduced the use of salt in winter by plowing the highways and applying cinders or sand to the plowed surface. In Vermont, the use of sand for this purpose would not be too unrealistic since sand is available in most regions. Admittedly, traffic cannot be maintained at high speed on highways that have been so treated, but the problem is one that needs a high priority.

SOLID WASTE

The disposal of solid waste has not, as yet, become a major environmental problem in the Brattleboro-Windsor region because the population density is still relatively low and development has not been excessive. As the region develops, however, and there is no reason to believe that growth will not occur, the problem of solid waste will become of major importance. It is the low volume of the waste now collected that has minimized the problem since current practices in the region are not satisfactory. Much of the waste of the whole region is collected by a single commercial firm and this has relieved the pressure on the towns and villages. Brattleboro township, however, still collects and disposes of waste in that section. The U.S. Environmental Protection Agency estimated that in 1969 the urban solid waste amounted to six pounds per person per day (U.S. Environmental Protection Agency, 1973). A substantial increase in the population therefore results in a voluminous increase in the amount of solid waste. Planning will be necessary to cope with the increased solid waste that will be generated by the expected population growth of the near future.

The disposal of solid waste involves geologic materials and processes and geologic study of a disposal site is imperative to avoid pollution. The saturation of refuse by water, even intermittantly, produces a liquid pollutant called leachate. This contaminant is the result of the decay of organic matter and other biodegradable waste and by the chemical action of acidic wastes on metallic materials and soluble components. The leachate is liquid, contains a variety of biological and chemical pollutants, and it moves downward and outward following the normal flow patterns of subsurface water. Kelley (1975) recently reported contamination of a lake, caused by subsurface flow, 1200 feet from a landfill in Rhode Island. In the Brattleboro-Windsor region, solid waste disposal practices should be chiefly concerned with methods for reducing the rate at which leachate is produced, prohibiting the contaminants from entering the fractures in the bedrock, preventing pollution of the ground water in the unconsolidated sediment in the valleys, and assuring that the leachate does not move laterally and enter surface streams or lakes. Most present practices in the region do not even consider these factors.

There are two major precautions that must be taken in the region to reduce the rate at which leachate is produced and to restrict the movement of the leachate that is invariably formed to a small area above the bedrock and above the water table. In the first place, care must be taken in the selection of a site for a landfill and, secondly, a low permeability material must be available for a cover. In this region, materials with a permeability low enough for landfill sites are the glacial tills and the lake silts and clays. Since silts and clays have a very restricted occurrence, glacial till is the only material available in most localities. According to the Illinois Geological Survey (Cartwright and Sherman, 1969; Hughes, Landon and Farvolden, 1971), a minimum thickness of 30 feet of impermeable material is necessary to prevent the seepage of the leachate. The Geological Survey of Georgia suggests 50 feet (Riccio and Hyde, 1971). This survey recommends 30 feet as a minimum in the Brattleboro-Windsor region since the surface material is similar to that in Illinois. Abandoned sand and gravel pits, favored sites for landfills in the region (Figure 28), are not suitable and their use for this purpose should be prohibited.

A suitable cover material for a landfill is necessary and is as important as the location of the site. The production of leachate is proportional to the amount of water that moves through the refuse. The cover material must therefore be low in permeability and applied in sufficient thickness to prevent as much water as possible from entering. Too much water entering the refuse causes a buildup in and along the sides of a landfill, causing the water to rise and seep out, at the surface, along the margins of the fill. This, of course, brings leachate to the surface and spreads it over the ground in the vicinity of the fill where it either sinks into the soil or runs off into the local drainage. The more water in the fill during the winter months, the more freezing and thawing that takes place. Freezing and thawing expands and contracts the refuse, causing it to be dislocated and loosened and allowing more water to enter. The most suitable cover, therefore, is an impermeable material such as till or silt and clay. Sand and gravel are too permeable and allow water to seep through the cover. Sand is also easily blown away by the wind,

Figure 28. Trench excavated in sand for the burial of solid waste, two miles north of Ascutney.

leaving the waste exposed at the surface.

Some recent studies of the movement of leachate, the work of Hughes, Landon and Farvolden (1969) in Illinois, for example, show that the pollution hazards from sanitary landfills may not be as difficult to control as it had been formerly assumed. These studies, however, have not been in areas of fractures, contorted and metamorphosed bedrock, and the results obtained do not apply to the Brattleboro-Windsor region. The studies do seem to show that modification of a site, even in a locality of questionable conditions, is possible. Modification as used in this report refers to the use of plastic liners, clay fill, spray seals, etc., that reduce the permeability to an acceptable level in the vicinity of the landfill. The evaluations of the solid waste conditions of this report (Plate IV) are based on potential use without modification. The modification of a landfill site, it should be noted, is a highly specialized procedure and should not be attempted without professional advice and in most cases professional supervision.

The solid waste conditions map of this report (Plate IV) gives a generalized classification of the surficial material as it relates to solid waste. The areas outlined on the map are delineated chiefly on the basis of the thickness and permeability of the surface with, as stated above, little or no regard for the possibilities of modification. The map is intended as a guide for use in the selection of landfill sites, but it is assumed that a detailed study of each site will be necessary. As a general rule, the hydrologic conditions vary so much from one locality to the next that it is not possible to predict the exact characteristics of each locality, and the scale of the map prohibits a more detailed analysis.

The sections legened green (g) on the solid waste conditions map have till or silt and clay covering the bedrock with thicknesses in excess of 30 feet. Till is the most suitable material for a landfill in the region inasmuch as it has a low permeability and is only relatively difficult to excavate. Silt and clay are suitable but they are not available in most cases.

The yellow (y) areas on the map have till or clay of unknown thickness. Much of the surface material of these tracts is suitable for landfill, but it is necessary to determine that the thickness is 30 feet or more. In locales where the thickness is 20 to 30 feet, a landfill may be developed with a minimum of modification. If the material above bedrock is less than 20 feet, modification to seal the walls and floor of the excavation is necessary and this is a costly procedure. In all cases, till or silt and clay should be used for a cover.

The sections legened r-2 on the map have surface material composed of sand and gravel. In some places, the sand and gravel extend down to the bedrock, but in other localities silt and clay, or possibly till, occur below them. If the sands and gravels are the only material above bedrock, the site is unsuitable for landfill and adequate modification is usually too difficult and the chance of leakage too risky. If over 20 feet of till or silt and clay underlie the sand and gravel, a landfill site may be developed only if some type of liner or seal is used to prevent the lateral migration of the leachate.

The r-1 legend on the map locates swampy and other poorly drained tracts. Some of these are in stream valleys where seasonal flooding is common. Landfills cannot be satisfactorily developed in these sections since it is impossible to prevent pollution of the surface water or the saturation of the refuse in the fill.

SEWAGE DISPOSAL

The problems associated with the disposal of municipal sewage was not of particular concern to this survey since state and federal regulations generally control these installations. Municipal sewage pollution is decreasing at a slow, but definite rate in the Brattleboro-Windsor region as a result of state programs to raise the classification of the surface water. Saxtons River, for example, built a new secondary sewage treatment plant in 1972; Windsor has constructed both primary and tertiary treatment facilities; and Bellows Falls will break ground for new installations in 1975. There are, however, several smaller villages in the region that have no municipal treatment facilities at this time and no plans for such installations in the near future. Unfortunately, the sewage treatment plants of two different villages were completely destroyed by the flood of July, 1973, and considerable damage was caused to the systems of other villages.

Municipal sewage is only one of the problems of stream pollution in the Brattleboro-Windsor region. Since, as stated above, many villages do not have municipal systems and since most of the increased population of the past decade has been in rural areas, septic tanks are probably one of the more critical environmental problems. In all areas where there are no publicly owned sewage facilities, including villages, the total population relies on individual septic tanks for sewage disposal. And, all of the development, including rural homes, that is beyond the reach of a municipal sewer line must install a septic tank with a leaching field or a seepage pit.

The septic tank with a leaching field is one of the more reliable and least expensive sewage disposal systems for rural use. The word rural as commonly used, however, implies a sparse population with large distances between individual homes. But since World War II, the septic tanks have not been restricted to rural use. They have instead been concentrated in small areas such as villages, housing subdivisions, summer colonies, ski resorts, and other developments where the environment is definitely not rural. In the Brattleboro-Windsor region, these practices have been as prevalent as elsewhere, and the concentration of septic tanks in several areas has been more than geologic conditions can bear. These uses of septic tanks are not rural.

The intermittent flow of waste in the septic tank is broken down and decomposed chiefly by the action of anaerobic bacteria. A properly constructed and installed septic tank generates an anaerobic bacterial treatment, removes and stores the solids from the waste and stores the sludge and scum produced. The septic tank treatment, nevertheless, does not purify the waste or remove the infectious bacteria or virus. The waste discharged from the septic tank into the leach line is an odoriferous fluid containing large amounts of anaerobic bacteria, suspended solids, nutrients, salts and, in some cases, infectious bacteria and virus.

The function of a leaching field or seepage pit is to dispose of the fluid waste by allowing it to seep into a suitable geologic environment. A series of activities take place as the liquids seep from the leach lines into and through the surrounding soil and unconsolidated sediment. According to Franks (1971, p. 195-96), a series of biological, chemical and physical changes take place during this phase of the treatment. The soil and unconsolidated surficial material act as a filtering agent and exchange ions with the liquid waste. Oxidation takes place, and bacteria in the soil and mantle attack bacteria in the waste. The U.S. Environmental Protection Agency (1973, p. 70-71) states that leaching fields located in the biologically active soil zone have soil bacteria available to stabalize the organic matter and that filtering and absorption removes the particulate matter and certain ions from the waste. If the seepage beds are located below the biologically active soil zone, organic matter is degraded by anaerobic conditions and filtering and absorption are the chief methods of purification. In Vermont, leaching fields that are located deep enough to prevent frost heaving are usually below soil zone.

Recent research concerned with the suitability of different kinds of surface material for leaching fields have shown that the texture of the unconsolidated sediment in which the leach lines are located is more important than the permeability (Romeo, 1970, p. 44). These and similar studies question the validity of percolation tests that have been recommended for many years to determine whether or not a particular site could be used for a leaching field and to establish the length of the leach line needed, (U.S. Department of Health, Education and Welfare, 1967, p. 4-10; Vermont Health Regulations, 1970, Chapter 5). The U.S. Environmental Protection Agency (1973, p. 76) suggests that the approval of septic tank sites by competent soil scientists and engineers should eliminate the need for percolation tests. They insist that the standard code for septic tank installation and the percolation tests as a basis of approval are inadequate criteria.

Many kinds of coarse-grained sands and gravels have permeabilities that are too high to provide sufficient filtering and absorption of the affluent from the leach line. In the Brattleboro-Windsor region, development has been encouraged on the more permeable sands and gravels with little regard for the rate of flow of the liquid wastes through these surficial materials, the rate of absorption, or the location in respect to surface drainage or surface water bodies. Research by others has demonstrated that bacterial pollutants are more effectively removed as effluents percolate through unsaturated surface material and soil than through saturated. The flow of liquid contaminants is always in the direction of the natural ground water flow (Franks, 1972, p. 202-03). It has been established, therefore, that investigations to determine the suitability of a site for a septic tank system should determine, in addition to the permeability, the direction of subsurface water flow, the distance of flow through unsaturated sediment, and the nature of the unconsolidated material in contact with the leach line.

The proper operation of a septic tank system is also influenced by the slope of the land surface on which it is located. It is regrettable that this important factor could not be illustrated on the septic tank map (Plate V), but the topography of the region is so irregular and slopes change so rapidly that inclusion on the map was impractical. The location of a septic tank installation on a hillside slope is not permissible since the surface material is usually thin, fractured bedrock is therefore near the surface, and the flow of the effluent is inevitably toward the surface.

The most hazardous result of septic tank operation on a hillside location is the pollution of both the subsurface and surface water supplies. Most homesites in such locations have both a private water supply and a sewage disposal system. Because the cover over the bedrock is usually thin, the waste from the leaching field reaches the fractures in the bedrock after a short flow. As has been noted earlier in this report, liquids passing through fractures are not filtered and may move for miles before bacteria and virus are removed. The rock fractures trend in all directions and the location of a well upslope from a septic tank is no assurance that contamination will not occur (Waltz, 1970, p. 42). Surface pollution results from the fact that the effluent from a leach line on a hillside slope will eventually surface a short distance downgrade. According to Franks, (1972, p. 201), effluent will probably surface on slopes of over 20% regardless of the surface material or the depth of burial. Effluent that covers the surface is odoriferous and undesirable to say the least, but the most serious result is the contamination of surface water. The saturation of the surface material by the liquid waste also makes it more susceptible to flow, slide and creep.

The septic tank conditions map (Plate V) describes the characteristics of the surface material as they relate to the disposal of domestic sewage, particularly septic tanks with leaching fields. This survey does not recommend the use of dry wells or seepage pits instead of leaching fields in the Brattleboro-Windsor region. There are some limitations to septic tank use, especially when the slope is considered, in most sections of the region, but many of the limitations can be handled by careful planning and detailed study of the site. The green sections on the map are areas of till where the thickness is sufficient to insure filtering, and the sand content of the till is high enough to allow it to transmit the effluent.

Most till areas, however, are designated y-1 on the septic tank map. The thickness of the till above bedrock is not known in these sections. The use of septic tanks in these areas is dependent upon the permeability of the till, the slope of the land surface and the thickness of the bedrock cover. For the most efficient operation of a septic tank, it is suggested that the slope of the land surface should be less than 20%, the thickness of the till above bedrock should be at least 10 to 20 feet, and 200 feet of leach line should be used to distribute the effluent.

The areas legened y-2 on the map have permeable sands and gravels at the surface. There is no doubt about the permeability of these sediments, but, as stated above, some of these are too permeable and too coarse grained to be used for leaching fields. Factors, in addition to permeability and texture, that must be considered when planning sewage systems in these materials are the thickness of the deposit, the depth to bedrock, the depth of the water table, and the kind of sediment, if any, below the sand and gravel. Much of the sand and gravel in this region is lake sediment that commonly overlies silt and clay. In these cases, the underlying finer sediment will retard or halt the downward movement of the effluent and pollution of ground water will not occur provided the water table is several feet below the top of the silt and clay. Lateral movement of the effluent, on the top of the silt and clay may occur and contamination of adjacent areas could result.

The areas designated r-1 on the septic tank map are stream bottoms that are usually poorly drained and covered with alluvium. Isolated swamps are also included in this class. The surface of the valley floors is frequently flooded and the surface material often has a low permeability and, as a result, is poorly drained. Septic tanks do not function properly in these sections except during the dry season.

The few small areas with lake silt and clay at the surface are designated r-2 on the map. The silt and clay is so fine textured and has such a low permeability that septic tanks will not function because the effluent cannot seep into or through the surrounding material. Instead, the effluent builds up in the trenches of the leach line and eventually comes to the surface. Under normal circumstances, septic tanks should not be permitted in these sections.

FOUNDATION MATERIAL

In spite of the rugged topography in many sections, the environmental problems associated with building and foundations is not as acute in the Brattleboro-Windsor region as those already discussed. The mountainous terrain in the rougher areas includes many localities where the slopes are too steep for construction but, generally speaking, limitations are not too severe. The factors that must be considered when judging the desirability of a building site include such geologic conditions as the strength and plasticity of the surficial material, the internal drainage of the surface sediment and the slope of the land. In the region of this study, cautious consideration must be given to the stream valleys because of flooding and the low strength of some of the alluvial sediment of the valley floor. Limitations are also necessary because of the steep slopes, the plasticity of the clay in some sections, and the internal drainage of the surficial material.

A fine-textured stream-deposited sediment called alluvium covers the bottomlands of most stream valleys. The material, because of its low strength, is one of the most undesirable foundation materials. The valley floor is frequently flooded and the internal drainage is often poor. If the bottomlands are to be used for heavy construction, the total thickness of the alluvium should be removed and special drainage should be included in the specifications. The flood of July, 1973, as will be discussed later, should have convinced the total population that the floodplains in stream valleys are not a desirable building location. The damage done by the flooding in the Brattleboro-Windsor region was immeasurably great and planning should definitely include precautions to limit the development on the valley floors. There is a historical justification for the location of cities and towns on the floodplains inasmuch as the streams were one of the few modes of transportation. There is absolutely no excuse, however, for continuing the practice of developing the bottomlands.

The most favorable materials for construction sites in the region are the sand and gravel deposits. Sands and gravels have a high strength and they are well drained. Many of these deposits, however, are of economic importance and as the population increases, the demand for these materials will also rise. It is the recommendation of this report that the better deposits of sand and gravel should be reserved for future use, and that construction on these should be prohibited. There will definitely be a need for these materials as soon as development proceeds. After the sand and gravel have been removed, most locations still make desirable construction sites with a minimum of grading and filling. The common practice of abandoning sand and gravel pits without reclamation, or using them as some kind of refuse dump, is indeed poor planning. These are choice locations for construction. Lake sands and gravels, the most common type in the region, often overlie silts and clays and these require special study to determine the thickness of the sand and gravel above the silt and clay. If the thickness of the sand and gravel is less than 15 to 20 feet, the plasticity of the underlying clay may be too high to support heavy construction and slumping, sliding and flowage may occur. It is therefore necessary to ascertain the physical characteristics of the sediment underlying sand and gravel deposits.

Lake clays are often so plastic that they are subject to flow and other types of mass movement. The areas of outcrop of these lake-bottom sediments are quite small in the Brattleboro-Windsor region, but, as stated above, they usually occur below lake sand and gravel. The internal drainage of the fine-textured lake sediment is generally quite low and special drainage provisions should be included in all building specifications. Steep slopes composed of clay or slopes with clay underlying surficial sand and gravel, should be avoided to assure that the foundations are not undermined by flowage or sliding of the slope. In this region, the stream valleys, particularly the smaller tributaries of the Connecticut River, are quite vulnerable to this kind of movement.

The general construction map of this report (Plate VI) classifies the different kinds of surficial material according to its suitability for foundations. The areas shown in green (g) are permeable sands and gravels. These deposits include the lake sand and gravel that may overlie the lake silts and clays and, as already noted, they should be investigated to determine the thickness and the type of sediment below them. The small section designated y-1 has lake clays and silts at the surface. They are often poorly drained and the plasticity of the clay is the major problem insofar as construction is concerned. The surface material in the areas legened y-2 is glacial till. The suitability of sites in this section depends on the thickness of the till. Till thicknesses vary greatly from one locality to the next and therefore building conditions also vary. The till is generally thin in the upland areas and excavation of the underlying bedrock is often necessary. The bedrock in most cases is fractured and weathered so that excavation is not difficult. But, in some places, the bedrock is an igneous intrusion such as granite or resistant quartzite and excavation of this kind of rock is very difficult. It is suggested, therefore, that the bedrock should be tested in all situations where excavation will extend below the sedimentary cover. The stream bottomland is classified r-2 on the map because of frequent flooding and the undesirable alluvium that covers the surface. Poorly drained, swampy areas are legened r-1 on the map and these are unsuitable for any kind of construction.

GEOLOGIC HAZARDS

There is a variety of different kinds of destructive, natural phenomena that are directly related to geologic materials and geologic processes that are collectively called geologic hazards. These natural happenings are of environmental significance because man, as a general rule, has not been successful in his efforts to control, regulate or decrease the damage caused by them. They must, therefore, be carefully considered when planning for land use. The hazards include volcanic eruptions that do not occur in Vermont, earthquakes and hurricanes that occasionally occur but usually with minimum effect, and landslides, flash flooding and stream flooding that are potential problems in the Brattleboro-Windsor region. Cautious planning cannot eliminate the cause or the effect of these phenomena, but careful selection of sites for industrial installations, municipal facilities and housing developments will assure their location where damage from these hazards is minimal.

Landslides

Landslides are always a potential threat along steep slopes composed of clay because, as already noted, the lake clays are quite plastic and become very slippery when wet (Figure 29). In the Brattleboro-Windsor region, many valleys of the smaller streams

Figure 29. Landslide on the north side of Salmon Brook valley one mile east of East Dummerston. Valley wall is composed of lake clay.

that flow into the Connecticut River are cut into the lake clay. These valley walls have a sand cover at the top and a thick sequence of clay below the sand. Inasmuch as the valleys are narrow and the valley walls quite steep, some almost vertical, the clay could not be illustrated on the surficial materials map. Planning in these areas should consider the valley walls and those composed of clay should be avoided. Construction should also be restricted at the tops and bottoms of these slopes to prevent damage in the event of sliding. The valley wall of a stream is particularly vulnerable because the stream is continually changing its course and lateral erosion is constantly altering the character of the slopes along the valley. The route of Interstate Highway (I-91) was first planned at a lower level near the Connecticut River, but the route was changed to the present, higher location after a detailed study of the lake clay.

Quick clay is the name applied to a particular kind of clay that may, for many reasons, be converted to a viscous liquid and subject to spontaneous flow. According to Liebling and Kerr (1965), much of the clay deposited in the Champlain Sea following the Great Ice Age has been classified as quick clay. Their studies were restricted mostly to the St. Lawrence River valley, but they do report that quick clay does occur in Vermont. It has also been established that quick clay is formed in fresh water lakes. At this time, little is known about the classification of the lake clays of the Connecticut River valley, but it is possible that some of the clay in the region does have quick clay characteristics. Until more conclusive research is completed and more definite information is available concerning the lake clay, planning should assume a severe potential danger from landslides along the clay slopes.

Flash Flooding

Geologic conditions in the Brattleboro-Windsor region are quite conducive to flash flooding. As has been explained earlier in this report, the major streams of the region, tributaries of the Connecticut River, all head in the Green Mountains or in the Green Mountain foothills. These streams have steep gradients in their upper reaches but the gradient is, as a general rule, rather low away from the mountains. A second factor that tends to increase flash flooding is that the surface of the higher elevations of the region are either barren or they are covered with only a thin veneer of glacial till. When precipitation occurs, most of the water runs off into surface streams since very little water can seep into the subsurface. Therefore, when a large amount of precipitation falls in a short period of time most of the water goes into small streams that flow down steep slopes at high velocities. The small mountain streams, in turn, carry large amounts of water into the major drainage lines. When this rapidly flowing, large volume of water reaches the lower sections of the stream, where the gradient is much lower, the velocity of flow is decreased, the water piles up and flooding results. Thus it is that flash flooding in the mountain sections results in general flooding of the trunk lines. Much of the flooding of the Connecticut River and the major tributaries is the result of flash flooding of the small, headwater streams that originate in the higher, more rugged terrain.

Flash flooding may, however, occur in the lower reaches of the larger streams as a result of adverse conditions such as torrential rain, saturated ground and/or unseasonably wet conditions. This was the case in July, 1973, when most of the state in general and the Brattleboro-Windsor region in particular experienced flooding that was reportedly the most damaging since the flood of 1927 and the highest since 1936 in the Connecticut River valley. The rainfall in June, 1973, had been the second highest on record with 7.69 inches of rainfall recorded for that month, 4.20 inches above average. The surficial material of the region became saturated, preventing more water from seeping into the ground, resulting in runoff of 100%.

Heavy rainfall in central and southern Vermont on June 29 and 30 and into July 1, according to the National Weather Service, resulted from the movement into the region of a north-south trending, moisture-laden, weather front that collided with southward moving moist air from the Atlantic Ocean. The meeting of the two air masses just east of the Green Mountains resulted in up to 5 inches of rainfall on the east side of the mountains and considerable rain on the Green Mountain crests and on the western slopes. The rainfall and resulting flooding was greatest in the southern and central parts of the state with gradually decreasing amounts northward. Whereas Rutland, for example, recorded 4.32 inches of rainfall for the three-day period, Burlington had

Figure 30. Railroad track undermined by erosion of a small stream one-half mile north of Healdville.

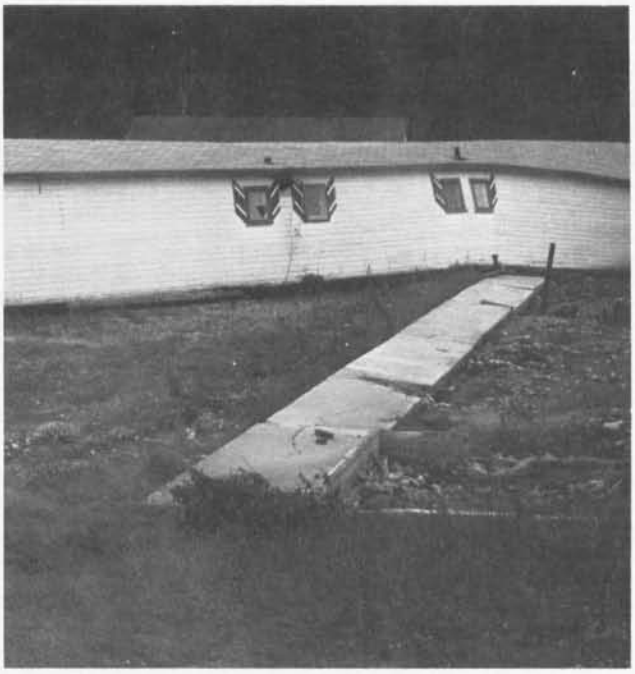

Figure 31. Motel washed from its foundation by the flooding of Branch Brook, a tributary stream of the Black River, two miles northwest of Grahamville.

only 2.35 (Burlington Free Press, July 3, 1973). In Windham County, a total of 5.07 inches of rainfall was measured over the four-day period between June 28 and July 1 (Brattleboro Reformer, July 2, 1973).

The hardest hit area of the whole state was the Black River valley in the towns of Plymouth, Ludlow and Cavendish. Since the Black River and its tributaries drain the eastern slopes of the Green Mountains the total length of Plymouth and Ludlow townships, and this was the area that was deluged with the highest rainfall, the flooding was highest and most devastating (Figures 30 and 31). Ludlow village and the villages to the east in the river valley (Smithville, Proctorsville, Cavendish and Whitesville) were isolated and flood damage was most severe. Two sewage disposal systems were destroyed (Figure 32), two manufacturing companies were heavily damaged, a restaurant was completely washed away, State Route 131 between Ludlow and Whitesville was washed out in many places and at least one-third of this route was completely washed away between Whitesville and Downers.

The Connecticut River was flooded by water carried into its course by streams flowing from the

Figure 32. The former site of the sewage disposal system of the town of Cavendish one year after the flood. One mile east of Cavendish village.

east side of the Green Mountains. The flooding in the Connecticut valley was considerably reduced by the flood control dams, built by the U.S. Army Corps of Engineers. Two of these dams are located in the Brattleboro-Windsor region on the Black and West rivers. According to the Brattleboro Reformer (July 2, 1973), the normal elevation of the Connecticut River at the Yankee Nuclear Plant in Vernon is 218 feet. During the 1973 flood, the water rose to 227 feet. During the flood of 1927, the rise was two feet higher than in 1973, but in 1936 the water rose to 231.4 feet in elevation (Brattleboro Reformer, July 2, 1973).

Flood control is a very real problem in all areas where flood loss is a threat. There are several geological aspects to the problem of flood control but a solution that is in agreement with the philosophies of the population is not in sight. In Vermont, the topography, the thickness of the mantle covering bedrock, and the configuration of the drainage pattern are natural phenomena that cannot be readily changed. Since these and other conditions already mentioned account for the rapid runoff it is readily apparent that flooding cannot be eliminated. The only two practices that would tend to decrease the damage from floods are the building of dams to hold back the runoff or restricting the use of the stream floodplains.

Experience has shown that the most effective way to control runoff is the construction of dams that hold back the water in stream basins. It cannot be disputed that the flood control dams in the Brattleboro-Windsor region greatly decreased the damage from the 1973 flood. The flood damage in the Ludlow section of the Black River valley, as bad as it was, would have been even greater had it not been for two or three small dams built by the U.S. Conservation Service. There have been serious objections to dams in recent years inasmuch as the damming of the streams disrupts the ecology of the stream valley. It is true that flooding is a normal stream process and certain ecosystems are propagated by the flooding and that an ecological imbalance results when the streams are dammed. The present dams and the tributary streams of the Connecticut River, however, do not maintain a high level pool, as the flood gates are closed only when flooding occurs.

A significant amount of runoff control can be accomplished by foresting the watersheds of stream systems. Several problems prevent this practice in most regions. The land of most watersheds is privately owned and legislatures hesitate to pass laws that regulate the use of privately owned land. Another important factor is the initial cost of reforestation which is almost prohibitive without government subsidy. In Vermont, many of the most critical watersheds do not have enough cover to support the growth of trees.

Undoubtedly the most effective method for decreasing flood damage is a detailed plan for floodplain management. In a sense, this practice requires a restriction on the use of privately owned land inasmuch as the purpose is to limit the use of the bottomland in the valleys. It is a fact that the best agricultural lands in Vermont, with the possible exception of a few areas of the Champlain Lowland, are the floodplains of streams, and these areas should be reserved for agricultural purposes. There is, of course, damage to crops during floods, but the greatest damage is to private, municipal, business and industrial installations and buildings in the valley. Floodplain zoning and planning should discourage construction in the valleys below flood level.

GEOLOGIC RESOURCES

At this particular time, there is a minimal amount of industry in the Brattleboro-Windsor region based on local geologic materials. There were in the past, however, several thriving industries that were utilizing granite, slate, talc, clay, sand and gravel in large quantities. The abandoning or decreasing of production of these resources, with the exception of sand and gravel, was prompted mostly by a decrease in the demand or a change in the economics of these materials rather than the exhaustion of the reserves in the region. The use of slate roofing and soapstone for stove liners, for example, has declined greatly or ceased completely over the years, and the demand for granite as a building stone has declined because of the almost prohibitive cost of production. The reserves of these materials in the region, nonetheless, could in the future support a renewal of industry utilizing these resources when, and if, the demand stimulates their extraction. The sand and gravel deposits are being used at the present time, but the demand for construction will be increased in the near future as the population increases and regional development progresses.

Talc

Talc has been mined and quarried in the Brattleboro-Windsor region, more or less continuously, for over 125 years. There are old soapstone workings south of the village of Grafton that reportedly have not been in operation for over 100 years. The talc belt, if indeed it can be correctly termed a belt, seems to extend from the vicinity of Athens Pond to the northern boundary of the region. According to Jacobs, (1914, p. 402) talc deposits are known to exist as far south as the northern part of Marlboro Township, but, to the writer's knowledge, no deposits south of Athens Pond have ever been used commercially. Abandoned mines and quarries are

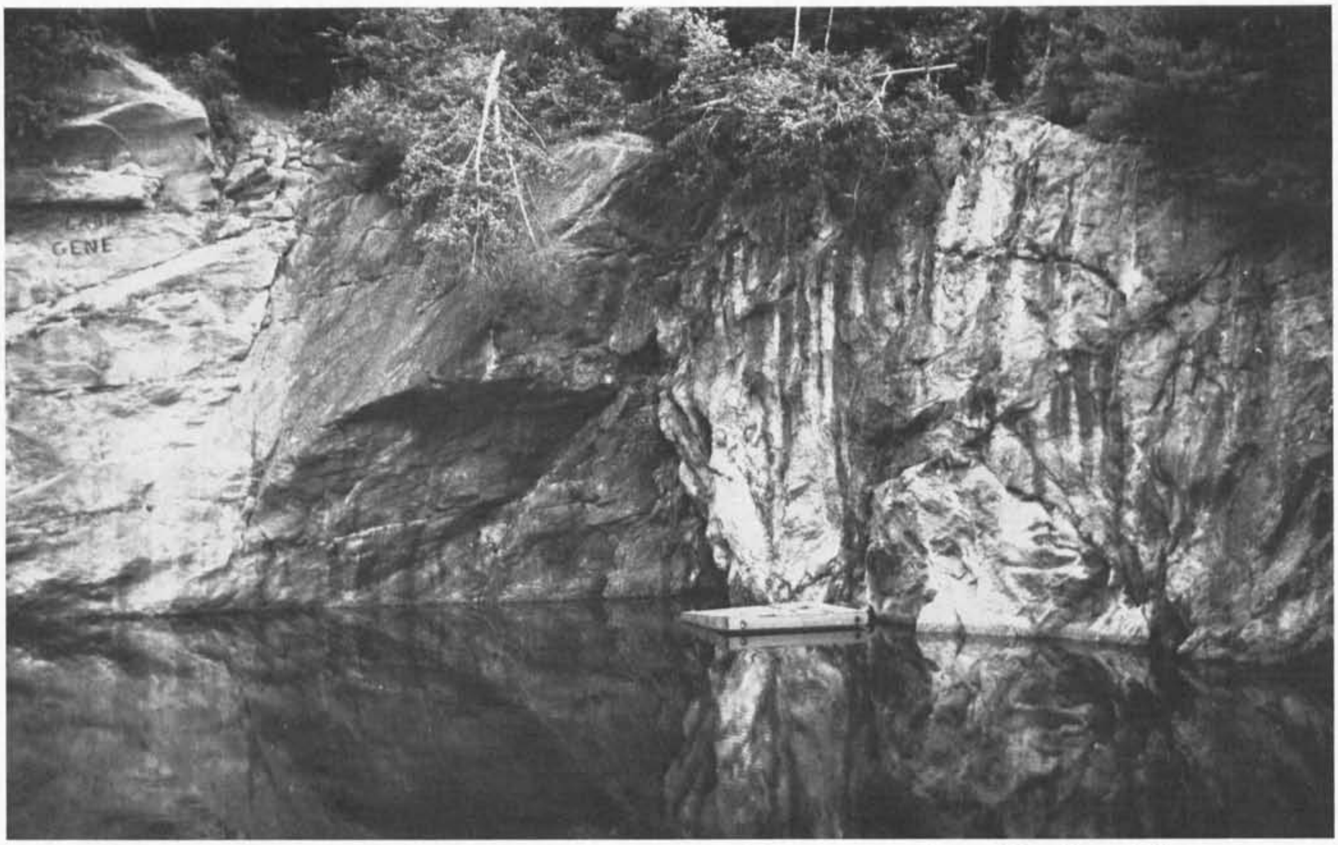

Figure 33. Abandoned talc mine filled with water one and one-half miles west-northwest of the village of Chester.

found two and one-quarter miles south of Grafton village, one and one-half miles southeast of South Windham, one and one-half miles west-northwest of the village of Chester (Figure 33), one mile west of Perkinsville and also immediately across the Black River from Perkinsville.

There is a talc mine still in operation one-half mile northeast of Hammondsville. This mine has been operating at the same location for many years. The removal of the talc was originally from an open quarry, and at one time plans were made to move to a location near Chester village because it was believed that the deposit had been exhausted. But, talc was discovered at a lower level and a mine was opened in the bottom of the pit. Mining operations have been in a northward direction and down the dip of the adjacent rock following the northern plunge of the Grafton Dome.

A small soapstone quarry is still operated intermittently two miles south-southeast of Chester village. This quarry supplies raw material for the soapstone company at Perkinsville.

There have been, from time to time, investigations by private industry to ascertain the talc reserves of selected localities of the region and economically important deposits are known to exist particularly in the vicinity of Chester village. There is no question but that talc still exists in concentrations that will be profitable to extract when they are needed.

Granite

Granite was formerly quarried on a commercial scale in many parts of the Brattleboro-Windsor region and large reserves exist that are suitable for abrasive and building stone. To the writer's knowledge, none of the granites has been used for monumental purposes, but some may be of that quality. There are old quarries along the Connecticut River in the northern part of Vernon township that were used for road construction back in the days of cobblestone streets. More recently, a quarry near U.S. Route 5 in the southeast corner of Guilford Township produced crushed stone for the base of the interstate highway (Figure 34). Brattleboro and West Dummerston were at one time granite producing centers when granite was quarried in quantities from the west side of the Black Mountain pluton. One of the quarries was located immediately south of West Dummerston and two were located directly across the West River from West Dummerston. In the northern part of the region, abandoned granite quarries are found

Figure 34. Granite quarry used to produce crushed stone for Interstate Highway 91. Just west of U.S. Route 5 four and one-half miles south of Guilford village.

on the north and western slopes of Mt. Ascutney. It is assumed that the rock from these operations was used locally for building stone. Small granite outcrops and abandoned quarries are found throughout the region.

Slate

The Brattleboro section was at one time actively producing slate in commercial quantity. The slate belt runs north-south through the village of Brattleboro and due south to the Massachusetts border. South of Guilford the zone parallels U.S. Route 5 and the highway skirts the western side of the outcrop. Slate quarries were located along the outcrop from Dummerston State Park, a mile south of Brattleboro village, southward for five or six miles (Figure 35). North of Brattleboro village the slate belt trends due north for about three miles and then slightly north-northeast through Putney village in the same general direction and never very far to the east of U.S. Route 5. Most of the production in this segment was between the intersection of U.S. Route 5 and State Route 9 (to New Hampshire) and Salmon Brook east of East Dummerston.

The slate produced in the Brattleboro area was used mostly for roofing and other building purposes. There are many buildings in the region that still have roofs of local slate. It is not of industrial quality

Figure 35. Slate exposed in an abandoned quarry three miles south of Guilford village.

as the slate in western Vermont. The slate quarries were abandoned because of the decreased demand for roofing slate and flagstone. The quarries were located where the rock was exposed at the surface, and since much of the formation is under a thin cover of surficial material, there is still a large reserve of slate.

Sand and Gravel

Sand and gravel deposits are scattered throughout the Brattleboro-Windsor region but the quality of the deposits vary greatly from place to place. Sand occurs in good quality deposits with large reserves up and down the Connecticut River valley and in most of the large tributary streams. Deposits of good quality gravel, however, are usually small and the total gravel reserve of the region is probably critically low. The environmental policies of the past few years have actually discouraged the opening of new gravel pits and the continued operation of some of the older workings. There are, therefore, a minimum of openings that allow a visual inspection of the aggregate. This report maintains that there is a real need for a detailed sand and gravel inventory in this region to establish the location and extent of the larger, better quality reserves. Those deposits of high quality and quantity should be reserved for future use, and housing development or other construction on them should be delayed until the sand and gravel are removed. As has been emphasized throughout this report, the region is going to be developing at an ever increasing rate and the demand for sand and gravel is going to increase proportionately. Present practices that encourage development of all kinds on these deposits are based on the erroneous assumption that drainage and septic tank operation dictate such a policy. This is definitely not the case and a reordering of priorities is deemed necessary.

The sand and gravel map prepared during this survey (Plate VII) classifies the deposits as to quality and the estimated reserve. There is no sand and gravel in the region that meets the standard specifications for cement and therefore the highest rank is classified as good. Classification of many of the deposits was quite difficult or impossible inasmuch as there were no pits or other excavations that would allow examination of the material. An adequate reserve of good quality sand is available for the foreseeable future, but the reserve of good gravel is questionable.

The largest reserves of sand occur along the Connecticut River more or less continuously the total length of the region. Most of the sand, as already explained, was deposited in the lake that occupied the valley during the recession of the last glacier. The sand therefore varies in texture and thickness from one locality to the next and usually overlies clay and silt. Most of the pebbly, surface sand was removed during the construction of the interstate highway, but the reserve of sand is still large. Similar lake sand deposits occur along the West River downstream from Brookline, the lower reaches of the Williams and Saxtons rivers and along the Black River upstream as far as Downers. A large, sandy deltaic deposit centering in the vicinity of North Springfield extends from Downers to Springfield village. There is a large reserve of sand in this section and gravel occurs sporadically either on the surface or interbedded with the sand. There is a lake sand deposit in the vicinity of Cavendish that was probably deposited in a local lake during the glacial recession. The deposit also contains some gravel.

The sand and gravel map (Plate VII) shows only a few areas with large reserves of good gravel. The largest reserves seem to be in the Black River valley north of the village of Ludlow. This section, including the areas of Amherst, Echo and Rescue lakes, should be carefully studied to determine the localities that should be reserved for gravel production. Building in the valley has already covered large sections of the deposits.

A few of the sand pits along the Connecticut River valley expose gravel under the surficial lake sand that, at some localities, can be identified as kame terrace or delta deposits. One of these deposits is located near the river a mile north of Ascutney village. Some of the pits between Brattleboro and Putney expose similar gravel. It is probable that a considerable reserve of gravel may exist below the lake sand and investigations to ascertain the location and extent of these should be undertaken. Large deposits of sand and gravel in the West and Williams river valleys of unknown quality and reserve may have moderate reserves of good gravel.

Clay

The economics of the lake clay in the stream valleys of the Brattleboro-Windsor region is not too well understood, but it is known that at several localities the clay is suitable for the manufacture of brick. According to Jacobs (1927), the Vermont Brick Company made brick from the clay deposits near the railroad station at Putney from about 1900 to 1921. Reportedly, the brick produced here was of excellent quality and was used for building purposes over much of New England. Jacobs also reported that bricks were manufactured from similar clay exposures in Westminster and Guilford townships for local building use about the turn of the century. It is apparent that large reserves of clay suitable for the manufacture of building materials exist in the region. To the writer's knowledge, the clays have not been tested for other uses.

ACKNOWLEDGMENTS

Dr. Charles G. Doll, the Vermont State Geologist, directed and arranged the financing of the survey that produced this report. The writer appreciates his continued support, assistance, and encouragement. David S. Scanlon and James Miller were field assistants and contributed much to the summer's work. They did the drafting for the planning maps. Scanlon was responsible for the bedrock maps and Miller collected much of the water data and assisted in the preparation of the ground water map. The writer also notes the assistance of Mr. Frank Lanza, Geologist, Vermont Highway Department, Mr. Arthur Hodges, Geologist, United States Geological Survey, and Mr. David Butterfield, Geologist, Vermont Water Resources Department. The writer also appreciates the cooperation of many land owners that gave this survey permission to do seismic work and other studies on their properties. Special mention is due the administrative officials of the Brattleboro Regional Vocational School for granting permission for this survey to use the drafting facilities of the school. Mr. Phil Shebel, the drafting instructor, was most helpful.

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APPENDIX A –

MAPS SHOWING LOCATIONS OF SEISMIC PROFILES

WALLINGFORD QUADRANGLE
LUDLOW QUADRANGLE
Figure 17
WINDSOR CO
RUTLAND CO
Lake Ninevah
Tiny Mtn
Tyson
Echo Lake
Plymouth Kingdom
Kingdom Br
Tiny Pond
Rescue Lake
Carpenter Pt
Prospect Hill
North Hill Sch
Reservoir Pond
Buttermilk Falls Branch
Cook Pond
Mt Gilead
Wheeler Sch
The Pinnacle
Grahamville
Whitney Bk
BLACK RIVER
L U D L O W
LUDLOW MOUNTAIN
Ludlow Mtn
Lookout Tower
OKEMO
STATE
Gilchrist Sch
Twentymile
Ludlow
Smithville
Proctorsville
South Mtn
Sanders Brook
Hemmingway Sch
Jewell Brook
Barton Sch
Wadleigh Sch
Bear Hill
Whetstone Hill
Williams River
Smokeshire Sch
Boynton Hill Sch
Healdyville
COFFEEN CEM

LUDLOW QUADRANGLE
CLAREMONT QUADRANGLE
Figure 18
W
E
Note: River channel has shifted to dotted line.
South Reading
Hurricane Hill
Brownsville
Rush Meadow Sch
Felchville Reading P O
Bowen Hill
Robinson Hill
Star Hill
Hardy Hill
Widow Hill
Stockin Sch
Ascutney Mtn
Greenbush
Tarbell Hill Sch
Eagleshead
Amsden
Downers
Nelsons Corner
Pikes Peak
Whitesville
Cavendish Gorge
HAWKS MOUNTAIN
RIVER
BLACK
Perkinsville
Quarry Pond
Weathersfield Center
Butterfield Hill
Baltimore Sch
BALTIMORE
Tolles Hill
Old Shincracker
Springfield Res
Kendricks Corner
SPRINGFIELD AIRPORT
Crown Point Country Club
Chandler Sch
North Springfield
Davidson Hill
Pudding Hill


LONDONDERRY QUADRANGLE
SAXTONS RIVER QUADRANGLE
WALLINGFORD QUADRANGLE
LUDLOW QUADRANGLE
S
N
Figure 20

LUDLOW QUADRANGLE
CLAREMONT QUADRANGLE
SAXTONS RIVER QUADRANGLE
BELLOWS FALLS QUADRANGLE
Figure 19
N
S
Figure 21
E
W
Figure 22
NE
SW
SPRINGFIELD
WINDSOR CO
WINDHAM CO
Bartonsville
Brockways Mills
Rockingham
Cambridgeport
Saxtons River
Bellows Falls
Athens
Bull Hill
Darby Hill
Signal Hill
Colley Hill
Jones Hill
Cobble Hill
Parker Hill
Coburn Hill
Hedgehog Hill
Hardscrabble Corner
Randall Hill
Minards Pond
ROCKINGHAM
North Walpole
North Westminster


LONDONDERRY QUADRANGLE
SAXTONS RIVER QUADRANGLE
WARDSBORO
Jamaica
East Jamaica
RIVER
College Hill
Rattlesnake
West Townshend
South Windham

Figure 24

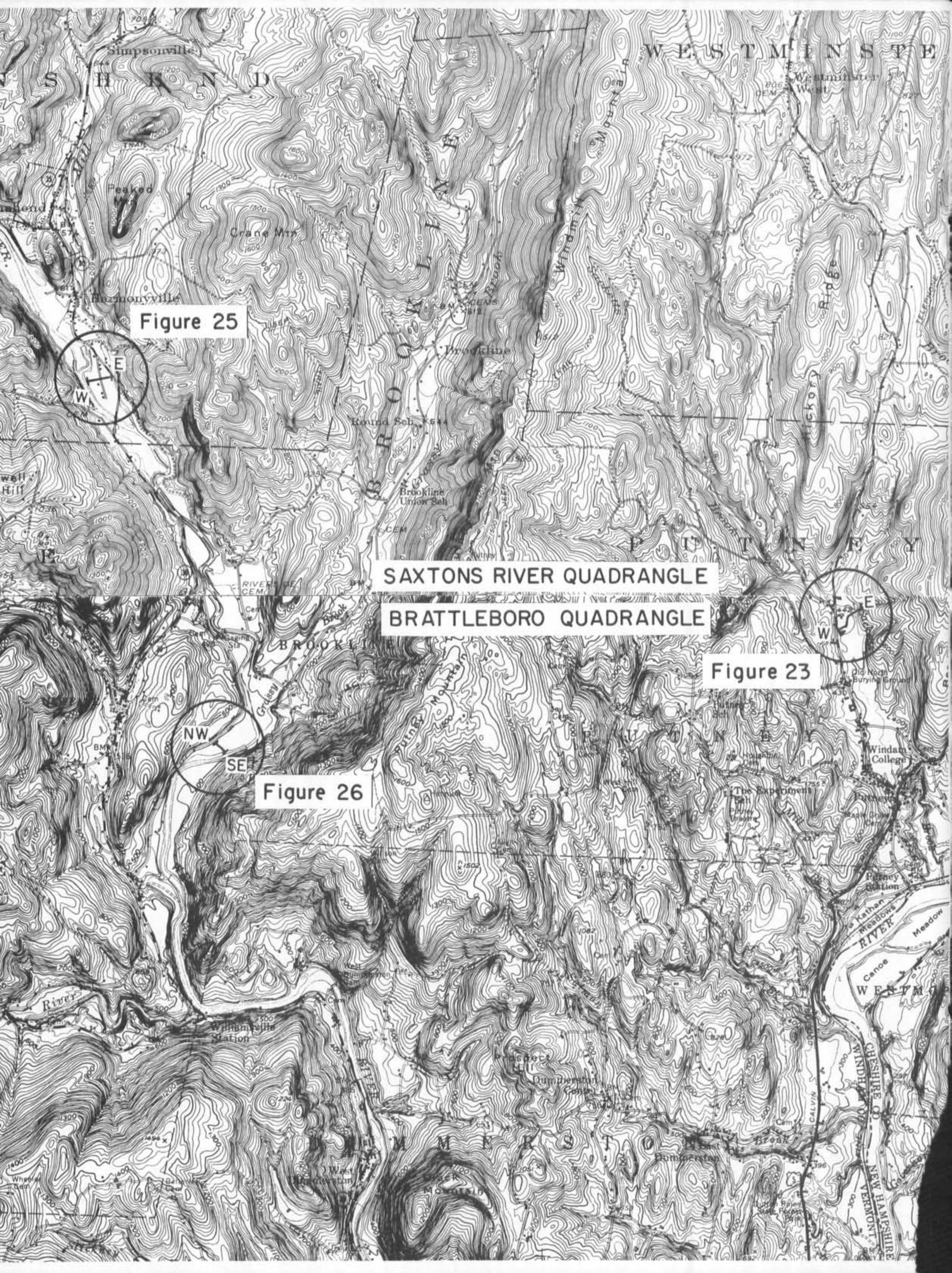
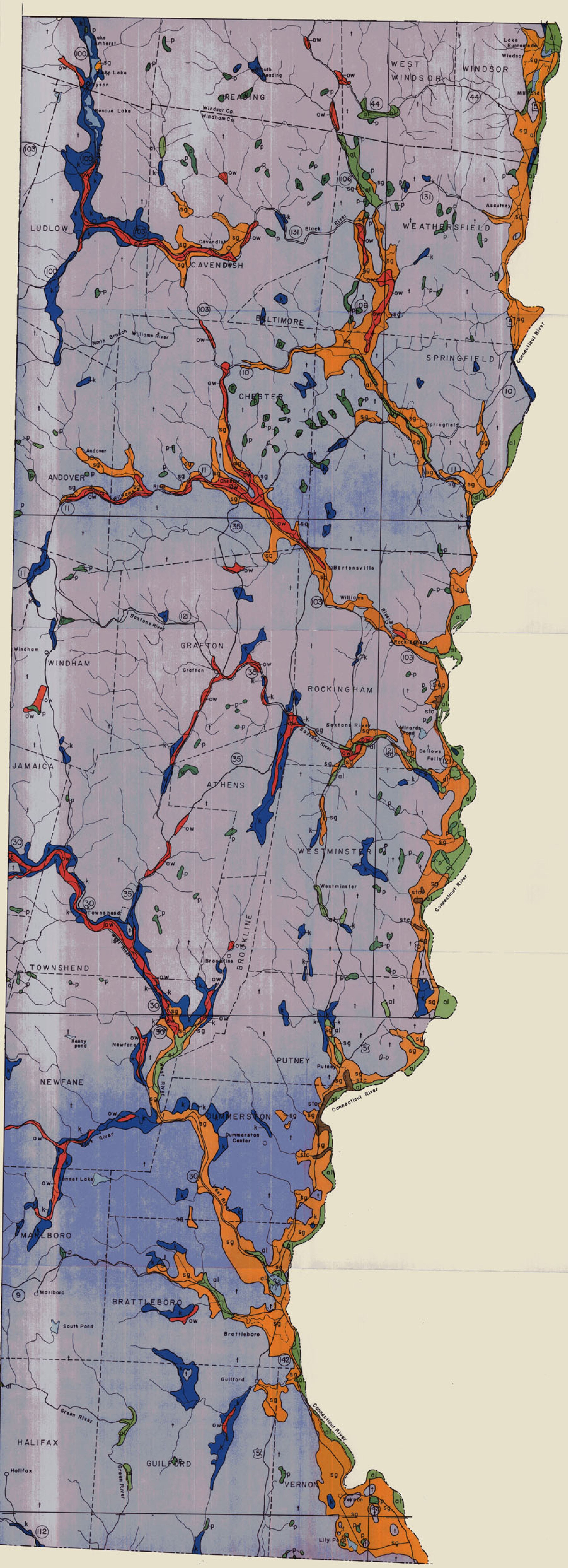


Figure 25
E
W
SAXTONS RIVER QUADRANGLE
BRATTLEBORO QUADRANGLE
Figure 23
E
W
NW
SE
Figure 26
Simpsonville
Peaked
Crane Mtn
Harmonyville
Brookline
Round Sch
Brookline Union Sch
Westminster West
Windham College
The Experiment
Putney Station
Williamsville Station
Dummerston Center
Dummerston
NEW HAMPSHIRE
VERMONT


WILMINGTON QUADRANGLE
BRATTLEBORO QUADRANGLE
Lake Raponda
Higley Hill
Hogback Mountain
Stratton Hill
Cooper Hill
Rice Hill
Negus Brook
Oregon Mountain
M A R L B O R O
W I E
Figure 27

SURFICIAL MATERIAL OF THE BRATTLEBORO-WINDSOR REGION

Plate I



LEGEND

t

Glacial Till - generally thin over bedrock, much bedrock exposed, unsorted, poorly drained, bouldery surface. Low water potential.

k

Ice Contact Gravel, mostly kame terraces - well sorted, may have a high sand content, well drained above the water table. Good gravel source. High water potential below the water table.

ow

Outwash (valley train) and Fluvial Gravel - in stream valleys, generally well drained above the water table. Fair to good water potential below the water table.

sg

Lacustrine Sands and Gravels. Predominantly sand and pebbly sand, well drained above the water table. Good source for sand. Moderate to high water potential below the water table.

stc

Lacustrine Clays and Silts. Poorly drained. Medium to high plasticity.

p

Peat and Muck - Swampy, poorly drained areas, water table at or near the surface.

al

Recent Stream Aluvium - thin, covering valley floor, poor to moderately well drained, low strength. Poor foundation material.

Scale

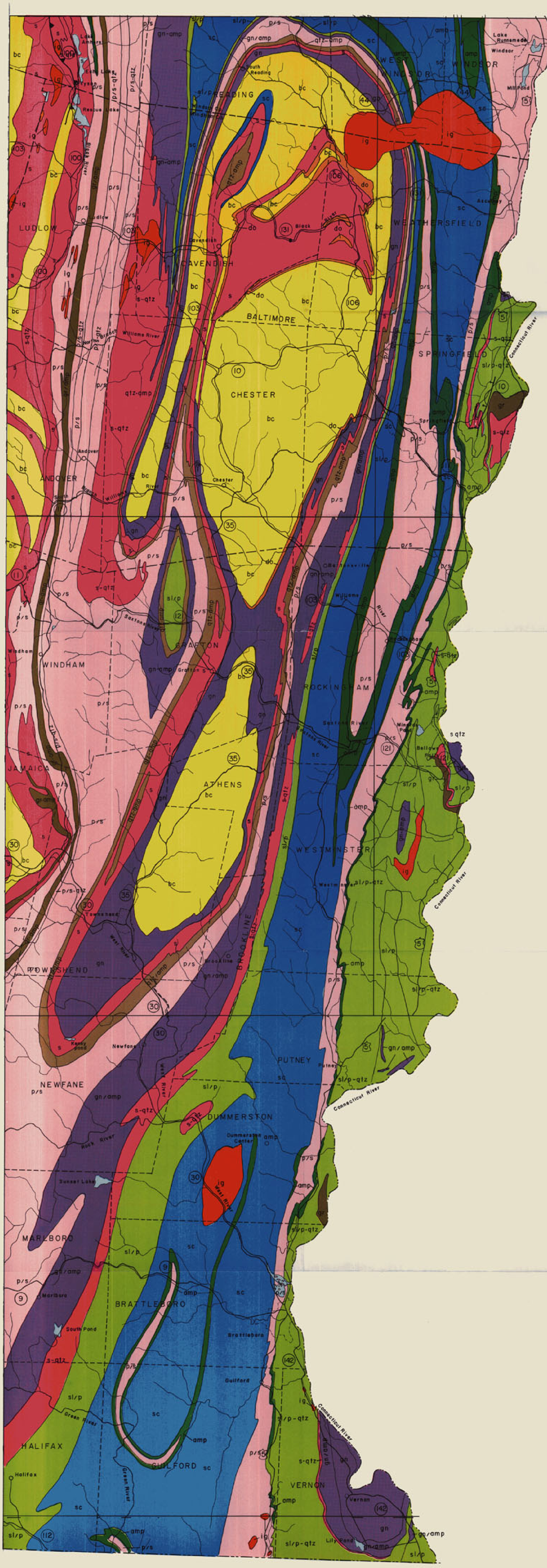
1 1/2 0 1 2

miles

true north

Geologic interpretation by David P. Stewart

Vermont Geological Survey
Charles G. Doll, State Geologist
Published 1975



BEDROCK OF THE BRATTLEBORO-WINDSOR REGION

Plate II

LEGEND

qtz

Quartzite, massive; white to buff in color; commonly highly fractured, interbedded with schists, phyllites, dolomites and amphibolites. Very resistant to both chemical and physical weathering and erosion; qtz - amp - quartzite with interbeds of amphibolite.

do

Dolomite, white to gray with interbeds of quartzite; susceptible to chemical weathering and erosion, solution weathering active along fractures.

s

Schist, pale silver gray to green. Locally interbedded with quartzite. Generally fractured, moderately resistant to erosion; s - qtz - schist with interbeds of quartzite.

sc

Schist (calcareous), gray to brown. Gradational to phyllites and schists. Highly fractured. Susceptible to chemical weathering and erosion.

gr

Greenstone, massive dark greenstones. Locally interbedded with amphibolites. Generally fractured. Moderately resistant to erosion; gr - amp - greenstone with interbeds of amphibolite.

amp

Amphibolites, green to black. Locally interbedded with gneisses, greenstones, quartzites, phyllites and schists. Susceptible to chemical weathering, moderately resistant to physical weathering.

gn

Gneiss, massive, green to black. Locally interbedded with amphibolites. Generally fractured, susceptible to chemical weathering, moderately resistant to erosion; gn - amp - gneiss with interbeds of amphibolite.

bc

Basement Complex — grey-green to black in color, includes gneiss, schist and amphibolite with numerous small granite bodies.

ig

Igneous plutonic — includes both light and dark colored rock.

sl/p

Dull grey to black slates and phyllites; sl/p-qtz — grey slates and phyllites with interbeds of grey quartzite.

p/s

Undifferentiated phyllites and schists.

Normal Fault bar and ball on downthrown side.

Thrust Fault sawteeth on upper plate.

Scale

1 1/2 0 1 2

miles

true north

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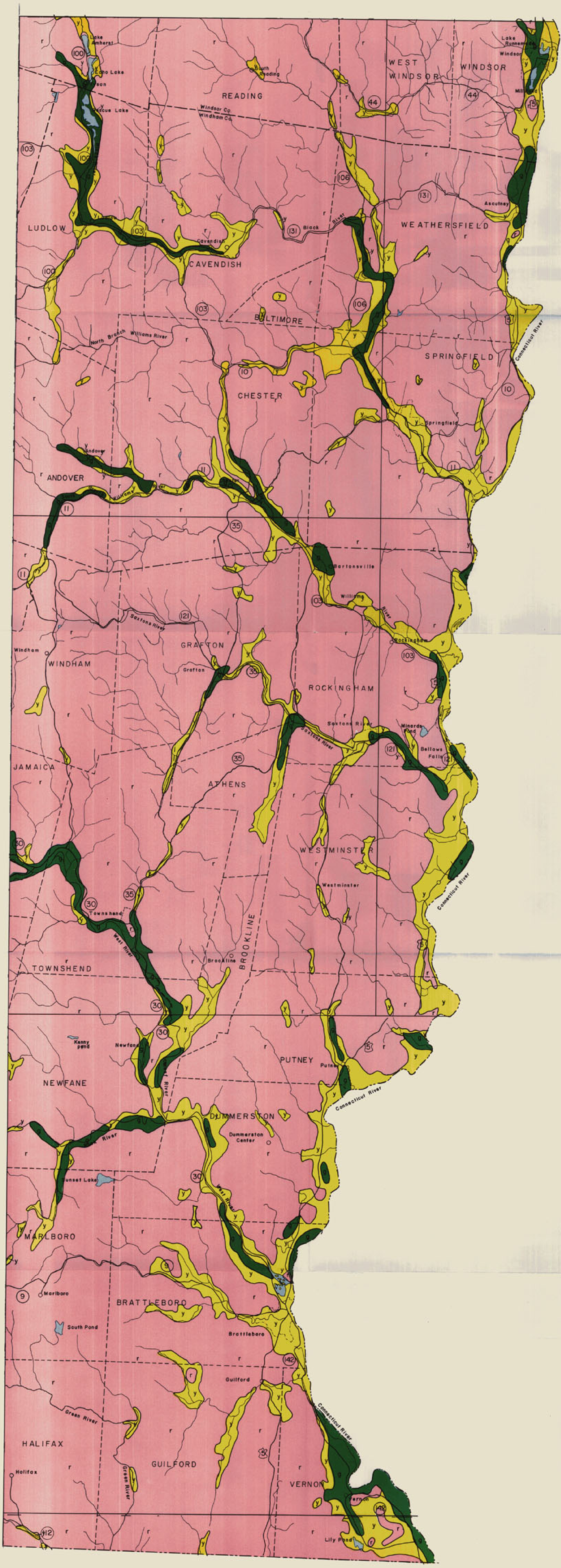

GROUNDWATER POTENTIAL MAP OF THE BRATTLEBORO-WINDSOR REGION

Plate III

LEGEND

g

Areas of good ground water potential. Water available in sand and gravel deposits in stream valleys or buried valleys. Water yield medium to high from the unconsolidated sediments.

y

Areas of moderate ground water potential. Water available from sand and gravel in stream valleys or from bedrock below the valley fill. Water yield low to medium at depths to 300 feet.

r

Areas of very low ground water potential. Water available in these areas from low yield, bedrock sources to depths of 300 feet.

Scale

1 1/2 0 1 2

miles

true north

Geologic interpretation by David P. Stewart

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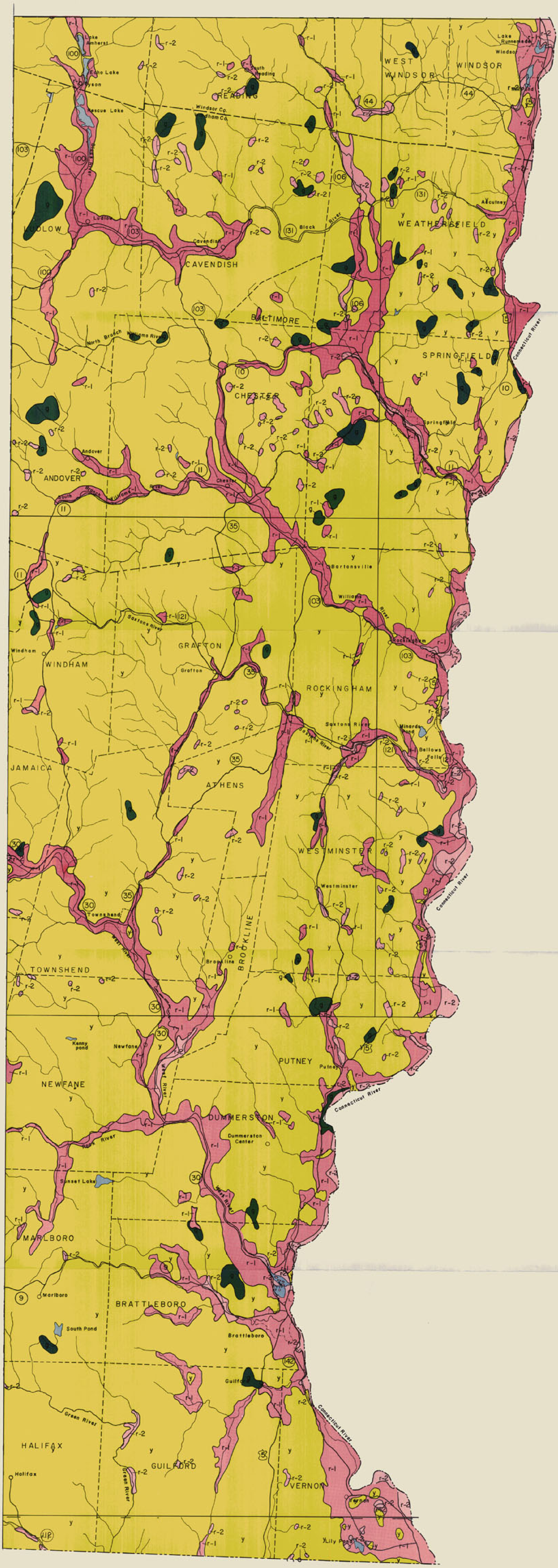
SOLID WASTE DISPOSAL CONDITIONS OF THE BRATTLEBORO-WINDSOR REGION

Plate IV



LEGEND

g

Areas of impermeable tills, silts and clays generally over 25 feet thick. Suitable for solid waste sanitary landfill with proper surface drainage precautions.

y

Areas of till over bedrock. Till cover usually thin with areas of bedrock exposed at the surface. Solid waste sanitary landfill only where till is over 30 feet thick and with proper surface drainage precautions. Contamination of ground water probable from barns, domestic sewage systems, landfills, etc., in areas of exposed bedrock or a till cover of less than 15 feet.

r-1

Areas of sand and gravel with medium to high permeability and medium to high water potential. Unsuitable for solid waste sanitary landfill.

r-2

Poorly drained, swampy areas. Mostly stream valley floodplains with low relief and periodic flooding. Unsuitable for solid waste sanitary landfill.

Scale

1 1/2 0 1 2

miles

true north

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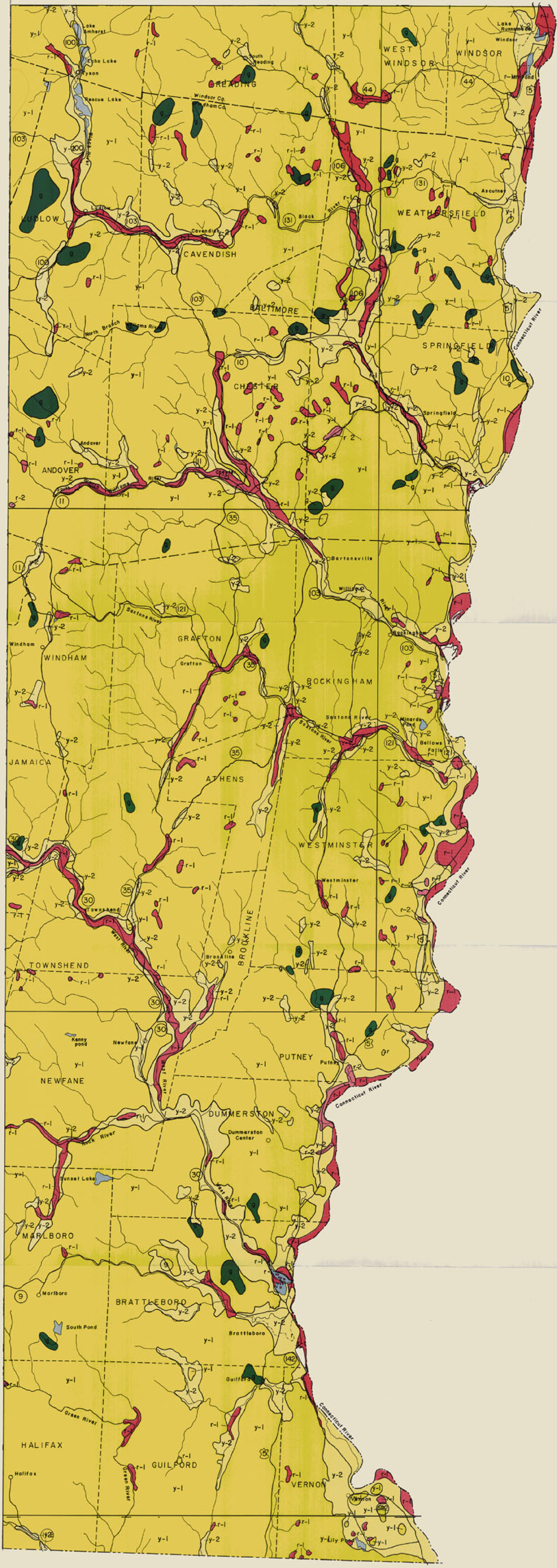

SEPTIC TANK CONDITIONS OF THE BRATTLEBORO-WINDSOR REGION

Plate V

LEGEND

g — Areas of till over 25 feet thick. Low to medium permeability. Suitable for septic tanks with leaching fields at least 200 feet long.

y-l — Areas of thin till over bedrock. Bedrock commonly exposed at the surface. Septic tanks with at least a 200-foot leaching field only in areas where till is over 10 feet in thickness.

y-2 — Areas of permeable sands and gravels. Suitable for septic tank use if deposit is over 15 feet thick and water table is over 25 feet below ground surface. Silt, clay or till below at least 6 feet of sand or gravel is desirable to prevent downward movement of affluent.

r-1 — Low, poorly drained, frequently flooded stream floodplains covered with alluvium and/or swamps. Unsuitable for septic tanks.

r-2 — Areas of silts and clays with very low permeability. Septic tanks will not function properly in these areas.

Scale

1 1/2 0 1 2

miles

true north

Geologic interpretation by David P. Stewart

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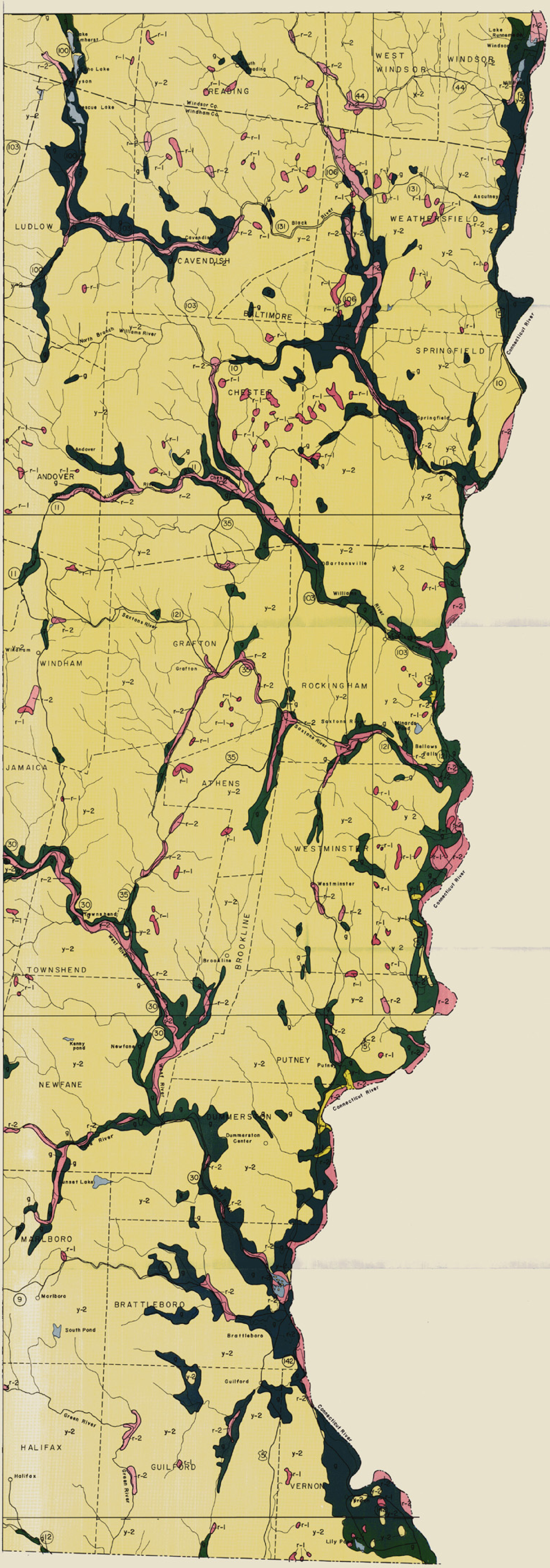
GENERAL CONSTRUCTION CONDITIONS OF THE BRATTLEBORO-WINDSOR REGION

Plate VI



LEGEND

g

Areas of thick, well drained sand and gravel deposits with adequate bearing strength.

y-1

Areas of lake sediment composed predominantly of silt and clay. May or may not be capped with sand and/or gravel. Steep slopes common on the outer margins of terraces.

y-2

Areas of till and bedbock. Till cover generally less than 20 feet. Permeability of till very low. Wide areas have bedrock exposed at the surface or bedrock with less than 5 feet of till.

r-1

Areas of poor drainage and swampy conditions. Ground water level near or at the surface. Contains wet, compressible sediment.

r-2

Areas of stream bottom-land covered with 10 to 25 feet of alluvium. Subject of frequent flooding. Alluvium unsuitable for foundations of heavy structures.

Scale

1 1/2 0 1 2
miles

true north

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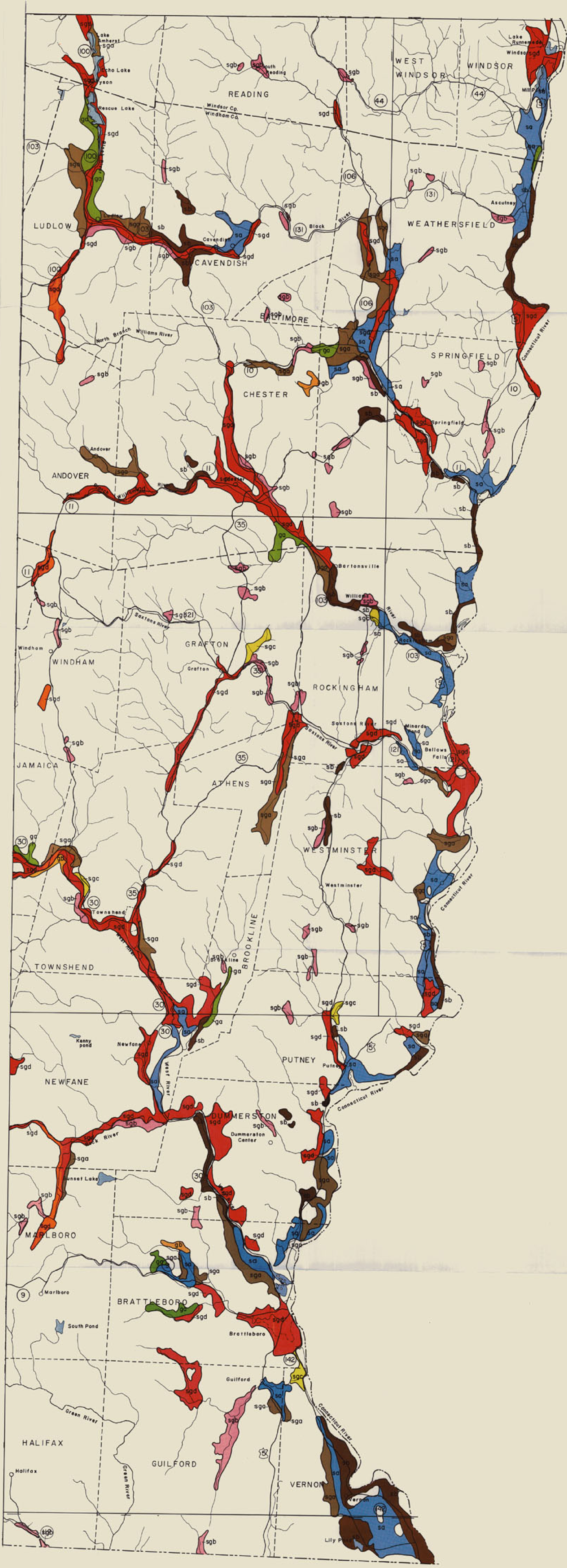

SAND AND GRAVEL RESERVES OF THE BRATTLEBORO-WINDSOR REGION

Plate VII

LEGEND

ga — Gravel deposits containing less than 25% sand. Medium to good quality. Large reserve. Less than one-half the original reserve depleted.

gb — Gravel deposits containing less than 25% sand. Low to medium quality. Low to medium reserve. Less than one-half original reserve depleted.

sga — Sand and gravel deposits of medium to good quality and large reserve. Less than one-half original reserve depleted.

sgb — Sand and gravel deposits of low to medium quality and low to medium reserve. Less than one-half of the original reserve depleted.

sgc — Sand and gravel deposits. Medium to good quality. Over half of the original reserve depleted.

sgd — Sand and gravel deposits of unknown quality and reserve.

sa — Sand deposits containing less than 25% gravel. Medium to good quality. Large reserve. Less than one-half of the original reserve depleted.

sb — Sand deposits containing less than 25% gravel. Low to medium quality. Low to moderate reserve. Less than one-half of original reserve depleted.

Scale

1 1/2 0 1 2

miles

true north

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