GEOLOGY FOR ENVIRONMENTAL PLANNING IN THE MILTON-ST. ALBANS REGION, VERMONT

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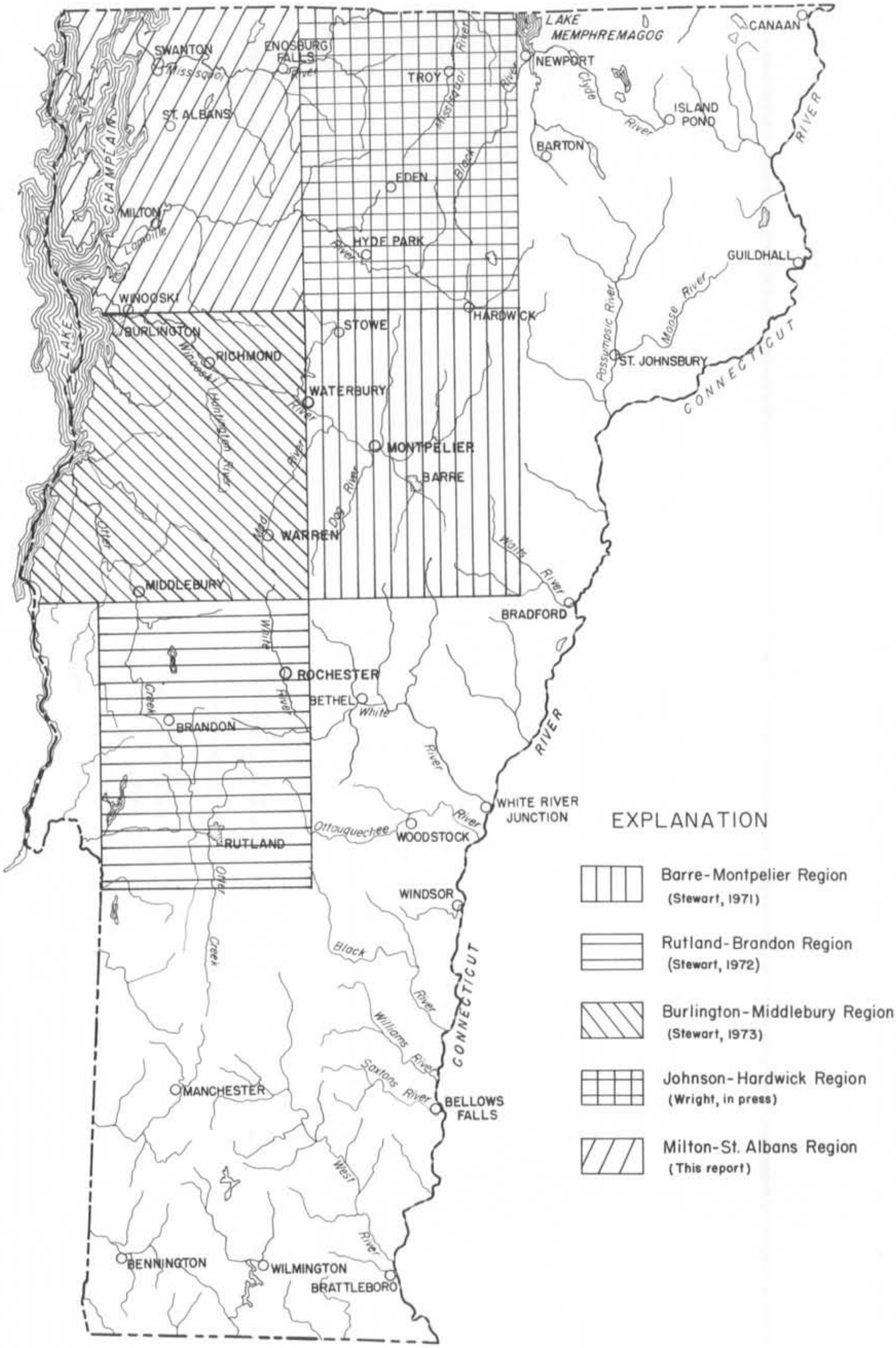

Figure 1. Index map showing regions where environmental geology studies have been completed.

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INTRODUCTION

The accumulation of geologic data is an essential prerequisite to many aspects of environmental planning. Geology adds a third dimension to planning inasmuch as it is concerned with the characteristics of the subsurface soil and rock as well as the obvious features on the surface. 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 the rock and soil, the degree of metamorphic changes, the fractures in the rock, the ability of the materials to hold and transmit water, and the plasticity. The availability of water and the contamination of water supplies are related to the movement of liquids. The thickness, strength, and stability of surficial materials 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.

This report is the fifth in a series concerned with environmental problems published by the Vermont Geological Survey. The purpose of these reports is to supply geological information in a condensed and modified form for use by environmental planners. The reports attempt to describe and explain the geologic conditions of a specific region, and to outline and summarize these conditions on a series of large-scale maps in such a way as to make the material useful for planners. Most planning agencies do not have geologists on their staffs, and these reports supply the geologic background necessary for adequate planning.

In the four-year period that the environmental geology program has been in progress, the regions studied have been selected because of their potential growth. The initial study was completed in the Barre-Montpelier region and a report on that investigation was published in 1971. The second survey concerned the Rutland-Brandon region and the report on that area was published in 1972. In 1973, a report was published on the Burlington-Middlebury region (Figure 1). In each of the regions, the field work was done during the field season of the year preceding the publication of the report. The environmental geology program was expanded in 1973, and during the summer of that year two field parties were working in two different regions. Frank M. Wright, III joined the program and studied the Johnson-Hardwick region and the writer completed the Milton-St. Albans region (Figure 1). The two reports are scheduled for publication in 1974.

The region about which this report is concerned includes six topographic quadrangle maps. It extends north and south from the latitude of Winooski to the Canadian border. In an east-west direction, the region extends from the Islands of Lake Champlain to the approximate longitude of Waterville and Berkshire (Figure 2). The area includes the Champlain Islands of the Plattsburgh and Rouses Point quadrangles, the Champlain Lowland of the Milton and St. Albans quadrangles and the Green Mountains of the Mt. Mansfield and Enosburg Falls quadrangles. The region has a wide variety of topog-

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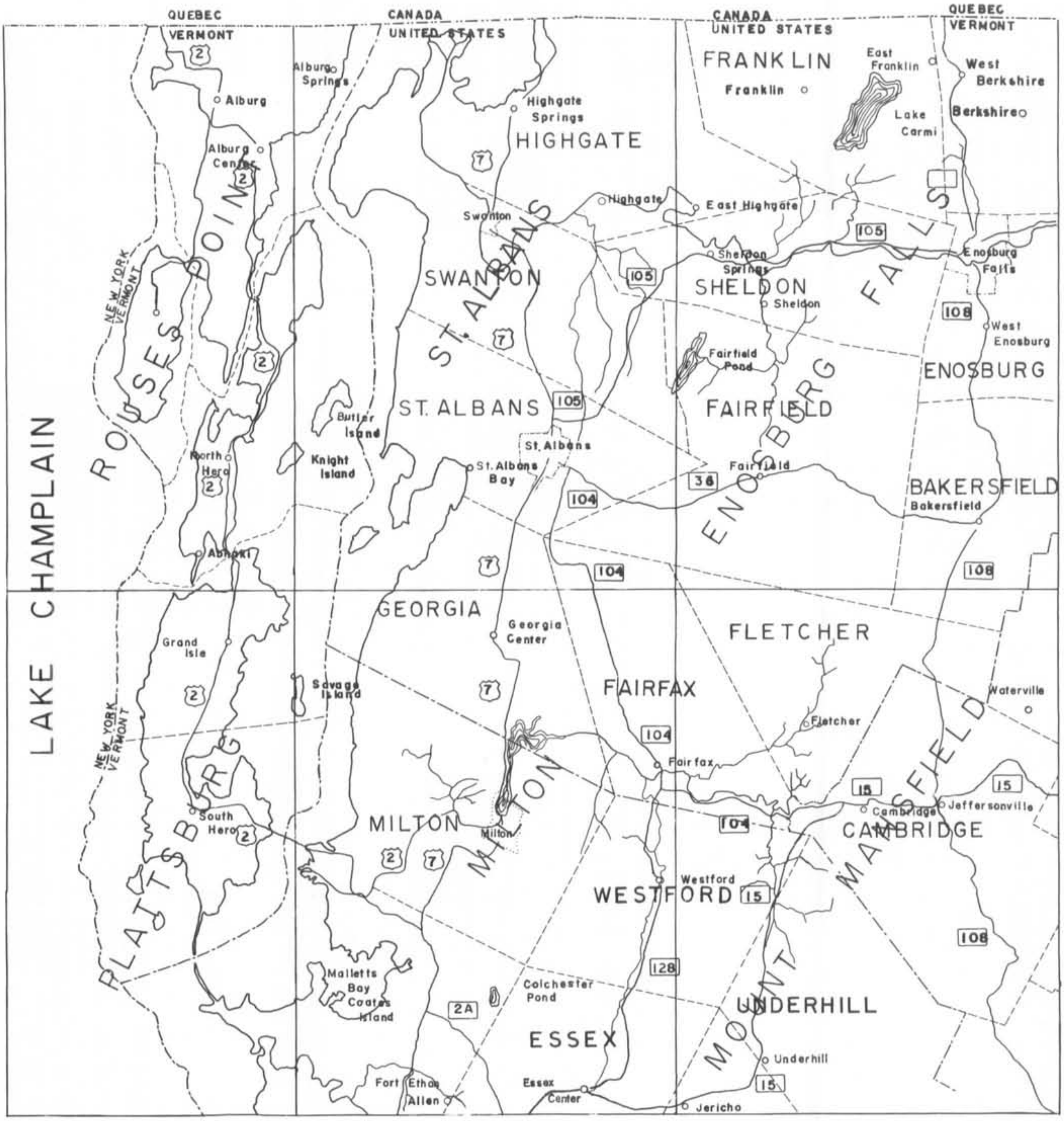

Figure 2. Index map showing the location of quadrangles, townships, cities, and villages of the Milton-St. Albans Region.

raphy with elevations ranging between the very low topography of the Champlain Islands to Mt. Mansfield, the highest mountain crest in the state (Figures 3 and 4).

The Milton-St. Albans region is located immediately north of the Burlington-South Burlington-Winooski-Essex Junction population centers, the largest and probably the most rapidly expanding population concentration in the state (Stewart, 1973). This fact alone assures an accelerated rate of expansion into the region to the north; a migration that has already begun. There are, in addition, population centers in

Figure 3. The Champlain Lowland and the Islands of Lake Champlain. Picture taken looking west from Bellevue Hill, one mile east of St. Albans.

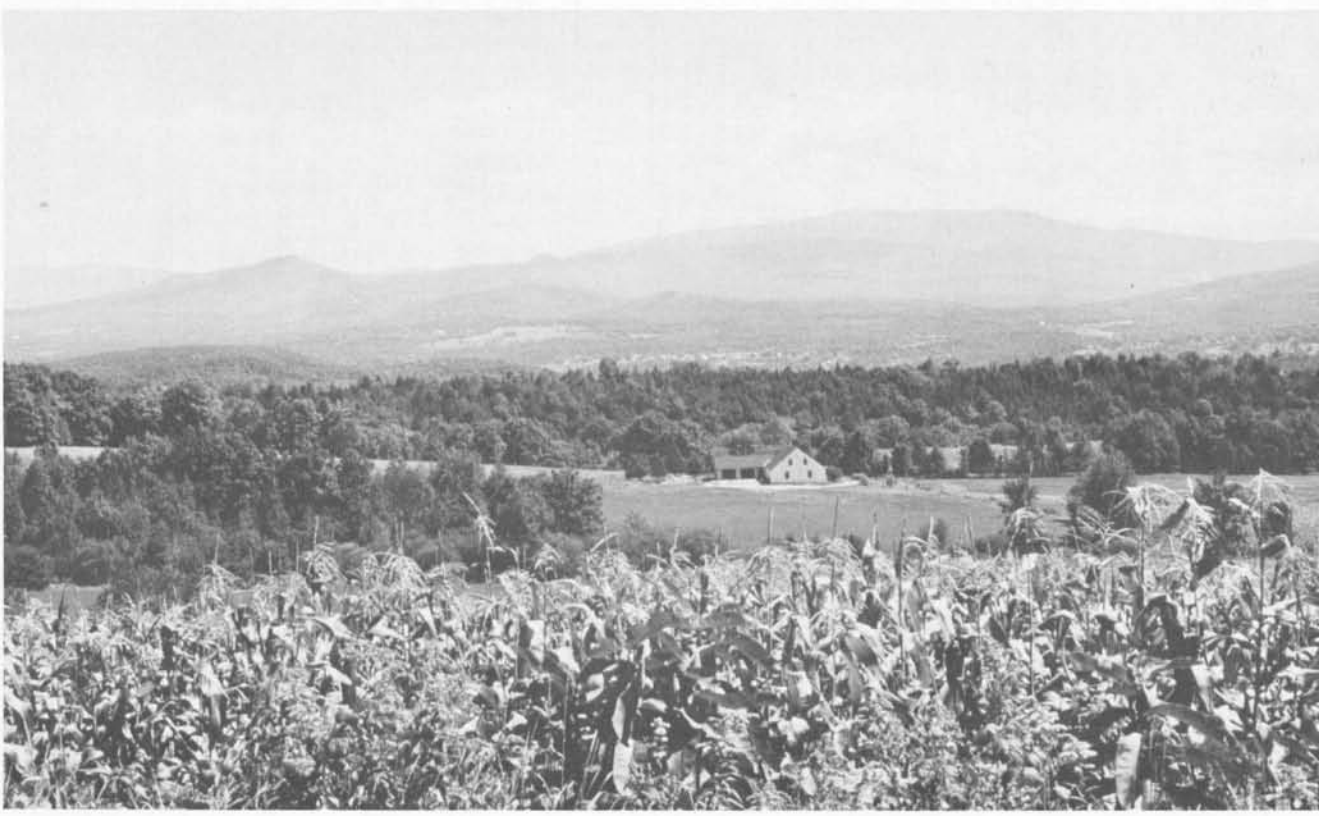

Figure 4. Mt. Mansfield looking toward the east side of the Mountain. Picture taken looking west from Stowe.

the region, St. Albans being the largest, that are also expanding into the environs. Population statistics of the Vermont Secretary of State (1970) show that the population of Milton and Colchester townships almost doubled between 1960 and 1970 and this trend has continued at an increased rate since 1970. The population of the towns of Underhill, Essex, Jericho, Georgia, Swanton, and St. Albans, increased at least 30 percent during the same ten-year period. Interestingly enough, the increased population has not been in the cities and villages but in the areas adjacent to these centers. This is not to say that development has been strictly rural since much of the increased population has been in housing subdivisions adjacent to the cities and villages.

The most notable population increases have been in a northward direction from the Burlington-South Burlington-Winooski-Essex Junction complex. The northward migration has caused the growth in the townships of Colchester, Milton, Georgia, St. Albans, and Swanton. The new Interstate Highway (I-89) through this section has no doubt been a contributing factor since any of these towns are now in easy access to Burlington. Very little development has occurred along the shore of Lake Champlain except in the St. Albans Bay and Colchester sections. The lake shore in many sections has a rather rugged topography that is not conducive to development. As might be expected, the greatest expansion has been in the immediate environs of Burlington and Winooski and some of this has been along the lake in Colchester.

The second area of conspicuous development in the Milton-St. Albans region is north, northeast, and east of Winooski and Essex Junction in the Green Mountain foothills along the southern border of the region. The expansion in this direction explains the substantial population growth in the townships of Essex, Jericho, and Underhill and a moderate increase as far north as the towns of Westford and Fairfax.

Growth to the east and west of Mt. Mansfield in the towns of Stowe and Cambridge has resulted chiefly from recreational developments in that area. Ski slopes on the east side of the mountain have been in operation for many years. Recently, however, the Madonna Peak area, on the north side of the ridge, has been developed for skiing (Figure 5) and this has been accompanied by increased real estate activity in the town of Cambridge, particularly along State Route 108 between Jeffersonville and Madonna ski area (Figure 6). The area adjacent to Mt. Mansfield, on both the Stowe and Cambridge sides, also has become popular for summer recreation. As a result, homes for occupancy throughout the year are becoming increasingly more numerous.

The Green Mountain foothills section north of the Lamoille River and east of Milton and St. Albans has not, as yet, experienced the growth problems of a rapidly increasing population. The fact is that most of the towns of this area had lower populations in 1970 than in 1950. The area is mostly rural and the largest village, Enosburg Falls, has less than 1500 inhabitants. Growth will probably spread eastward across this region from the more populated lowland to the west, but it seems unlikely that the migration will be accelerated to a high degree in the next decade or two.

It is inevitable that the expansion of the population into the Milton-St. Albans region will continue, probably at an increasing rate. The Burlington-South Burlington-Winooski-Essex Junction complex as a population center is too large and too far advanced to cease to grow in the foreseeable future. And, as population increases in the nucleus of this complex, continued movement into the region to the north is a foregone conclusion. Increased population has already created problems in many areas, and the need for planning is lagging far behind.

There has been little development on the Champlain Islands in recent years except on South Hero. Development will probably be slow on the Islands inasmuch as there is little industry other than agriculture and summer recreation. The increased population on South Hero Island is no doubt due to the easy access to Burlington via Sand Bar Bridge and, because of the expansion in the Burlington complex, this trend may continue and probably at an increased rate.

SOURCE OF MATERIAL

Much data is already available from many sources that relate to environmental planning and this is true of geologic information. The geologic material available, however, is usually in technical language and requires interpretation by a trained geologist. Included in the data used in the preparation of this report were materials available from many state and federal agencies.

The surface materials map was modified from the *Surficial Geologic Map of Vermont* (Stewart and MacClintock, 1970). The writer mapped the Milton and St. Albans quadrangles during the survey that produced the state map. The Enosburg Falls, Plattsburgh, and Rouses Point quadrangles were mapped by William F. Cannon, and G. Gordon Connally mapped the Mt. Mansfield Quadrangle (Stewart and MacClintock, 1969, p. 14). The units on the surficial map were combined and the descriptions modified to simplify the interpretation for planning use. The explanations were rewritten to include those properties that are directly related to the environment. The maps were checked in the field and adapted for environmental use (Plate I).

Bedrock data were obtained chiefly from the *Centennial Geologic Map of Vermont* (Doll, Cady, Thompson, and Billings, 1961). The centennial map gives the names of the rock units, the stratigraphic and age relationships of the rock layers, and

Figure 5. Ski slopes of the Madonna Ski Area. Six miles south-southeast of Jeffersonville.

Figure 6. A portion of Madonna Village, a development near the foot of the Madonna Ski Area. Four miles south-southeast of Jeffersonville.

Figure 7. Power auger on trailer pulled on a Jeep used for percolation tests.

the geologic description of each. Such a map is indispensable in most geologic studies, but it contains much technical data that do not pertain to environmental planning. For this reason, the bedrock map was modified to show only the different kinds of rock and the explanation was rewritten to emphasize those properties of each kind of rock that are most useful for planners (Plate II). There are several published reports that give detailed descriptions of the bedrock of the region. The most applicable of these are the reports by Shaw (1958) on the St. Albans area, Dennis (1958) on the Enosburg Falls Quadrangle, Christman (1959) on the Mt. Mansfield Quadrangle, Stone and Dennis (1964) on the Milton Quadrangle, and Erwin (1957) on the Champlain Islands.

Percolation tests were made at irregular intervals over the region to determine the water-related properties of the top three feet of the surface material. A six-inch power auger mounted on a small trailer was used to auger holes three feet deep (Figure 7). The holes were filled with water and the drop of the water level in a given time was recorded. These measurements were made to determine the relative permeability of the various types of surficial material. The augering also brought the material to the surface and the texture, degree of sorting, compaction, and composition could be ascertained.

Water-well records, on file at the Water Resources Department, were compiled and plotted on base maps to assist in the determination of the water-bearing characteristics of the subsurface unconsolidated sediment and bedrock. These data were also used to ascertain, where possible, the thickness of the surficial material above bedrock, the depth to the water table, and the location, depth, and extent of buried valleys. The type of unconsolidated material in stream and buried valleys and the sequence of the sediment in these valleys was ascertained where the number of well records permitted. Such information was essential for the construction of the ground water potential map (Plate III). Well records were also studied to locate desirable locations for seismic study.

Solid waste disposal sites now in operation were studied to determine the geologic and hydrologic conditions (Plate IV). Sewage disposal practices were investigated with particular emphasis on domestic installations (Plate V).

Seven localities were selected for seismic study to better understand the ground water characteristics. These investigations were in stream valleys where surface studies and well records indicated considerable depths of unconsolidated sediment that might contain large quantities of water. The seismic work was completed by the Weston Geophysical Engineers, Inc. of Westboro, Massachusetts. The twelve point seismic refraction method was employed using a portable twelve-channel seismograph. The refraction method is used to determine the depth to bedrock, the depth to boundaries between sedimentary layers having different properties, the depth to the water table, and the velocity of the seismic wave through each layer. These data assist in the determination of the ground water potential of a particular area. The profiles reproduced in this report were made by the Weston Geophysical Engineers during the seismic study.

During the floods of early July, 1973, observations were made in the Milton-St. Albans region and in regions to the south to try to determine the cause, extent, and damage done by the flooding. Records were also studied to ascertain the effect on the water level of Lake Champlain.

EXPLANATION OF THE PLANNING MAPS

The planning maps (Plates I through VII) in the pocket at the end of this report are a summation of the investigations made during this survey and the chief purpose of the text is to explain the geology shown on them. The maps show the surficial material, the kinds of bedrock, the ground water potential, the suitability of the various sections for different uses, and the distribution of sand and gravel deposits. The color schemes on certain maps (Plates III through VI), green for go, yellow for caution, and red for stop, were copied, in modified form, from the Illinois Geological Survey reports (Hackett and McComas, 1963; Jacobs, 1971). Areas shown in green are interpreted as offering minor problems and minimum limitations. Areas shown in yellow have moderate to 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 necessary controls. Areas mapped 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 different symbols are used for the same color, g-l and g-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 map of the surficial material (Plate I) and the bedrock map (Plate II) show the distribution of the various types, since each kind of bedrock and surficial material has different characteristics insofar as the environment is concerned.

The planning maps showing the solid waste, septic tank, and general construction conditions are, of course, interpretations based on the most up-to-date concepts as viewed by this survey at this particular time. Admittedly, however, there is debate among authoritative sources as to the correct environmental interpretation of the geology in each of these cases. Geologists and planners may have different views on many aspects of such environmental problems, and undoubtedly certain concepts will change in the future. For this reason, the boundaries of the different units on each of the maps are, in most cases, essentially the same as the boundaries between the various kinds of surficial material. In addition, the explanations of the maps describe the characteristics of the surficial material used for interpretation. This method of classification, plus the inclusion of surficial and bedrock maps, it is believed, will make the maps usable for planning even to those using different concepts for interpretation.

GEOLOGIC SETTING

The Milton-St. Albans region is divided into two distinctly different geomorphic subdivisions; the Champlain Lowland on the west and the Green Mountains on the east (Figure 8). The two subdivisions are characterized by uniquely different topography, bedrock, and structure, and any one of these characteristics is different enough to be used to mark the boundary between them. The boundary is also marked by the Hinesburg-Oak Hill fault that trends generally north from the west side of Essex Junction to pass one-half mile east of Milton and St. Albans and then north-northeast through Sheldon Springs and Franklin to the Canadian border (Plate II). The distinctive differences between the two geomorphic regions is a reflection of the differing geologic histories. The depositional environment for the sediments that formed the Green Mountains was much more active than that for the Champlain Lowland, and the mountains have been subjected to more deformation of greater intensity. As a result, the rocks forming the Green Mountains province are more crystalline, more highly metamorphosed and more complex than the rocks of the Lowland. Similarly, the structures of the Green Mountains show that they have been subjected to more frequent periods of deformation with greater stresses accompanied by more uplift and dislocation than those of the Champlain Lowland.

Champlain Lowland

The Champlain Lowland is not a lake plain in the ordinary sense of the word. Whereas the term *lake plain* implies low, almost level land bordering a lake, the Champlain Lowland has an irregular topography that is in many sections quite high in relation to the lake. Hills and low mountains with sharp, bold relief are common. Many of the areas of high relief are remnants of blocks or slices of rock that were moved by great stresses along fractures in the rock. Such displacement of rocks parallel to fractures is called faulting and the resulting structure is termed a *fault.* Thrust faulting is the lateral displacement of a large slice of rock along a fracture with a very low inclination. Thrust faults are very common structural features in the western part of the Milton-St. Albans region where the rocks have been dislocated by compressive stresses and pushed westward along low-angle fracture zones. For this reason, the inclination (dip) of the rock layers is commonly eastward and the hills thus formed have a steeper slope on the west side than on the east.

The Lowland topography adjacent to the hills may be quite level inasmuch as lake and marine sediment of glacial and post-glacial times covers much of the surface below 700 feet elevation. The topography in the lower sections varies depending on the kind of bedrock, the thickness of the sediment covering bedrock, and the amount of erosion. In some areas, the erosional topography is carved into the bedrock whereas in other sections erosion is limited to the surficial material covering it.

The structural relationships of the rocks of the Champlain Lowland are quite complex. In general,

Figure 8. Geomorphic subdivisions, major structures and topographic features of the Milton-St. Albans region.

the major features that formed before the faulting are parts of two large structural basins. The southernmost of the structural basins is the Hinesburg synclinorium that trends generally north-south from the vicinity of Hinesburg to Milton and extends in an east-west direction across the lowland from Lake Champlain to the Green Mountains (Cady, 1945, p. 562). The basin is designated a synclinorium because of its large size and because smaller folds occur on the sides of the basin. The northern end of the structure extends into the southern half of the Milton Quadrangle. The northern basin, the St. Albans synclinorium, trends northward from St. Albans to the Canadian border and for approximately 30 miles into Quebec (Cady, 1960, Plate I). Approximately one-third of the structure, the southern end, lies in the northern half of the St. Albans Quadrangle.

After the initial folding that formed the two basins, the region was subjected to compressive stresses that formed low-angle thrust faults. It is apparent that the stresses came from the east since the rock slices above the fracture zones were moved westward over the bedrock below. One of the most important of these is the Champlain thrust that runs northward from the vicinity of Snake Mountain (south of Vergennes) to the Canadian border. The fault is best displayed at Lone Rock Point in Burlington, one mile south of the Milton-St. Albans region. From Lone Rock Point, the western margin of this thrust sheet trends northward through Colchester to Marble Head on the west side of Malletts Bay. From Malletts Bay, the fault follows closely the lake shore to Eagle Mountain and then northward one-half to one mile east of the lake to St. Albans Bay. North of St. Albans Bay the fault trends inland from the lake to pass through Swanton Junction and passes one-half mile east of Swanton and one mile east of Highgate Springs to the Canadian border. The slice of rock moved westward by the faulting that lies between the fault margin and the Green Mountains is commonly referred to as the Rosenberg slice. Although Stone and Dennis (1964, p. 69) objected to the use of this term in the Milton area, it is used in this report for convenience. It is estimated that the Rosenberg slice, as here described, was a mass of rock that was moved westward approximately 6 to 11 miles by conservative calculations to as much as 20 miles by more liberal estimates (Cady, 1945, p. 468; Stone and Dennis, 1964, p. 60; Shaw, 1958, p. 555). Topographically, it is the western margin of the Rosenberg slice that forms the relief of Ethan Allen Park in north Burlington and the line of low hills trending due north to Marble Head. The western edge of the slice also forms the steep slopes along the shores of Lake Champlain south of Eagle Mountain. Eagle Mountain is an eroded remnant of the thrust sheet. North of Eagle Mountain to St. Albans Bay, the relief of the western side of the displaced strata is one-half to one mile east of the lake shore. Farther north the topography is lower, but in many areas the margin of the slice exhibits conspicuous relief as it does, for example, east of U.S. Route 7 at Swanton Junction.

To the east, the Hinesburg-Oak Hill thrust, as already noted, marks the boundary between the Champlain Lowland and the Green Mountains (Figure 8). The westward movement of this fault brought the more complex rocks of the Green Mountains over the rocks of the Lowland. The western margin of this body of rock forms the steep slopes along the western margin of the mountains. The Green Mountain front is not as abrupt and high as it is to the south (Stewart, 1973, p. 16; 1972, p. 10), but in many sections the relief is quite conspicuous as in Georgia Mountain east of Milton, Bellevue Hill southeast of St. Albans, Rice Hill north of Sheldon Springs, and Minster Hill north of Franklin. The Green Mountain slice must have extended farther west at the time of its origin inasmuch as a line of low mountains composed of Green Mountain rock parallels the fault one-half to two miles west of it. These hills that were separated from the main slice by erosion include, from south to north, Cobble Hill, Arrowhead Mountain, St. Albans Hill, Aldis Hill, and Bridgeman Hill (Figures 8 and 9).

In addition to the two major thrusts, the Rosen-

Figure 9. Aldis Hill, an erosional outlier of the Hinesburg-Oak Hill thrust. Picture taken looking northwest from Bellevue Hill, one and one-half miles southeast of St. Albans.

berg slice has been displaced in some localities by smaller thrust faults. According to Shaw (1958, p. 563) minor thrusts are "literally countless" in northwestern Vermont, particularly near the Canadian border. Likewise, minor thrusts are reported to be numerous in the Milton Quadrangle (Stone and Dennis, 1964, p. 65). Welby (1961, p. 199) reported that the Champlain Lowland has been cut into a series of blocks by high-angle faults trending both north-northeast and east-west and that fractures without displacement (joints) are common.

The structure of the bedrock in the Islands of Lake Champlain is by no means simple. The strata are folded and faulted but there has been a minimum of thrusting. According to Hawley (1957, p. 84) the shales of the Islands are folded and sheared, but the displacement along the shear zones is difficult to measure. The limestones, however, are faulted to the extent that they form a series of displaced blocks in many parts of the Islands (Erwin, 1957, p. 58). In general, the topography on the Islands is not a reflection of the structure except in local areas. Erwin, (1957, p. 10), for example, explains the low swamp area across Isle La Motte (The Marsh) to be the result of faulting.

Green Mountains

The major structure of the Green Mountains is the Green Mountain anticlinorium. The structure is called an anticlinorium because it is a region where the rocks were arched upward into a huge upfold and smaller folds were superimposed across its entire width. The axis of the anticlinorium trends generally north-south and roughly parallels the main ridge. According to Christman (1959, p. 42: Christman and Secor 1961, p. 47) the folding does not have a single axis, but it consists of a series of axes that are offset one from the other. Inasmuch as the structure is an anticlinorium, it is not a single fold, but a series of essentially parallel folds distributed across the great arch. The axis of the Green Mountain anticlinorium cuts across the extreme southeastern corner of the Milton-St. Albans region. The axis follows the mountain crest through Mt. Mansfield, but the main ridge veers off to the north-northeast north of Smugglers Notch and the main axis continues to the west of the crest. The main ridge thus occupies only the extreme southeast corner of the region. It is in this section, however, that the mountains have their highest elevations, 4393 feet at the chin of Mt. Mansfield. The western side of the anticlinorium is therefore the only part of the structure in the Milton-St. Albans region. The Cambridge syncline parallels the main axis to the west of Mt. Mansfield from a few miles south of Cambridge to the latitude of Enosburg Falls. Dennis (1964, p. 39) identified a second syncline between the Cambridge syncline and the main ridge that he called the Richford syncline. The Enosburg anticline lies to the west and trends north-northeast from near Jericho through Fletcher and Enosburg Falls to the Canadian border. The Dead Creek syncline and Georgia Mountain anticline parallel the Hinesburg thrust near the western margin of the Green Mountains.

South of the Milton-St. Albans Region the Green Mountains can be divided into three distinct ranges that are designated the western, middle and eastern ridges (Stewart, 1973, p. 16; 1972, p. 10). North of the Winooski River, however, the mountains are essentially a conspicuous single range. On the east, the Worcester Mountains are separated from the main ridge by the Stowe valley and on the west by the Green Mountain foothills which have no alignment that can be called a western ridge. There are high peaks and ridges in this section, but their distribution and geographic trend are quite irregular.

The rocks and structures of the Green Mountains are so complex, because of the severe deformation, that the structures are not apparent in most localities except to the trained geologist. The complexities of the mountain region can probably best be understood by noting that studies made by Christman (1959) and Dennis (1964), for example, record complicated secondary structures such as schistosity, drag folds, fracture cleavage and jointing as being common to all areas of the mountains.

Environmental Significance of Structures

The above very brief description of the geologic structures is necessary to explain the topography of the Green Mountains and the Champlain Lowland. It should be noted, however, that the structural relationships of the rocks emphasize the fact that the whole region has been subjected to great stresses and that the rocks have been folded, faulted, jointed, crushed, and broken. Inasmuch as the rocks have been metamorphosed, they do not contain pore space between the grains in which water can be held or through which water can move. Instead, the water in the rock can be held and move only through the various types of fractures. The occurrence of water in the rock is related to the amount of fracturing. The pollution of this water is of great importance, and the installation of sewage systems and the selection of sanitary landfill sites must take note of the fractured bedrock. These aspects of the rock structure will be treated at length in subsequent chapters of this report.

DRAINAGE

The only three rivers that flow through the Green Mountains of Vermont, the Winooski, Lamoille and Missisquoi, empty into Lake Champlain in the Milton-St. Albans region. The most southerly of these streams, the Winooski River, drains only a very small portion of the southwestern section of the region.

The Winooski River enters the region just west of the city of Winooski and flows in a northwest direction for about four and one-half miles and enters Lake Champlain just north of Burlington. This section of the river drains a small area south of Malletts Bay between Fort Ethan Allen and the lake. Alder Brook, a tributary of the Winooski drains a north-south trending strip of land about six and one-half miles long and one to two miles wide that lies immediately to the west of Essex Center. This is the extent of the Winooski River drainage in the region.

The Lamoille River enters the region four miles east of Jeffersonville. The river flows northwest for about two miles and then southwest for three miles to reach Jeffersonville. From Jeffersonville, the river flows almost due west to Fairfax and then it swings to the northwest to East Georgia where it enters Arrowhead Mountain Lake. Arrowhead Mountain Lake occupies a north-south section of the river valley between East Georgia and Milton. From Milton, the river runs west and then southwest to enter Lake Champlain south of Sand Bar Bridge. East of Fairfax the valley floor is one-half to three-quarters of a mile wide and the river meanders from one side of the valley to the other. East of Jeffersonville, the floodplain is wide and flat and oxbow lakes are common.

Tributaries of the Lamoille River are numerous in the Milton-St. Albans region and some of them are rather large and complex. The Browns River, for example, heads high on the western slope of Mt. Mansfield, just below "The Nose," and flows westward through Underhill Center, Underhill and Jericho villages to Essex Center. At Essex Center, the river turns and flows north through Westford to the Lamoille River at Fairfax. Southward flowing tributaries of the Browns River drain the southwestern one-third of the Mt. Mansfield Quadrangle west of the mountain (Figure 10).

The Brewster River heads on the north slopes of Spruce and Madonna peaks and flows north-northwest for seven miles to enter the Lamoille River at Jeffersonville. In spite of its short length, the river carries a large volume of water, particularly during wet periods, because it carries the runoff from the north slope of Mt. Mansfield and the western slope of the Sterling Range. The river gradient drops almost 200 feet in less than a mile where the water drops over three falls just south of Jeffersonville. The falls section is a spot of rare natural beauty and surprisingly the falls, to the writer's knowledge, have not been named. This report suggests the name Brewster Falls. The Seymour River, also seven miles long, drains the area south of Cambridge. Several smaller streams drain the section south of the Lamoille River between Cambridge and Fairfax.

The area north of the Lamoille River that is drained into it is quite small. The northeastern corner of the Mt. Mansfield Quadrangle is drained by the North Branch, but this stream flows for only four miles in the region. Stones Brook heads east of Metcalf Pond, three miles north of Fletcher, and flows south to Fletcher and then west-southwest to enter the Lamoille River one mile downstream from Fairfax Falls. Mill Brook heads in the northwest corner of the Town of Fairfax and flows south and east to Buck Hollow and then south to the Lamoille River at Fairfax. Polly Brook that drains the Buck Hollow section is a tributary of Mill Brook. Several small, short streams drain the area north of the Lamoille River between Fairfax and Arrowhead Mountain.

West of Arrowhead Mountain, the surface material is lake sediment that is low, flat, and poorly drained. Streams heading on the west side of Arrowhead Mountain flow into the swampy section. This water is carried away by Streeter Brook that flows south from the swamp and enters the Lamoille River two miles west of Milton.

The Missisquoi River enters the Milton-St. Albans region and flows west-southwest for three miles to Enosburg Falls. From Enosburg Falls, the river flows westward to Sheldon Junction. The course of the river between Sheldon Junction and Highgate is in a west-northwest direction but the river winds and meanders both north-south and east-west in this stretch of the valley. It is apparent that the bedrock valley in this section is much wider than east of Sheldon Springs. From Highgate, the river flows southwest and makes a wide swing around Swanton and then it continues north-northwest from Swanton to Lake Champlain. Three miles northwest of Swanton the river turns north over deltaic deposits made by the river. This is undoubtedly a recent course of the river formed after drainage change caused by glaciation and the filling of the pass between the shore and Hog Island with glacial, lake, and river sediment.

The Missisquoi River and its many tributaries drain approximately one-third of the Milton-St. Albans region east of Lake Champlain and most of the area drained is south of the river.

Tyler Branch, which enters the Missisquoi River from the south one mile west of Enosburg Falls, and its tributaries drain most of the Enosburg and Bakers-

Figure 10. Drainage Basins of the Milton-St. Albans region.

field townships. The Branch, a tributary of Tyler Branch heads on the slopes of Shattuck Mountain and flows north, passing Bakersfield, to enter Tyler Branch near West Enosburg. Black Creek, a tributary of the Missisquoi, heads in the vicinity of North Cambridge and flows north to East Fairfield then northwest to near Fairfield and north again to enter the Missisquoi one mile north of Sheldon. Tributaries of Black Creek drain the valley south of Fairfield (Fairfield River), Fairfield Pond, and the large swamp south of Fairfield Pond (Dead Creek).

Hungerford Brook heads east of St. Albans between Aldis Hill and the Green Mountain front and flows due north to the Missisquoi River one mile west of Highgate. This stream and its small tributaries drain the Champlain Lowland south of the river and east of U.S. Route 7 between St. Albans and Swanton.

The narrow east-west strip north of the Missisquoi River that is drained by its tributaries (Figure 10) contains several small, short streams that flow southward to the river. The most notable of these streams are Trout and Giddings brooks north of Enosburg Falls, McGowan Brook north of Sheldon Junction, and Kelly Brook east of Swanton.

The northern border of the Milton-St. Albans region, north of the Missisquoi divide, is drained chiefly by two streams that flow north into Canada, one of which flows back into Vermont to Lake Champlain. The Pike River heads in the extreme northeast corner of the region north of Berkshire. The stream flows south and then northwest and enters Canada one and one-half miles north of East Franklin. Lake Carmi is drained by this stream. The Rock River heads in the valley just west of Franklin and follows a winding, westward course to a point two miles northeast of Highgate Center where it turns north to flow into Canada. The stream comes back into Vermont three and one-half miles north-northeast of Highgate Springs and flows southwest to enter Lake Champlain one mile north of Highgate Springs. The Rock River and its tributaries therefore drain all of the lowland north of the Missisquoi basin between Highgate Springs and Franklin (Figure 10).

The Champlain Lowland along the lake is drained by several small streams. Stevens Brook and its tributary, Jewell Brook, drain the low section north of St. Albans Bay. Mill River and its tributary, Rugg Brook, drain the area between St. Albans Bay and St. Albans Hill and the section to the south of St. Albans Hill. Farther south, Stone Bridge and Trout brooks flow down the steep slope bordering Lake Champlain.

In the southeast corner of the region, the Waterbury River and its headwaters drain the eastern slope of Mt. Mansfield. The river heads at Big Spring, one-half mile south of Smugglers Notch, and flows southeast to the southeast corner of the region. Tributaries of the river, however, head near the crest of the mountain near Spruce Peak to the north and Needles Eye on the west.

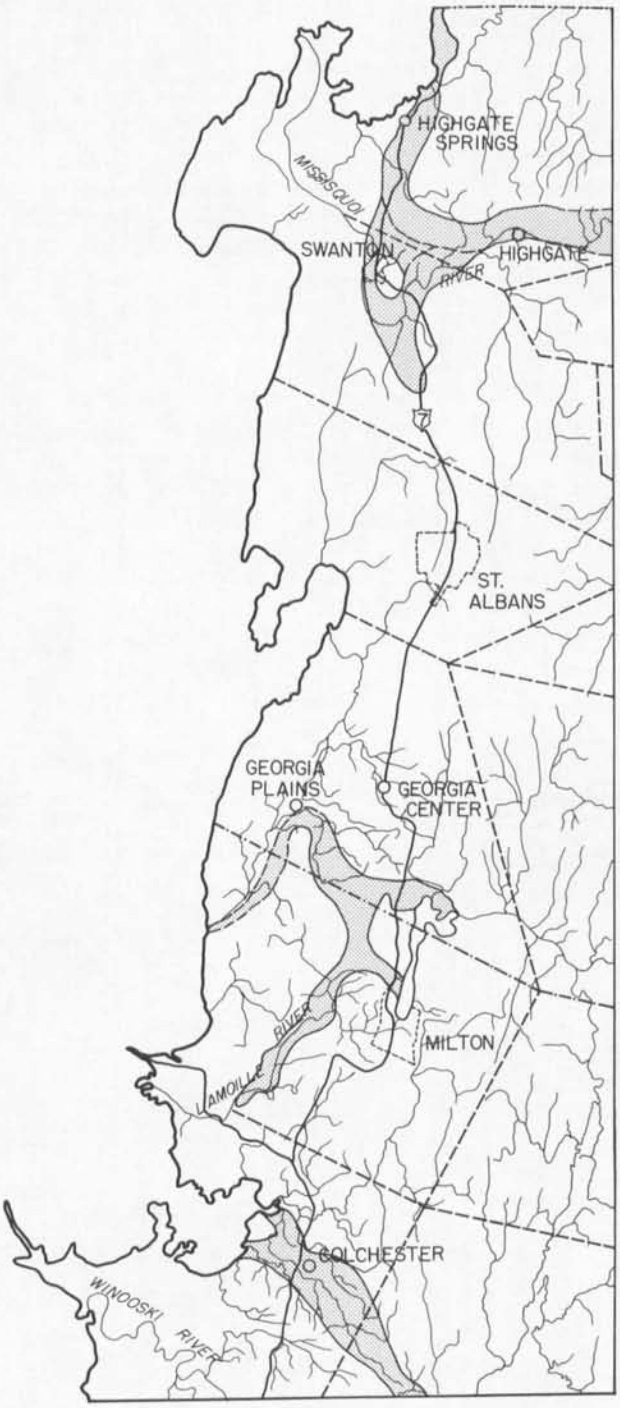

Figure 11. Map showing the former buried valleys of the Winooski, Lamoille, and Missisquoi rivers.

BURIED VALLEYS

Three noteworthy buried valleys that indicate recent changes in the lower courses of the Winooski, Lamoille, and Missisquoi rivers were discovered during the investigations made for this report. These valleys were delineated from field observations and from the study of water-well records.

In the report on the Middlebury-Burlington region, the writer stated that the Winooski Gorge seemed to be of recent origin and that an older, buried valley might exist north or south of the gorge (Stewart, 1973, p. 17). It is now believed that the former course of the river turned northeast, probably upstream from the falls at Essex Junction, and followed closely the present highway (U.S. Route 2A) between Essex Junction and Colchester village and then west to Malletts Bay (Figure 11). Well records show a valley 150 to 200 feet deep. The record is incomplete at both ends of the valley, however, so that the point of departure from the present course as well as the exact location of the mouth of the river at Malletts Bay cannot be ascertained.

The former history of the lower Lamoille River appears to be more complex than the Winooski. It seems certain that the present route of the Lamoille, north-south along the east side of Arrowhead Mountain, is a relatively new valley. Field observations and well-records suggest that the former course was north of Arrowhead Mountain and at one time the river flowed west-northwest to Georgia Plains and then to Lake Champlain probably along the present route of Stone Bridge Brook. Well records define a valley 100 to 165 feet deep from the northwest side of Arrowhead Mountain to Georgia Plains. It should be noted, however, that neither well records nor field study has definitely established the outlet west of Georgia Plains or the former channel north of Arrowhead Mountain. A second route of the river is around the north end of Arrowhead Mountain and then south along the western side of Arrowhead Mountain to the present river three or four miles west of Milton. Well data for this section show a valley 100 to 275 feet deep. There is also a possible channel south of Arrowhead Mountain to the channel described above (Figure 11).

The Missisquoi River formerly flowed one-half to one mile south of the present course at Highgate and then west, northwest, and north to Lake Champlain near the present mouth of the Rock River (Figure 11). This valley is 130 to 150 feet below the present land surface. The river may have had other courses prior to establishing its present course inasmuch as a valley exists between Swanton and Swanton Junction that may have been a former bend in the river or a former tributary.

The time that the above described drainage changes took place has not been determined. It is probable that they all took place during the ice age. One possibility is that glacial damming caused the change. A more likely hypothesis, however, is that

Figure 12. Bouldery surface of till on the Champlain Lowland. Fine sediment was removed by wave action of Lake Vermont. One mile northeast of St. Albans.

the former valleys were filled with lake sediment as the last glaciers receded, and the streams found a new course on the lake sediment and cut down to their present positions. Well records indicate that the sediment in these buried valleys is mostly silt and clay, no doubt deposited in a lake environment.

SURFICIAL MATERIAL

The surficial materials of the Milton-St. Albans region (Plate I) were deposited during and immediately following the Great Ice Age. These materials include unsorted detritus that was deposited directly from the ice, stratified sand and gravels transported and deposited by streams flowing from the melting glaciers, sediment deposited in ice dammed lakes as the ice receded, and marine deposits made by a sea that invaded the Champlain Basin after the glaciers had melted. The surficial materials were laid down during and following the last glacial interval in Vermont that is designated the Burlington Stade of the Wisconsin Glacial Stage (Stewart and MacClintock, 1969, p. 56).

A large part of the region is covered by a veneer of glacial till, the unsorted debris deposited directly from melting ice. Till, being unsorted, is composed of particles of all sizes ranging from clay to large boulders. Till in the Milton-St. Albans region covers the uplands as a thin veneer generally less than 10 feet thick. The till may be of greater thickness in stream valleys. The Champlain Lowland in this region contains patches of till that were eroded by wave action during the lake and marine episodes that followed glaciation. These areas are usually strewn with boulders except where the boulders have been removed by man (Figure 12). Generally, however, lake and marine sediments cover the lowland below elevations of 700 feet. Till, as a general rule, has a low permeability because it is unsorted, but in this region the sand content of the till is higher than normally expected and the permeability is somewhat higher.

Outwash is formed during the melting phase of glaciation since it is deposited by meltwater streams flowing from the melting ice. The deposits are well sorted, have a high porosity and permeability, and usually contain a high reserve of available ground water. Kame terraces are outwash deposits found along valley walls and along slopes of mountains. These features were made by flowing water between the valley walls (or mountain slopes) and glacial ice. The deposits are identified by the slumping structures that formed when the ice on the valley side of the structure melted. Kames are rounded hills of outwash and eskers are elongate ridges of the same materials, and both structures were deposited in contact with ice (Figure 13). Stream valleys are often filled with outwash deposited by meltwater streams. These deposits are horizontally bedded and are called valley trains. Outwash deposits are scattered all over the Milton-St. Albans region.

Figure 13. Gravel face of a pit exposing the cross-section of an esker with well-developed ice contact structures. One and one-half miles northeast of Enosburg Falls.

Lake and marine sands and gravels, including beach gravel and deltas, are shallow water deposits that are usually well sorted. In the Milton-St. Albans region, the marine deposits occur below an elevation of 400 feet in the southern part of the Milton Quadrangle, but the elevation rises northward to about 600 feet in the northern parts of the St. Albans and Enosburg Falls quadrangles. The sands and gravel vary in permeability depending on the degree of sorting and the amount of silt contained in them. In general, however, both the porosity and the permeability are good. The gravel is usually much thinner than sand and both commonly occur above silt and clay.

Lake and marine silts and clays are fine-textured bottom sediments. These materials usually 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 therefore they do not yield the water contained in them.

Recent alluvium is post-glacial sediment deposited by modern streams. This material usually forms a layer over the valley floor that ranges from 5 to 25 feet in thickness. It is a poor foundation material that must be removed for heavy construction. The deposit usually indicates a valley floor that is frequently flooded.

Peat and muck are deposits made in swamps and other poorly drained areas. Most of these are small swamps occupying shallow depressions in the surface material or bedrock.

BEDROCK

As explained earlier in this report, the rocks of the Champlain Lowland are distinctly different from the rocks of the Green Mountains. The rocks of the Lowland are only slightly metamorphosed and, except for some slate, they are nonfoliated. The rocks of the Green Mountains, however, are very complex, mostly foliated, and a high percentage of the minerals composing them were formed as a result of metamorphism. The rocks in the two sections are different because the sediments from which the rocks formed were deposited in distinctly different environments. The rocks of the Green Mountains were deposited in a much more tectonically active basin than those of the Lowland. The rocks are also different because the Green Mountain region has been subjected to several episodes of mountain building with greater deformation and more intense metamorphism than the Lowland. As a result, the two provinces can be delineated solely on the basis of rock types.

The bedrock map prepared for this report (Plate II) is not a geologic map in the ordinary sense of the word since it does not use formation names, geologic sequences, or age relationships. It is the opinion of this survey that these aspects of a geologic map are not of significant importance to planning. The map of this report (Plate II), therefore, concentrates on the lithologies of the rocks, their physical description, and their significant chemical properties. These are the characteristics that are relevant to environmental planning and this is all that the map is intended to show. It is believed that this 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 information is needed, it is available on the Centennial Geologic Map.

Rocks of the Champlain Lowland

The rocks of the Champlain Lowland are a sequence of moderately metamorphosed sedimentary rocks composed primarily of limestone and dolomite marbles, with an occasional quartzite or slate. The geologic ages of the Lowland rocks are approximately the same as those of the Green Mountains but the rocks are different in the two regions because they have differing geologic histories.

Quartzite is a very hard, massive rock that is formed by the metamorphism of sandstone. It has been changed to the degree that the quartz (silica) has recrystallized but no new minerals have been

Figure 14. Fractures enlarged by solution weathering of dolomite rock. Exposed in a stone quarry in the village of Milton.

Figure 15. Weathered slate exposed in an abandoned quarry on North Hero Island.

formed. The rock is composed predominantly of quartz and is therefore most resistant to both chemical and physical weathering and erosion. For these reasons, it often forms the crests of the hills and low mountains on the Lowland.

Limestone marble (designated limestone on the bedrock map) is, as the name implies, the metamorphic equivalent of limestone. In the Milton-St. Albans region, these rocks are fine grained, do not take a good polish, and for this reason geologists commonly refer to them as simply limestone. They have, none the less, been recrystallized and can correctly be classified as marbles. Limestone marble is composed predominantly of the mineral calcite (calcium carbonate) and is therefore quite susceptible to chemical weathering and erosion. Acid as simple as that formed by the combining of atmospheric carbon dioxide and water forms rills on exposed surfaces of the rock, and enlarges the fractures in the rock below the surface. Limestone marble is a fairly soft rock and is readily weathered and eroded by physical processes.

Dolomite marble (called dolomite on the bedrock map) is similar in appearance to limestone marble. It differs from limestone marble, however, because it is composed mostly of the mineral dolomite, a calcium-magnesium carbonate. The magnesium in the composition of dolomitic marble makes it somewhat harder and more resistant to physical weathering and erosion, and less susceptible to chemical decomposition. Dolomite marble is, however, slowly dissolved by acid waters and conspicuous enlargement of the fractures in the rock does take place (Figure 14). The resistance of the dolomite marble to erosion is the reason for the steep bluffs along Lake Champlain south of Eagle Mountain inasmuch as dolomite limestone caps the Rosenberg slice in that section.

Shale or slate is limited in its areal extent at the surface in the Milton-St. Albans region. Shale and slate are very fine textured and are relatively soft and easily eroded by physical processes. Slate and shale, for example, form the bedrock in the low section west of Arrowhead Mountain in the Milton area. The rocks are usually fractured and the fracture zones are the first to be attacked and the rock breaks up into thin slabs (Figure 15).

Some of the rocks of the Champlain Lowland are composed of two or more combinations of the above rock types (Plate II). The properties, both chemical and physical, of the combined rock types are determined by the relative amounts of each kind of rock. The quartzite with interbedded dolomite, for example, is predominantly quartzite with subordinate layers of dolomite and is therefore quite resistant in most localities. The proportion of each type of rock varies from place to place in a single layer and study of the rock is necessary to ascertain its composition at any particular place.

Rocks of the Green Mountains

Compared to the Champlain Lowland, the rocks of the Green Mountains are very complex and highly metamorphosed. The complexity of the rocks is chiefly due to the fact that the metamorphism was so intense that new minerals were formed by the great heat and pressures. It is assumed that the metamorphism of the rocks was caused by regional stresses because the more intense metamorphic zones parallel the Green Mountain anticlinorium. Most of the rocks are foliated because recrystallization formed platy and elongate minerals that were aligned parallel to the bedding by movement along the bedding planes. Geologists call this bedding schistosity and the alignment of the platy and elongate minerals into layers is called foliation.

Schistose greywacke is a complex, foliated rock formed by the intense metamorphism of sandstone. The rock contains a moderate amount of dark minerals that were formed by the metamorphism. The dark minerals are susceptible to chemical weathering, but they are disseminated throughout the rock and chemical weathering is not, therefore, concentrated along fractures as it is in the marbles. The rocks vary from light to dark grey in color.

The other rocks of the Green Mountains are mixtures of varying proportions of phyllite, schist, gneiss, and greenstone. The chief differences among these rocks are the degree of metamorphism, the texture, and the foliation. Phyllites are very fine textured and are finely foliated, whereas gneiss is coarsely textured and has thicker foliation. Schist is intermediate in texture and foliation. Amphibolite is composed predominantly of the mineral amphibole. Greenstone has a green color mainly because of the chlorite, a mica, formed by the alteration of other minerals during metamorphism. In general, these rocks are very difficult to differentiate in the field because of their similar appearance. The rocks have similar characteristics insofar as their reactions to weathering and erosion are concerned. For this reason, they are all designated by a single color on the bedrock map and the variations are indicated by letter symbols.

SURFACE WATER

Surface water in the Milton-St. Albans region, particularly in the western part, has a good potential for an unlimited supply. Lake Champlain is being used as a source of water at an increasing rate. Since the ground water potential is quite low on the Champlain Lowland and the Champlain Islands, this is undoubtedly the most important future source of water for those areas. The amount of water available in Lake Champlain is, for all practical purposes, unlimited. The quality of the water, however, is a problem that will require strict adherence to future restrictions regulating the dumping of wastes into the lake as well as the streams flowing into the lake. The term future restrictions is used advisedly in this regard inasmuch as adequate restrictions have not, as yet, been enacted. Because of the length of the time it would take to rectify the abusive practices of the present time, this report recommends immediate action to cut off completely the pollution of the lake-water. Probably the most difficult aspect of such a clean up would be the problems associated with the tributary streams. The action would, of necessity, require state legislation to standardize the practices all along the lake. Admittedly, progress is being made in the upgrading of the lake water, but pollution abatement has been at a rate that is much too slow.

The two largest inland lakes with water potential are Lake Carmi and Fairfield Pond. Lake Carmi is not at this time in an area of high water demand, but as development progresses into the region there may well be a demand for the lake water. Fairfield Pond has been a source of water for the Village of Swanton, but pollution of this pond has reduced the quality of the water to an unsatisfactory level. The problem of water quality in the small lake is the result of lake-side development for both permanent and seasonal homes. Many of these dump raw sewage into the lake or they have septic tank installations that are inadequate, malfunctioning, or improperly installed. This problem exists in the vicinity of all lakes including Lake Champlain where lake-side development has occurred. The problem needs study and remedial action.

A few smaller ponds and lakes have water potentials of varying quality and quantity of water. These include Colchester Pond in the northeast corner of the Town of Colchester, Milton Pond, two miles east of Milton, and Metcalf Pond, three miles north-northeast of the Village of Fletcher. There are also a few streams that head high in the Green Mountains that are potential sources of surface water. The headwaters of the Waterbury, Brewster, and Browns rivers, for example, might be a future source of large quantities of water.

GROUND WATER

To ascertain the ground water potential of a particular region, it is necessary to collect data from several different sources. The specific information accumulated during this survey pertaining to the water supply was obtained chiefly from water-well records, seismic investigations, field observations, and the *Ground Water Favorability Map* of each river basin (Hodges and Butterfield, 1967a, 1967b, 1967c).

Water-well records have been required of all drillers in Vermont since 1966. These 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. These data also assist in the locating of buried valleys, the determination of suitable locations for seismic studies, and in ascertaining, in general, the regional water-bearing characteristics of the bedrock and surficial material.

Seven locations where well-log and field data indicated good water potential, were selected for seismic study. The seismic data collected from these studies gives information about width, depth, and shape of a stream valley, the location of buried valleys, the depth to the water table, and a generalized profile of the surficial material above bedrock. In this region, the seismic studies were made chiefly to ascertain some significant characteristics of the unconsolidated sediment in stream and buried valleys. Seismic data alone allows materials to be classified into broad groups based on the velocities of the seismic wave transmitted through them. Each velocity does not, however, have a unique material classification, but most unsaturated bedrock and surface material have a definite velocity range. Saturated sediment has about the same velocity regardless of the texture of the material. For these reasons, it is advantageous to have records of water wells located nearby for correlation with the seismic profile. Certain seismic profiles made during this survey are difficult to interpret because there are no records of wells located in the vicinity for comparison.

In general, bedrock has a high seismic velocity above 12,000 feet/second because of its density. The seismic velocities of unconsolidated sediment are much lower. Compact, dense till may have velocities as high as 8,000 feet/second. Alluvium, stream sediment on the valley floors, has seismic velocities ranging between 800 and 2,000 feet/second. Unconsolidated sediment that is saturated with water usually has a seismic velocity between 4,000 and 5,500 feet/second. Ground water in quantities great enough for a municipal water supply has been restricted to material with velocities between 4,800 and 5,300 feet/second. The seismic work completed during these investigations was done by the Weston Geophysical Engineers, Inc. of Westboro, Massachusetts, and they supplied the seismic profile reproduced in this report. The exact location of each seismic profile is shown on the maps in Appendix A.

The *Ground Water Favorability Map* of each stream system (Hodges and Butterfield, 1967a, 1967b and 1967c) was used to ascertain the available ground water data at the time of its publication. The maps show all of the significant ground water information and the most favorable ground water sections known at that time. They contain statistics about water wells of high yield and the location and description of significant Highway Department drill-holes. It is not intended that the *Ground Water Potential Map* of this report supersede the favorability maps. The favorability maps are accurate and have supplied much data for this study. The ground water map of this report (Plate III) brings the ground water data up to date by utilizing well logs, geologic information, and seismic data.

All of the data collected during this survey indicate that ground water is in short supply in most areas of the Milton-St. Albans region. There is a predominance of lake silts and clays in the buried and stream valleys that is of low permeability, and the water yield is low in spite of saturation. The spotty occurrence of surficial sediment with high water potential emphasizes the probable dependence of this region on surface water as future development progresses. East of the Champlain Lowland, however, the reserve of surface water is so limited that, as the Green Mountain section continues to grow, ground water will no doubt be the most readily available water resource. It seems inevitable, nonetheless, that future demands will necessitate the cleaning and regulating of discharge into Lake Champlain, developing a few mountain watersheds, and restricting the use of the small lakes and ponds to supply water to the region.

There are five modes of occurrence of ground water that have been studied during the course of these investigations. These are: 1) in zones of intense faulting; 2) in fractures other than faults; 3) in solution cavities and enlarged fractures of the limestone and dolomite marbles; 4) in outwash deposits, mostly kame areas, throughout the region; and 5) in the unconsolidated sediment in stream and buried valleys. As near as it is possible to determine, the above five factors are listed in order of their increasing importance (1 through 5). At any rate, the kame areas and the unconsolidated sediment in stream and buried valleys have the greatest potential and water can probably be produced from them with the least amount of expense.

Zones of closely spaced, intricate faulting that are believed to have moderate to high ground water potential are designated y-2 on the *Ground Water Potential Map* (Plate II). Only one small area on South Hero Island is classified in this category simply because this is the only section where the faults have been mapped in such detail. Undoubtedly there are other sections of the region that are as intensely faulted and therefore have similar ground water possibilities. Planners should be mindful of the fact that such potentials exist. It should be stated, however, that there is no documentary evidence available at this time that the fault zones do actually yield water differently from other types of fractures in the rock. Since 1966, when well records have been available, few water-wells have been drilled in sections of known faulting and the wells that have been drilled do not yield water in quantities different from other areas. Until such a time when wells are located using geological data to intersect faulted strata, evaluation of the faulted zones as water-bearing structures, will have to remain an unanswered question.

Since, as has already been stated, the rocks of both the Champlain Lowland and the Green Mountains are metamorphosed and crystallized they contain little or no pore space between the grains that would allow rocks to hold water or through which water could readily move. It is a fact, therefore, that these rocks would produce little or no water if they were not fractured. Fractures in the rocks are open at the surface and water can readily pass through them. The width of the fractures decrease downward, however, and usually at depths of 300 to 400 feet most of them are 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 many different depths, and for this reason the water is usually under hydrostatic pressure and rises in the well. Water wells producing from fractures, as a general rule, have very low yields that range between 2 and 15 gallons of water per minute with a few wells with yields as high as 50 to 60 gallons per minute. Since the uplands and parts of the lowlands have bedrock exposed at the surface or the bedrock has a thin cover of low permeable till, the fractures in the rock are the only source of ground water. The bedrock of the Champlain Lowland is in many sections covered with lake silts and clays with low permeability, and in other sections the bedrock is barren of sediment. In these areas, ground water is available only in the solution cavities and fractures in the rock. Usually, enough water can be obtained from bedrock fractures to supply a one-family home or small business, but only in rare cases will the yield be enough for even a very small community.

The fractures in the limestone and dolomitic marbles of the Champlain Lowland are similar to those of the other kinds of bedrock. These rocks, however, are composed predominantly of carbonate minerals that are susceptible to solution weathering. In many cases, the fractures have been significantly enlarged and cavernous channelways have been formed in the rock (Figures 16 and 17). The enlarged fractures and channels allow the water to enter the rock more rapidly, move more freely, and collect in larger quantity. It is assumed that wells producing water from these features would have a higher yield than insoluble rock. But, as in the case of the faulting, there is little data available to substantiate this assumption. The well records available do not show higher yields for wells in the carbonate rock. Drillers' records, however, do not show sufficient data to ascertain whether or not enlarged fractures or solution cavities were encountered. There have been no studies in Vermont to try to determine the effect of solution on the water yield of limestone and dolomite marble.

Ground water that occurs in rock fractures and

Figure 16. Enlarged fractures in carbonate rock, one mile east of Highgate Springs.

Figure 17. Solution channel in dolomite rock. Exposed in a stone quarry in Winooski.

solution cavities is most susceptible to contamination. Whereas organic pollution would be removed from water as it filtered for a short distance through porous unconsolidated sediment or rock, it might travel for miles through fractures without 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 contaminant and therefore control and abatement are most difficult.

The most favorable possibilities for ground water in most regions of Vermont are the unconsolidated sediments in stream and buried valleys. In the Milton-St. Albans region, however, stream and buried valleys, as a general rule, are filled with fine-textured, low permeability lake silts and clays and the probability of ground water in large quantities is quite low. It is possible that certain of the kame gravel deposits scattered through the Green Mountain section may have a greater water potential than the stream and buried valleys. Field investigations, water-well data, and seismic study, gave discouraging results in most sections of the major valleys.

The Missisquoi River valley seems to have good ground water potential in only three short sections. West of Enosburg Falls the south side of the valley contains gravel that is outwash, at least in part, inasmuch as a kame area lies to the north and south of the river. A seismic profile across the valley at North Enosburg, three miles east-northeast of Enosburg Falls, shows the buried valley to be 70 to 90 feet deep and to contain saturated sediment, probably sand and gravel, in the middle of the valley. Unconsolidated sediment of higher density believed to be till occurs at both ends of the profile (Figure 18). Efforts by the village of Enosburg Falls, however, to find adequate quantities of water for a water supply just west of the village were unsuccessful. The Missisquoi Valley from Enosburg Falls to Sheldon Junction is in places shallow, with bedrock exposed in the stream channel for part of the distance and lake silts and clays fill the deeper portions. A short stretch of the valley between Sheldon Junction to Sheldon Springs, at the mouth of Black Creek, has a good ground water potential. Highway Department borings near the mouth of Black Creek encountered gravel at the bottom of a drill-hole 62 feet below the surface (Hodges and Butterfield, 1967a).

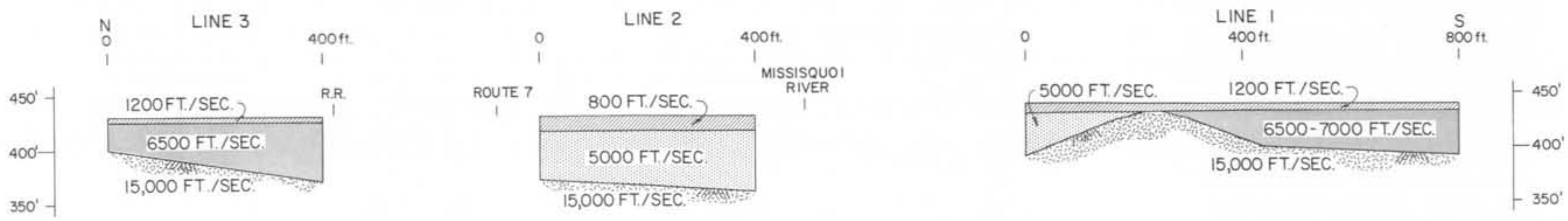

Figure 18. North-south seismic profile across the Missisquoi River valley at North Enosburg.

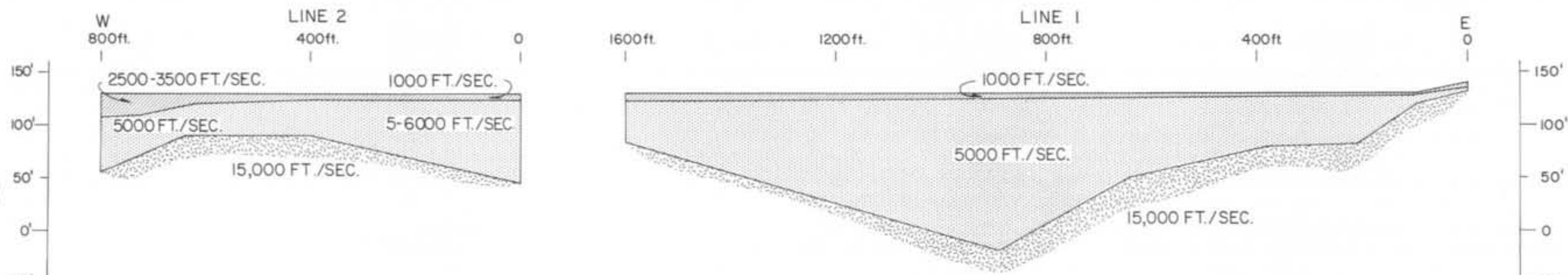

Figure 19. East-west seismic profile across a buried valley immediately east of Highgate Springs.

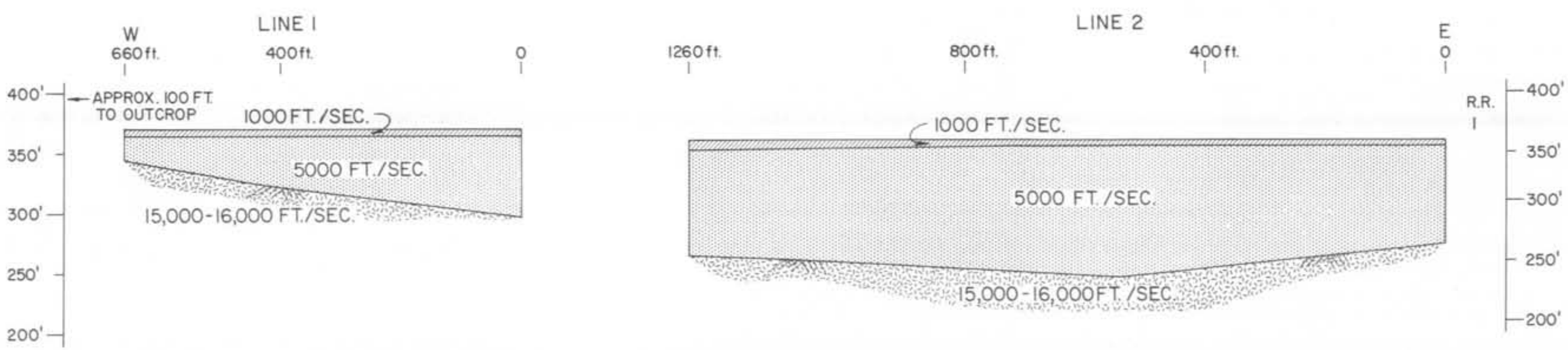

Figure 20. East-west seismic profile across Black Creek valley, two and one-half miles south of Sheldon village.

The Missisquoi Valley between Sheldon Springs and the vicinity of Swanton is wide, and is in some sections deep, but the valley fill throughout this stretch of the river is lake silts and clays except for a veneer of sand on the surface. There is good coverage with well records for this section and several of the wells in the vicinity of Highgate penetrate 100 to 190 feet of fine-textured sediment to reach bedrock. The most promising section along the Missisquoi River, insofar as ground water is concerned, is a north-south buried valley that extends from Swanton Junction to Lake Champlain north of Highgate Springs (Plate III). As noted earlier in this report, at least a part of this valley is a former channel of the Missisquoi drainage. Well records show the buried valley to be 90 to 150 feet deep between Swanton and Highgate Springs, but the depth south of Swanton cannot be accurately determined. A seismic profile across this valley at Highgate Springs indicates a valley with a maximum depth of 150 feet filled with saturated sediment (Figure 19). There are, however, no known water wells of high yield in the valley which seems to imply that part of the saturated sediment is fine textured.

The only tributary of the Missisquoi River that has a buried valley with ground water potential is Black Creek valley between Sheldon and Fairfield. Hodges and Butterfield (1967a) classified this part of the valley as having a high potential. And, a seismic profile, made during this survey, two and one-half miles south of Sheldon, describes a wide valley with a maximum depth of 115 feet filled with saturated sediment (Figure 20). But there are no well records for this valley and field investigations reveal only silts and clays at the surface. This survey therefore classified the valley sediment as having only moderate ground water potential and interprets the saturated sediment of the seismic profile as fine textured. A test well located in the vicinity of the line where the seismic profile was made is needed to establish the texture of the sediment.

The Lamoille River valley, like the Missisquoi Valley, has a limited number of sections that have good ground water potential. One of the deepest buried valleys along the Lamoille River is in the extreme eastern part of the region three miles northeast of Jeffersonville (Plate III). A seismic profile in this section, located three and one-half miles east-northeast of Jeffersonville, shows the buried valley to be 220 feet deep and that it is filled with saturated sediment (Figure 21). The ground water potential in this section is probably the highest of any buried valley in the Milton-St. Albans region. There are no well records available for this area, however, and test drilling will be necessary to establish the available water. A second section of the valley with good water potential extends from two miles upstream from Cambridge village downstream for a distance of about five miles (Plate III). A water well at the western end of this stretch penetrates 150 feet of sediment above bedrock and a seismic profile one mile west of Cambridge shows the wide valley to be generally 70 to 90 feet deep (Figure 22). The saturated sediment in the valley is interpreted to be mostly sand and gravel, but test drilling is needed to obtain more detailed information about the texture of the sediment.

Except for the two sections described above, the Lamoille Valley is filled with fine-textured lake sediment or glacial till and the water potential is moderate to quite low. The former channels of the Lamoille River west of Arrowhead Mountain, as described earlier (Figure 11), are 275 feet deep in some places, but numerous well records show silt and clay below a veneer of sand throughout the buried valley.

Some tributary valleys to the Lamoille have a higher ground water potential than the main valley. The North Branch valley in the vicinity of Waterville has lake sand and gravel along the valley walls that should contain much water. Some of these sediments are delta-type deposits. The Brewster River valley south of Jeffersonville and upstream from the falls is deep and, according to well records, filled with lake sand and gravel. Records for wells located west of the river and west of State Route 108 show bedrock as deep as 200 feet suggesting that a former channel of the river emptied into the Lamoille between Jeffersonville and Cambridge. The course of the river across the falls south of Jeffersonville therefore seems to be relatively recent, probably since the lowering of the lake that deposited the sediment in the Lamoille River valley.

The Browns River valley upstream from Essex Center and as far east as Underhill Center has one of the highest ground water potentials of any stream in the region. The sediment in the valley seems to be a combination of outwash and lake sands and gravel with glacial till at the bottom in some sections. Just east of Essex Center water-well records indicate the bottom of the buried valley to be as much as 125 feet below the surface with sand and gravel the predominant sediment filling the valley. East of Jericho village the percentages of sand and gravel increase. Two seismic profiles were made in this part of the valley. The more westerly seismic site is located one mile south of the Village of Underhill. At this place, the valley has a maximum depth of 165 feet, but a layer of dense sediment, believed to be till, occurs at the bottom on the north side (Figure 23). The maximum depth of saturated sands and gravels is 135 feet. A well located near the south end of this profile yields 60 gallons of water per minute from sand and gravel at a depth of 41 feet. A well at Underhill village is 28 feet deep and yields 150 gallons of water

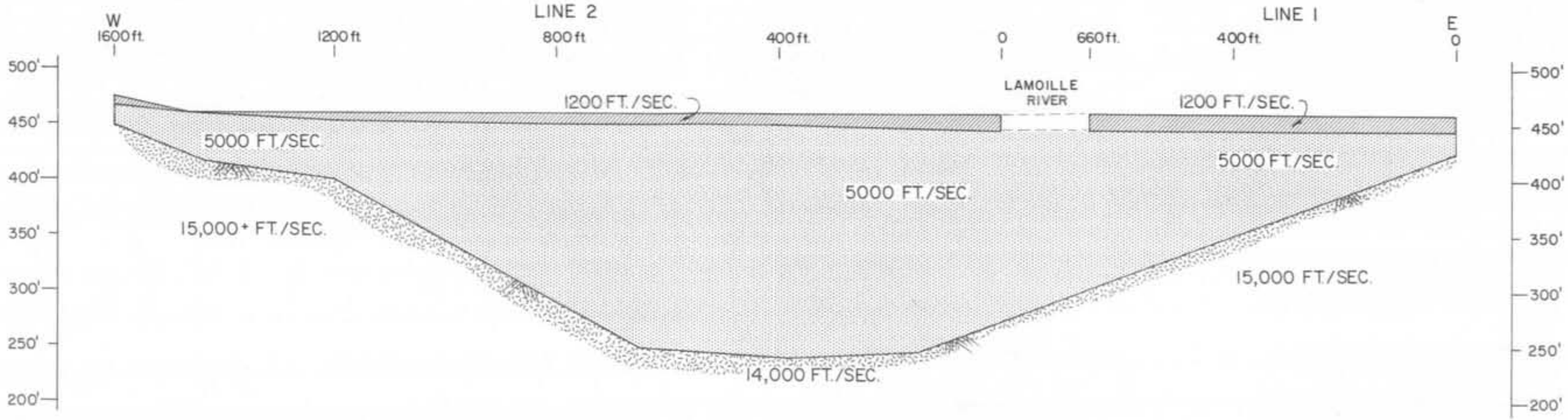

Figure 21. Northeast-southwest seismic profile across the Lamoille River valley, three and one-half miles east-northeast of Jeffersonville.

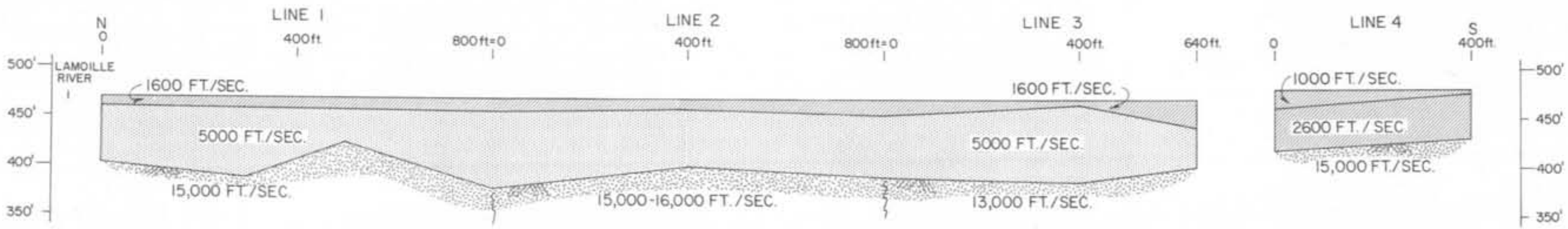

Figure 22. North-south seismic profile across the Lamoille River valley, one mile west of Cambridge village.

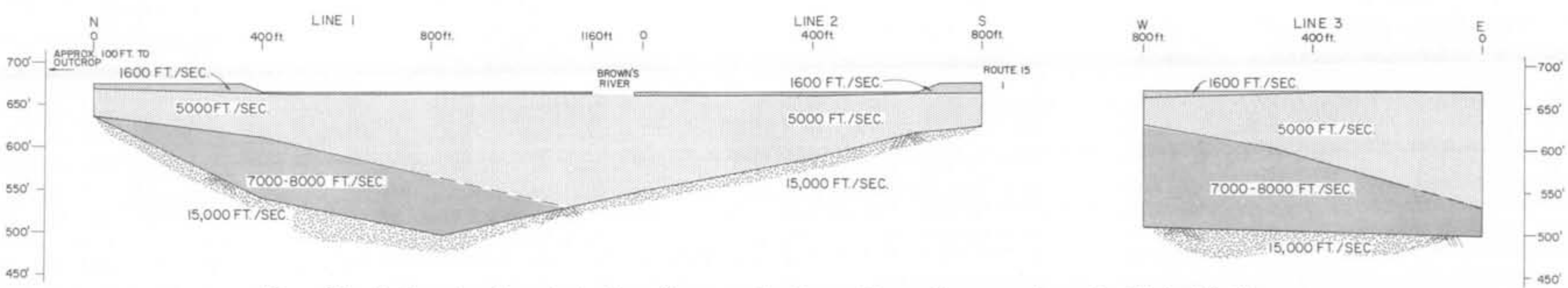

Figure 23. Northeast-southwest seismic profile across the Browns River valley, one mile south of Underhill village.

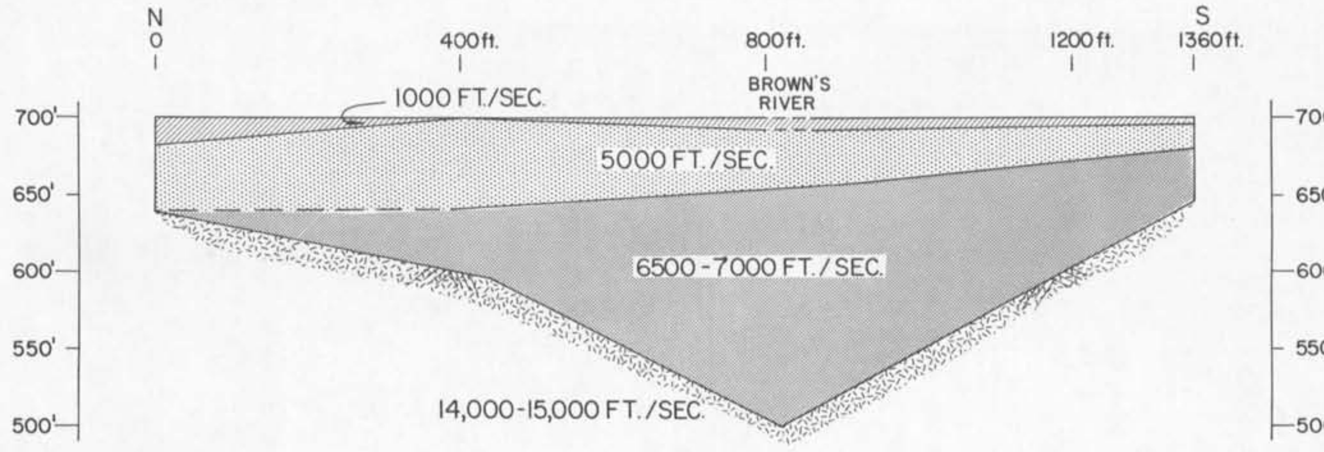

Figure 24. North-south seismic profile across the Browns River valley, one mile east of Underhill village.

per minute. The second seismic profile, located one mile east of Underhill village, shows a maximum depth of 200 feet for the buried valley, but 150 feet of till occurs at the bottom in the deepest section (Figure 24). The sand and gravel above the till is 40 to 60 feet deep. In spite of the shallow depth of the sand and gravel, it should contain much water. A water well in the valley one-half mile downstream from Underhill Center produces 20 gallons of water per minute from gravel at a depth of 70 feet.

A buried valley trending southward for approximately three miles from the south end of Arrowhead Mountain Lake is believed to have good ground water potential. Water-well records show the valley to be 160 to 260 feet deep a mile south of the Village of Milton. Inasmuch as this is a locality of residential development, a number of water wells have been drilled in recent years. Very few of these wells, however, produce water from the unconsolidated sediment. One driller reported 40 gallons of water from gravel at a depth of 117 feet, but the well was continued to a depth of 519 feet, through 400 feet of bedrock, and the finished well yields 2 gallons of water per minute.

The Winooski River valley, in the extreme southwestern part of the Milton-St. Albans region, is filled with fine-textured lake sediment and therefore has a very low ground water potential. The abandoned valley of the Winooski, described earlier (Figure 11), that trends northwest from Essex Junction to Lake Champlain is 100 to 200 feet deep but it is also filled with lake silts and clays.

In view of the discouraging ground water possibilities in the stream and buried valleys of the region, the ground water potentials of a few kame (outwash) gravel areas scattered over the region, mostly in the Green Mountain section, are of major interest. Unfortunately, there are few well records for these deposits on which to judge the water reserve, but the characteristics of the sand and gravel composing them imply high porosities and permeabilities. The largest of the outwash areas is the Berkshire kame complex that extends from West Berkshire southward to the Missisquoi River one mile east of Enosburg Falls (Plate I, Figures 25 and 26). The Village of Enosburg Falls has a water well located in this deposit two miles north-northeast of the village. The well is 78 feet deep and yields 600 gallons of water per minute. The Town of Enosburg has a well near the village well that produces 50 gallons of water per minute from gravel at a depth of 52 feet. South of Enosburg Falls, the Tyler Branch valley and some tributary valleys have kame deposits that may contain much water. These valleys are designated in green on the *Ground Water Potential Map* (Plate III).

The kame deposit on the west side of Fairfield Pond is another gravel deposit that should be investigated to determine the water reserve. There are no well records available, but gravel pits located in the outwash indicate an adequate thickness of gravel. To the south of Fairfield, the kame deposits of Buck Hollow should have a large reserve of water. There are no well records for this area but the gravel is of considerable thickness. In the southeastern part of the region, the kame deposits along the Waterbury River have a high ground water potential. Kame deposits north of Underhill Center and the Village of Underhill also bear investigation.

SOLID WASTE

As the population of a region increases, the problems associated with the disposal of solid waste become more acute. The U.S. Environmental Protection Agency estimated in 1969 that urban solid waste

Figure 25. Gravel exposed in a gravel pit in the Berkshire kame complex, one and one-half miles northwest of Enosburg Falls.

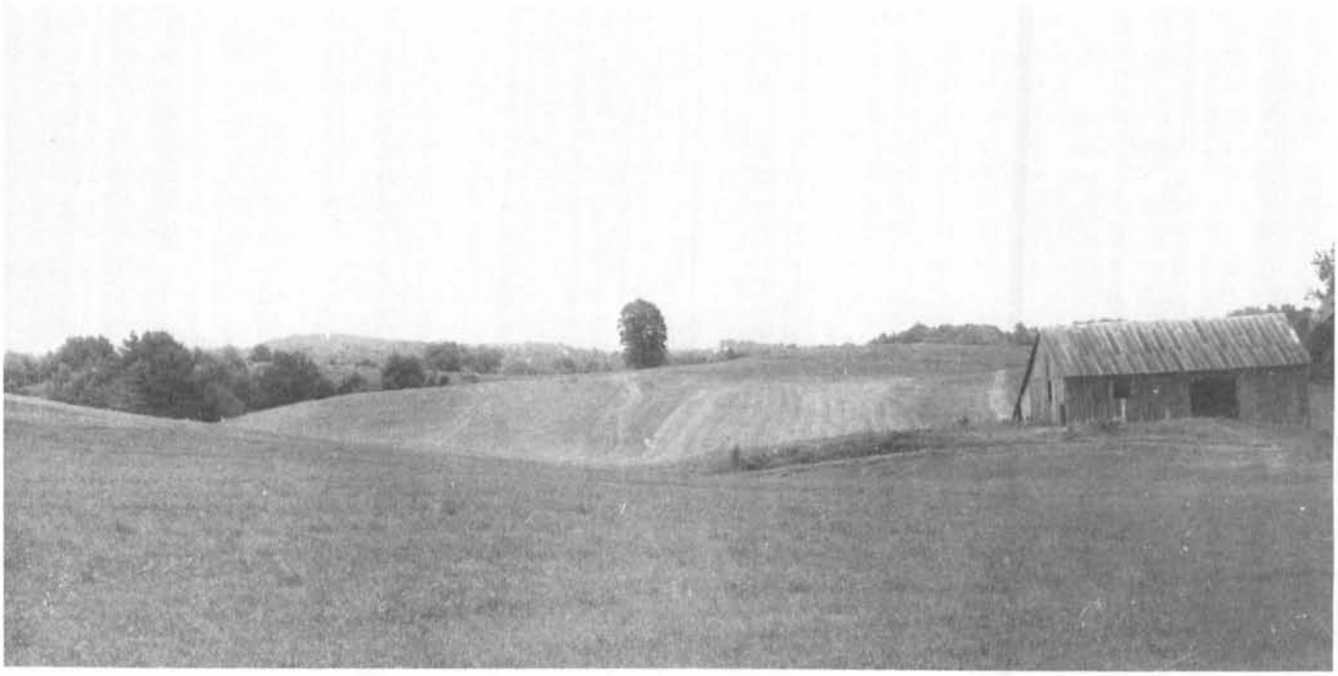

Figure 26. Kame and kettle topography of the Berkshire kame complex. Picture taken looking east, one mile south-southeast of West Berkshire.

Figure 27. Landfill in gravel of the Buck Hollow kame deposit. Five miles north of Fairfax.

amounted to about six pounds per person per day for a total of 250 million tons per year (U.S. Environmental Protection Agency, 1973). The population growth in most sections of the Milton-St. Albans region has not been great enough for the solid waste problem to be too severe. But, as the region develops, the problem will grow and present solid waste disposal practices will be inadequate and unsatisfactory.

The major problems related to the disposal of solid waste, other than the cost of collecting and disposing of such large volumes of waste, result from the fact that water passing through a dump or landfill produces a contaminant called leachate. The leachate is liquid and contains a variety of biological and chemical pollutants that move downward and outward following the normal flow patterns of the subsurface water. Since the leachate is liquid, it is an effective transporting agent for the contaminants it contains. In the Milton-St. Albans region, solid waste disposal practices should concentrate on the lowering of the rate at which leachate is produced, prohibiting the leachate from entering the fractures in the bedrock, preventing the contamination of ground water in the unconsolidated sediments of the streams and buried valleys and in the kame areas that are potential sources of water, and preventing the leachate from entering surface streams. Most present practices in the region do not even consider these factors.

Since the production of leachate in a landfill is proportional to the amount of water that percolates through the landfill, the most acceptable practice is to dispose of the refuse in such a way as to prevent water from entering. The sources of water that might affect the production of leachate include precipitation, lateral movement through surficial material, and the water table. The second important consideration is the containing of the leachate produced so as to prevent it from moving downward to the water table or outward into the surrounding area. Thus, the most desirable method of disposal is the so-called sanitary landfill. To properly establish and maintain a landfill requires the selection of a suitable site, the compaction of the refuse and the use of a suitable cover material.

The surficial material in which a landfill site is located should have a relatively low permeability and sufficient thickness so that the bottom of the excavation will be well above bedrock and the water table. It has been fairly well established that a thickness of 30 to 50 feet of impermeable material above bedrock is a safe depth (Cartwright and Sherman, 1969; Hughes, Landon and Farvolden, 1971; Riccio and Hyde, 1971). Certain recent studies, Hughes,

Figure 28. Sand used as a cover for a landfill, one mile west of Highgate Falls.

Landon and Farvolden (1971) for example, have minimized the environmental effects of solid waste disposal and the necessity for a specified distance above bedrock and the water table. These studies, however, have been in regions of horizontal, non-crystalline bedrock with high-yield bedrock aquifers. The writer does not consider these findings to be applicable to Vermont where the water comes from crystalline, fractured rock or from shallow depth, unconsolidated sediment. To decrease the seepage of water, waste material should be compacted, covered daily and placed in compartments to prevent lateral movement of fluids. The cover material for the landfill also should be of low permeability to prevent water from entering the fill. When the site is completed, the surface should be sloped in a direction that will drain the water away from the site.

In the Milton-St. Albans region, most dumps and landfills do not conform to the methods described above. The most common site for a landfill is an abandoned sand or gravel pit. Landfills are located in abandoned pits in the Berkshire and Buck Hollow kame deposits described earlier as possible sources of water (Figure 27). Other landfills are located in pits in sand and gravel lake deposits. The kame deposits are of such high porosity and permeability that the movement of the leachate to the ground water below is unrestricted. Fortunately, there is usually silt and clay below lake sand and gravel that restricts downward movement but lateral movement can occur. Most of the sites located in lake sediment and some of those in kame gravel use sand to cover the fill that does not prevent water from entering (Figure 28). A sand cover, in addition to being permeable, is easily blown away by the wind and the refuse is exposed at the surface (Figure 29). Another common practice in the region is the disposal of only the household garbage, paper and small items in the landfill. The larger pieces such as stoves, refrigerators, automobile tires, etc., are piled up on the surface and not covered. This practice is acceptable only if the material is to be removed after a short time and sold for recycling. If the material remains on the surface for a period of time, a leachate will form because of the chemical action of the weather elements. In some places, the smaller refuse is burned and the larger items are merely pushed over the hill with a bulldozer (Figure 30). These practices are seemingly not in conflict with any state or local landfill regulations.

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 have been so designated chiefly on the basis of permeability and thickness of the unconsolidated sediment above bedrock without consideration of the possibilities for modification. The map is intended as a guide for use in the selection of landfill sites, but it does not assume that detailed study of each site will be unnecessary. As a general rule, the hydrologic conditions vary so much from one locality to the next that it is not possible to predict exact characteristics.

The sections legened green (g) on the map have till or silts and clays covering bedrock with thicknesses in excess of 30 feet. This is the thickness suggested by the Illinois Geological Survey (Cartwright and Sherman, 1969) as a minimum to assure the containing of the leachate, but the Geologic Survey of Alabama recommends a thickness of 50 feet (Riccio and Hyde, 1971). Till is probably the most desirable material for a landfill site inasmuch as it has low permeability and is generally not too difficult to excavate.

The yellow (y) areas on the map are sections with silt and clay or till of variable or unknown thickness. Much of this area is suitable for landfills, but it will be necessary to determine that the thickness is over 30 feet. In localities where the thickness is 20 to 30 feet, a landfill site may be developed with a minimum of modification. If the cover is less than 20 feet, modification is necessary to seal the walls and floor of the excavation to prevent the escape of the

Figure 29. Landfill site, one mile west of Highgate Center. Sand cover has blown away exposing the refuse.

Figure 30. Material not buried in landfill pushed over the valley wall of a tributary of the Browns River. Two miles south-southeast of Fairfax village.

leachate. In all of these cases, till or silt and clay should be used for cover.

The areas legened r-2 on the map have permeable sands and gravels at the surface. In some places the sand and gravel extend to bedrock, but in other localities silt and clay, or possibly till, underlie them. If the sands and gravels are the only material above bedrock, or if these permeable sediments are possible sources of water, the site is unsuitable for a landfill inasmuch as it is too difficult to seal the excavation. If till or silt and clay underlie the sand and gravel, and the underlying impermeable sediment is over 20 feet in thickness, the site may be used for landfill only if some kind of liner or seal is used to prevent the lateral migration of the leachate. In this case, an impermeable material, till for instance, must be used for cover. Development of a landfill that requires modification should have a detailed study of the site and professional advice in the selection and installation of a seal or liner.

The r-1 legend on the map locates swampy and other poorly drained areas. Many of these sections are in stream valleys where seasonal flooding is common. These areas cannot be used for landfill since it is impossible to prevent pollution of the surface water and the saturation of the landfill.

Sewage Disposal

The investigations for this report were not particularly concerned with municipal sewage disposal inasmuch as these installations are generally controlled by state and federal regulations. It is significant, however, to point out that, except for the city of St. Albans, there are no municipal sewage systems in the Milton-St. Albans region. Admittedly, the region is still mostly rural, but there are at least five villages with populations of over 1000. All of the sewage disposal in the region, except for St. Albans, to the writer's knowledge, is by individual septic tanks. For this reason, individual septic tanks are probably one of the most critical environmental problems in the region.

The septic tank with a leaching field is one of the most reliable sewage disposal systems for rural use. Rural, however, implies a sparse population with large distances between individual homes. But, the use of septic tanks in the Milton-St. Albans region concentrates the septic tanks in villages, housing subdivisions, in summer colonies along lakes, and in developments adjacent to ski slopes. These uses of septic tanks are by no means rural.

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

The function of the leaching field or seepage pit is to dispose of the liquid waste from the septic tank by allowing it to seep into a suitable geologic environment. A series of physical, chemical, and biological activities take place as the liquid from the leach line seeps into and through the surrounding unconsolidated soil and surficial material (Franks, 1971, p. 195-96). In leaching fields located in the biologically active soil zone of the soil mantle, organic matter is stabilized by soil bacteria, particulate matter is filtered out and certain ions are absorbed by the soil. If the seepage beds are located below the biologically active zone of the soil, as they often have to be in Vermont to get below the frost line, filtering and absorption are the chief factors and organic matter is degraded by anaerobic conditions (U.S. Environmental Protection Agency, 1973, p. 70-71).

In spite of the importance that has been placed on percolation tests as a measure of the suitability of the surface material for septic tanks, recent studies have shown that the texture of the unconsolidated material in which the leaching field is located is more important than the permeability (Romero, 1970, p. 44). The permeability of coarse-grained material may be too high. The U.S. Environmental Protection Agency (1973, p. 76) suggests that the approval of competent soil scientists and engineers should eliminate the need for percolation tests inasmuch as they maintain the simple percolation test and standard codes are inadequate criteria. Other studies have shown that bacterial pollutants are removed more effectively in unsaturated surficial material than in saturated and that the flow of contaminants in liquid waste is always in the direction of the natural ground water flow (Franks, 1972, p. 202-03). Therefore, the location of a septic tank system should consider, in addition to the permeability, the nature of the unconsolidated material in contact with the leach lines, the distance of travel of the effluent through unsaturated sediment, and the direction of flow from the system.

Equally important to the proper operation of a septic tank is the slope of the surface in which the system is located. Unfortunately, it is impossible to take the slope into account when constructing the planning maps inasmuch as the size of the plot of land necessary for a leaching field is too small to show on a map of that scale. Slopes also change too rapidly to be included on a generalized map. Since a large number of new homes in the region are located on hillsides, the effect of the slope is an important factor. Septic tank installations on hillside locations are difficult because the surficial material above bedrock is usually thin and fractured bedrock lies just below the unconsolidated cover. Recent studies have shown that the movement of liquid waste is not parallel to the slope, and that the flow of the effluent is eventually toward the surface.

The most hazardous result of septic tank operation in mountainous terrain is the pollution of the water supply. Most homesites in these locations must have both a water supply and a sewage disposal system, and the lot size is commonly less than one-half an acre. Because the cover over the bedrock is usually thin, the effluent from the leaching field reaches the fractures in the bedrock after a short flow. Liquids passing through fractures, as has already been noted, 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).

Another environmental problem associated with the operation of a septic tank on a hillside slope concerns the inevitable surfacing of the effluent a short distance downslope from the leaching field or seepage pit. Federal regulations require at least six feet of unconsolidated sediment below the leaching field, but a more reliable practice is in accordance with the standard plumbing code that specifies a fifteen-foot horizontal distance between the bottom of the leaching field and the ground surface. According to Franks (1972, p. 201), experience has shown that the effluent will probably surface downslope from the system if the surface exceeds 20% regardless of the type of surficial material or the depth of burial. When the effluent comes to the surface, in addition to being odoriferous and unsanitary, the fluid will flow downslope to enter the nearest surface drainage. The liquid coming to the surface also saturates the surficial material causing it to creep, slide and flow downhill. These data strongly suggest that regulations should limit the angle of the slope on which a septic tank with leaching field, seepage pit or dry well can be constructed.

A mechanical or aerobic septic tank is often recommended for use in difficult areas. The mechanical tank has an electrical motor that is either used to inject air into the tank or to turn a stirring mechanism. The major difference between the action of a mechanical tank and a regular septic tank is that the addition of oxygen either by air injection or stirring creates aerobic conditions in the mechanical tank. This causes a more complete treatment of the sewage. Some mechanical systems are said to perform as well as a primary or secondary sewage treatment plant and others claim that the effluent from a mechanical tank is purified enough to flow into surface water. Statistics, however, do not prove that purification is that complete or that the harmful bacteria count has been so reduced. A leaching field is therefore necessary to distribute the waste from a mechanical tank to assure the removal of harmful bacteria and virus (Goldstein, 1972, p. 39-40).

In areas where the surface material is not suitable for the effective operation of a leaching field or where the slope is too steep, it is sometimes possible to build a holding tank for the effluent. The liquid wastes are stored in the holding tank and periodically transported by truck to a sewage system. This method is probably not feasible for a permanent family dwelling, but it could be used for seasonal homes such as the summer camps along lake shores or winter lodges near ski slopes.

The septic tank conditions map (Plate V) describes the characteristics of the surficial material as they relate to the disposal of domestic sewage, particularly septic tanks with leaching fields. This report does not believe the use of dry wells and seepage pits should be approved for use in the region. The wide use of yellow and red on the septic tank map as compared to small patches of green, suggests at a glance that there are few localities that do not have some limitations for septic tank use. The green areas on the map are sections where the till is known to have sufficient thickness and a sand content that should make the permeability high enough to transmit the liquid from the leaching field. Seepage pits and dry wells are definitely not recommended in till areas since these methods concentrate the effluent in a smaller area and must be placed at a greater depth where the till is compact.

Most till areas are designated y-1 on the septic tank map. The use of septic tanks in these localities is dependent on the permeability of the till, the thickness of the till above bedrock and the slope of the land. For most efficient operations, there should be 10 to 12 feet of till above bedrock, the slope of the surface should be less than 20%, and at least 200 feet of leach line should be used to distribute the effluent.

Areas legened y-2 on the map have permeable sands and gravels at the surface. As has already been noted, some of these materials are too permeable and too coarse grained to be used for leaching fields. The thickness of the deposit, the depth to bedrock, the depth to the water table, and the kind of sediment below the sand and gravel are factors that must be considered when planning sewage systems in these areas. Many of the areas designated y-2 are lake and marine sands and gravels that commonly have silts and clays below. In these cases, the finer sediment below the sand and gravel will retard the downward percolation of the effluent, if lateral movement is possible without the contamination of the adjacent area.

The areas designated r-1 are low, poorly drained stream bottoms covered with alluvium that may contain swamps. Isolated swamps are also included in this class. The surface material is poorly drained, often wet, frequently flooded, and the permeability is generally low. Under these conditions, septic tanks would operate only in the dry season.

Areas with considerable thicknesses of lake and marine silts and clays are legened r-2 on the map. These areas are so designated because of the extremely low permeability of the silts and clays. Septic tanks as they are normally installed, cannot function in these areas because the liquid wastes cannot seep into the surrounding material. Instead, the effluent builds up in the trenches of the leach lines and eventually comes to the surface. The mechanical tank with a 200-foot leach line might alleviate some of the problems. Leach line trenches could be three feet wide with two feet of gravel fill instead of the normal width and depth. The holding tank might be the most efficient way to dispose of the waste since treatment of the sewage in a mechanical septic tank is more complete. Under normal circumstances, septic tanks should not be permitted in these sections.

FOUNDATION MATERIAL

Foundation and building conditions in the Milton-St. Albans region are not as critical as the environmental problems already discussed. The mountainous terrain in the eastern part of the region includes many sections that are too steep and too rugged for construction but, generally speaking, limitations are not severe. The criteria for judging the desirability of a site for construction include such geologic considerations as the slope of the land, the internal drainage of the surficial material, the plasticity of the surface material, and the strength. In the region of this study, special planning and some limitations are necessary because of the flooding and low strength of the alluvial sediment on stream floodplains, the steep slopes in the mountains, the composition and slope of the valley walls, the plasticity of the clay, and the poor drainage in some sections (Plate V).

The floodplains (bottomlands) of most streams are covered with 5 feet to 25 feet of stream-deposited, fine-textured sediment called alluvium. The alluvium is the most undesirable foundation material in the region inasmuch as its strength is usually too low to support heavy construction. The material is poorly drained and the surface of the floodplain is frequently flooded. The flood of July, 1973, to be discussed later in this report, gives ample proof of the damage done to construction on the valley floor. If the bottomlands are to be used for heavy construction in spite of the flooding, the total thickness of the alluvium should be removed and special drainage provided.

Sand and gravel deposits are favorable construction sites since they are well drained and have adequate strength for heavy construction. The economic value of some of these deposits, however, should be given consideration when such areas are zoned for future use. Good quality gravel reserves should be set aside for use as gravel before construction. The economics of good gravel reserves is particularly important in the Milton-St. Albans region since good gravel deposits are quite limited. After sand and gravel has been removed, most locations still make good construction sites with a minimum of grading and filling. The practice of abandoning gravel and sand pits without reclamation, or using them for some kind of a refuse dump, is indeed poor planning. These are choice sites for construction. Lacustrine and marine sands and gravels that overlie silts and clays require special study since the plasticity of the clay may be too high and slumping, sliding, and even flowage may occur. In these cases, the physical properties of the sediment underlying the sand and gravel must be determined.

Lake and marine clays are often subject to flow inasmuch as they have a high plasticity. In the Milton-St. Albans region, lake clay covers the bedrock in the lower sections of the Champlain Lowland and fills several sections of the stream valleys in the Green Mountains (Plate I). The internal drainage of the clay is quite low and this property makes it necessary to include drainage provisions in all building specifications. Steep slopes in areas of predominantly clay surficial material, particularly the walls of stream valleys, should be avoided to assure that flows and/or slides do not undermine foundations. It is also advisable to refrain from using areas adjacent to such slopes since damage caused by slides can be disastrous. Tests to determine the bearing strength of the surficial clay as well as tests for plasticity are recommended for each site to be used for heavy construction.

The general constructions map (Plate VI) classifies the surface material according to its suitability for foundations. The areas shown in green (g) are predominantly sand and gravel deposits. These include lake and marine sands and gravels that may overlie lake and/or marine silts and clays. As already noted, investigations should be made to ascertain the depth of the sand and/or gravel and the thickness and type of sediment underlying it. The sections designated y-1 have a surficial material composed predominantly of lake and marine silts and clays. These are often poorly drained and, as stated above, the plasticity of the clay often causes problems, particularly in areas of steep slopes. Till sections are legened y-2 on the map and the suitability of a site in these areas is dependent upon the thickness of the till. Since the thickness of the till varies greatly from place to place, building conditions also vary. In most uplands, the till is thin and excavation of the underlying bedrock is often necessary. The bedrock, however, is usually fractured and weathered so that excavation is not too difficult. The stream bottomland that is covered by alluvium is designated r-2 on the map. As described above, this is poor foundation material and must be removed. Poorly drained, swampy areas are marked r-1 on the map and these are unsuitable for any kind of construction.

GEOLOGIC HAZARDS

The term geologic hazard refers to a variety of destructive, natural phenomena that are directly related to geologic materials and geologic processes. Man has been unsuccessful, as a general rule, in his efforts to control or regulate these activities, but they should definitely be carefully considered when planning for land use. Many of man's activities tend to increase the frequency of occurrence and the amount of damage done by some of these phenomena. These hazards include volcanic eruptions that do not occur in Vermont, earthquakes and hurricanes that occasionally occur with minimum effect, and landslides, flash floods and river flooding that are potential problems in the Milton-St. Albans region. Careful planning can facilitate the selective location of industrial installations, municipal facilities, and housing development where the damage from these hazards is minimal.

Landslides

Lacustrine and marine clays, as noted earlier, are quite plastic and become slippery when wet. For this reason, landslides are always a potential threat along steep slopes composed of clay. Quick clay is the name applied to a particular kind of clay that may be converted to a viscous liquid and therefore subject to spontaneous flow. As an example, it was the instantaneous liquification of quick clay that caused the damaging landslides during the earthquake in Alaska. 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 mostly in the St. Lawrence River valley but they do report that quick clay has been identified in Vermont. It has also been established that quick clay is formed in fresh water lakes and some of the lake clay in the Milton-St. Albans region may be of this type. At this writing, little is known about specific properties of the clays in Vermont, and until such a time as more conclusive research has been completed, the potential effect in the region cannot be evaluated.

From the planning point of view, steep clay slopes should be avoided for any kind of development. Extreme care should be taken to avoid construction above and below slopes to prevent damage in the event sliding does occur. Valley walls composed of clay are particularly vulnerable since the lateral erosion by the stream is continually changing the character of the slope.

Flash Floods

Flash floods are common in the Milton-St. Albans region, particularly in the Green Mountains. The streams that flood from the mountains, however, are tributaries of the major streams that drain the region. As a result, flash flooding in mountainous sections results in general flooding of the trunk lines. There is much bedrock exposed at the surface in the higher parts of the mountains and most of the water that falls as rain runs off instead of sinking into the ground. During periods of torrential rain, therefore, the water runs down the slopes at high velocities and eventually swells the flow of the headwater streams. The mountain streams that are swollen by flash flooding flow into the main drainage of the lowland. The larger streams are then flooded in a very short period of time. In the region of this report, most of the drainage is into Lake Champlain which, in turn, is subject to high water.

A case in point was the flood of early July 1973, when the state experienced flooding that was reportedly the most damaging since the flood of 1927. The rainfall in June had been the second largest on record with 7.69 inches measured for that month, 4.20 inches above average. Rainfall on Mt. Mansfield was 12.32 inches during the same period. Records at the Champlain Transportation Company show that the level of Lake Champlain stood 3 1/2 to 4 inches above a mean level of 95 feet above sea level throughout the month. The soil and rock mantle were therefore saturated prior to the first of July.

Heavy rainfall in central and southern Vermont on June 29 and 30 and into July 1 was caused, according to the National Weather Service, by the approach of a north-south trending weather front. The slow moving, moisture laden front 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 was greatest in southern and central Vermont and diminished gradually to the north. The rainfall on the headwaters of the Winooski, Lamoille and Missisquoi rivers was therefore much less than along tributaries of Otter Creek and the Connecticut River south of the White River. Whereas Rutland, for example, recorded 4.32 inches of rainfall, Burlington had 2.35 inches and 2 to 3 inches fell in Montpelier, Marshfield, West Danville, Waterbury and Newport (The Burlington Free Press, July 3, 1973).

The runoff from these rains was very rapid for three reasons. In the first place, as explained above, the soil and rock mantle were already soaked with water by the high rainfall during the month of June and more water could not be absorbed. Secondly, the bedrock surface of the high parts of the Green Mountains is usually barren of sediment and it can only absorb water into the fractures. This is a slow process and most rain that falls on these surfaces runs off before it can sink into the ground even during drier periods. A third factor is the slope. Regardless of the surface, runoff is always high on steep slopes and steep slopes are very common in the Green Mountains. As a result of these conditions, the runoff from the rains of June 29 and 30 and July 1 was extremely rapid and headwater streams in the mountains were swollen in a short time, resulting in widespread flash flooding. The mountain streams flow into a few major trunk lines that eventually empty into Lake Champlain or the Connecticut River. The major drainage lines were flooded which, in turn, flooded the Connecticut River and the level of Lake Champlain rose .65 inches between June 29 and July 3.

In the Milton-St. Albans region, and the area immediately south of it, most of the flooding was along the Winooski and Lamoille rivers since the headwaters of the Missisquoi River crested one and one-half feet above flood stage at Montpelier. The river overflowed its banks at both Barre and Montpelier but there was little damage. To the west, however, the tributary streams draining the Green Mountains, the Mad, Huntington and Waterbury rivers, dumped large quantities of water into the Winooski and at Essex Junction the river crested six feet two inches higher than the top of the Green Mountain Power Company dam, the highest level in twelve years. Farmlands along the river were flooded in all low places between Richmond and Lake Champlain and the floodplain in the western part of Colchester was completely inundated with water (Figure 31). Fortunately, little damage was done in the city of Winooski (Figures 32 and 33).

The Lamoille River overflowed its banks in most low sections downstream from Hardwick. Bridges were washed out, railroad tracks were undercut, and the foundation of a motel in Hardwick was washed away. Agricultural land was extensively damaged, particularly in the Johnson-Jeffersonville-Cambridge stretch of the valley. Crops were washed out, hay fields were inundated, fields were covered with silt, banks were eroded and farm buildings were destroyed (Figures 34 and 35). In the Milton area, there was considerable damage to personal property.

Because of the great amount of damage, the state was declared a disaster area by the President of the United States. Estimating the total damage was very difficult, but efforts were made by several agencies, both state and federal. Nonagricultural damage was estimated to be approximately 47 million dollars. About 19 million dollars was estimated for the

Figure 31. The Winooski River valley inundated by flood waters on July 1, 1973. Picture taken looking west from State Route 127, one mile north of Winooski.

Figure 32. The Winooski River in flood stage on July 1, 1973. Picture taken looking upstream from the bridge at Winooski.

Figure 33. The Winooski River level at normal flow. Same location as Figure 32 but taken six weeks after the flood.

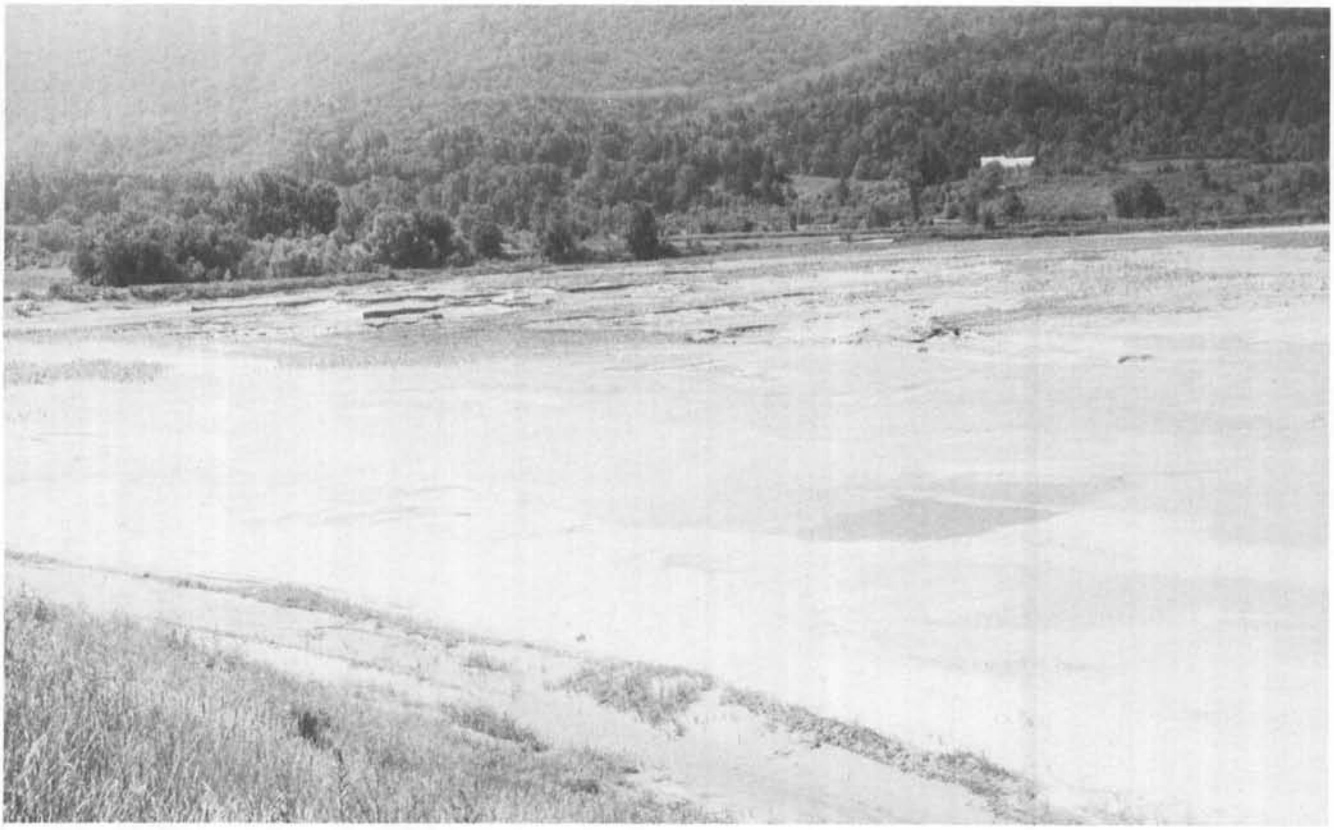

Figure 34. Bottomland along the Lamoille River covered with silt and sand by the flooding of the river. Four miles east-northeast of Jeffersonville.

Figure 35. Erosion along the Lamoille River. Across the river from Cambridge village.

damage to government-owned property such as roads, bridges, water and sewer facilities and public buildings. Damage to homes was estimated at about 15 million and business and industry 13 million. The farm-agricultural loss is more difficult to estimate inasmuch as damage to crop and farm land is not known for some time after the flood. It was estimated, however, that the damage that could be seen three weeks after the flood amounted to 15 million dollars. This included crops, erosion damage and farm buildings. The amount of soil washed away or the ultimate effect of the sediment covering much of the bottomlands could not be determined (The Burlington Free Press, July 6 and July 25, 1973).

Flood control is a problem that has been studied in all areas where flood loss is a threat. There are several geological implications to the flood control problems, but a solution 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. It is readily apparent that floods cannot be eliminated since it is the natural surroundings that account for the rapid runoff. The only two practices that would tend to decrease flood damage are the holding back of the runoff or the controlling of use of the stream floodplains.

Experience shows that the most effective way to control runoff is to construct flood control dams that hold back the water in stream basins. The dams already constructed attest to the fact that they diminish the flooding downstream from the dam. Flooding would have been much more severe during the 1973 flood had it not been for flood-control dams on tributary streams of the Connecticut and Winooski rivers. Flood-control dams are costly to construct, however, and they are usually planned, built and maintained by federal agencies. Recently, there has been criticism of the dams because of their influence on the ecology of the valley.

A second method for holding back the runoff is the planting of forests on watersheds of stream systems. Several problems prevent this practice in most regions. In the first place, most watersheds are composed of privately-owned land and legislatures do not pass laws that control the use of private land. Secondly, the initial cost of reforestation is almost prohibitive without government subsidy. In Vermont, many of the most critical regions do not have enough cover over the bedrock to support the growth of trees. The time involved in reestablishing the forests is also a factor.

The best method for decreasing damage from floods, particularly in regions such as Vermont where other practices are impractical, is a detailed plan for floodplain management. This report agrees with a statement made by Vermont's Governor Salmon that "instead of trying to keep the rivers away from man, we ought to be keeping man away from rivers" (The Burlington Free Press, July 7, 1973). There was a time when the location of villages and cities along streams and on stream floodplains was necessary because of water power and the routes of transportation. This is not the case at the present, however, and better use of the stream valleys should be encouraged. The best farm land in Vermont is in the stream valleys and these valuable bottomlands should be reserved for that purpose. There is of course, damage to crops and land during flood. But, the greatest losses from flooding are to private, municipal, business, and industrial buildings in the valley. The location of the interstate highway is an example because it was nowhere damaged by the flood because it was purposely located above flood level, even in the Winooski valley. Floodplain planning should discourage construction in the valleys below flood level. Actually, a floodplain zoning bill was introduced into the Vermont Legislature during the 1973 session but it was not enacted. The writer does not know the status of the bill at the present time.

GEOLOGIC RESOURCES

Although Dennis (1964, Plate I) reported ancient copper prospects in the Town of Berkshire and iron in the vicinity of Sheldon village, there are no known metallic mineral deposits in the St. Albans-Milton region of economic importance. Instead, the valuable geologic resources are the carbonate bedrock of the Champlain Lowland and the sand and gravel deposits scattered throughout the region. The demand for sand and gravel will increase as the development of the region progresses, but the utilization of limestone and dolomite marble for uses other than crushed stone has been declining in recent years. The carbonate rock, however, has a good potential as an industrial raw material if and when it is needed.

Sand and Gravel

Sand and gravel deposits are distributed over the Milton-St. Albans region but the quality of the deposits varies greatly from place to place. The sand and gravel map prepared during this survey (Plate VII) classifies the deposits as to their quality and reserve. There is no sand and gravel in the region that meets standard classifications for cement and therefore the highest rank is classified as good. Although many of the deposits could not be definitely classified because there were no pits in them, it is believed that there is an adequate reserve of both sand and gravel for the foreseeable future. The locations of the deposits with highest quality and greatest reserve are not, however, in the areas of the greatest demand at the present time. Local environmental policy and public sentiment have actually prevented the development of some sand and gravel deposits and, as a result, gravel is transported into regions of adequate supply. In an effort to keep the land unspoiled, the general policy has been to discourage the opening and operating of sand and gravel pits. Local residents object to the unsightly appearance of the sand and gravel pits, the dust, the trucks, danger to children, and other factors that are not serious environmental problems. Residents of the Town of Essex, for example, recently objected to the opening of a gravel pit on these grounds. Gravel from outside the town would cost over twice as much because of the long haul (The Burlington Free Press, September 20, 1973). These practices increase the cost of construction, particularly roads, since the sand and gravel must be obtained from distant sources. This report questions the soundness of such policies that seem to restrict the visible and ignore the unseen. The unsightly appearance of sand or gravel pits and the pollution from the dust it generates, are two of the least important environmental problems in the region. Sound environmental policy promotes the wise use of these resources.

The largest reserves of good quality gravel in the Milton-St. Albans region are in the Berkshire kame area described earlier in this report. The deposit extends northward from State Route 105, two miles east-northeast of Enosburg Falls, to the vicinity of Berkshire village and then north-northwest to West Berkshire. A part of this kame complex is covered with lake sand and the exact areal extent of the gravel below the sand is not known, but that portion of the deposit that is not covered has a large reserve of gravel. This deposit, located as it is in the extreme northeastern corner of the region should be reserved for the future, and regulations should be enacted to prohibit other types of development, housing for example, until the gravel has been removed. There is a considerable amount of sand associated with the kames, particularly in the low areas, and a part of this reserve is good quality sand (Plate VII).

In the vicinity of Bakersfield, there are a few kame deposits of known quality and others of unknown quality (Plate VII). Undoubtedly there is a large reserve of gravel in that section. The demand for gravel has not been great enough to stimulate the development of the gravel and therefore evaluation of some of the deposits was impossible.

The gravel deposit on the west side of Fairfield Pond has a large reserve of good quality gravel. There has been much gravel removed from this locality since it is near the Champlain Lowland where there is a need for the gravel. The northern part of the deposit has been worked out but slightly more than half of the original reserve still remains in the southern three-fourths of the area. The rate at which the gravel is being used will probably exhaust the supply in the next five to eight years.

A moderate amount of good quality gravel occurs along the eastern slope of Mt. Mansfield near the base of the mountain (Plate VII). There has been so much development in this area because of the ski slopes, however, that much of the gravel is no longer available. This demonstrates the need for planning so that development will not occur on valuable deposits until after the gravel has been removed.

The Buck Hollow kame area has a large reserve of sediment composed of about equal amounts of sand and gravel. This report ranks the importance of the Buck Hollow kame area second only to the Berkshire kame area. Like the Berkshire gravel, the Buck Hollow deposit should be reserved until after all of the gravel has been removed.

A small sand and gravel deposit north of Underhill Center is also believed to have a moderate reserve of good sand and gravel. Several sand and gravel deposits of unknown quality and reserve that occur between Underhill and Underhill Center and those east of Underhill Center should be studied to determine the availability and quality of the deposit.

Sand is in good supply in the Milton-St. Albans region. Most of the surficial lake sediment in the region is composed of sand and, although the deposit invariably grades into silt and clay at depth, a large quantity of good sand is available. This includes the sand deposits north of the Winooski River in Colchester, the deposits along the Lamoille River between Cambridge and Fairfax, the present and former course of the Lamoille River in the vicinity of Milton, and the sand deposits along the Missisquoi River between Sheldon Springs and Swanton (Plate VII).

Crushed Stone

There are two quarries operating in the Milton-St. Albans region that produce crushed stone. One of these, located in Winooski, produces only crushed stone. The second quarry, in operation in Swanton since 1847, manufactures other products in addition to crushed stone. Actually, most of the bedrock of the Champlain Lowland, with the exception of shale and slate, could be used for crushed stone. An abandoned quarry in Milton village, for example, produces crushed stone when needed. Most of the rocks of the Green Mountains, however, are not suitable for crushed stone because they contain too much mica, and similar minerals, that are too soft for road base, foundations, or even driveways.

Figure 36. Quarry in dark colored limestone marble. One and one-half miles southeast of the village of Isle La Motte.

Figure 37. Oil-gas drilling rig. Three miles northwest of the city of St. Albans.

Lime and Chemical Products

The stone quarry at Swanton produces, in addition to crushed stone, lime and limestone for the chemical industry. Former use of the rock in certain areas suggests that there is other rock in the region that is pure enough for similar uses.

The old Fonda Quarry, one mile south of Swanton Junction, at one time produced limestone for chemical uses and for burned lime. This quarry has not operated since 1908. There was also a large lime plant just east of Highgate Springs that operated for many years. The limestone for this operation came from a quarry one mile east of the village. These statistics emphasize the quality of the limestone and dolomite marble of the Champlain Lowland. There is a large reserve of carbonate rock in the region that is of high enough quality for use as agricultural lime or as a raw material for the chemical industry should there ever be a demand.

Dimension Stone

The only quarry where dimension stone is presently produced is on Isle La Motte, one and one-half miles southeast of the village of Isle La Motte (Figure 36). The rock at this location, commonly called Isle La Motte, or Radio City marble, is quarried periodically by the Vermont Marble Company. The same rock has been recently quarried at two other localities in the southern part of the island. Dolomite marble was formerly quarried for dimension stone from an old quarry located one and one-half miles south-southeast of Swanton.

Natural Gas

There is one oil and/or gas drilling derrick located in St. Albans Township three miles northwest of the city of St. Albans (Figure 37). Drilling at this location has occurred periodically for several years. In 1960, there was similar exploratory drilling on the south side of Malletts Bay just east of the Colchester Town Park. Reportedly, there have been indications of gas in these drillings, and although the volume was small an analysis shows a high percentage of methane gas. There has been much debate about the possibility of gas in the region, but no extensive exploration program has been initiated and all of the drilling to date has been financed by local and out-of-state interests.

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APPENDIX A –

MAPS SHOWING LOCATIONS OF SEISMIC PROFILES .

ENOSBURG FALLS QUADRANGLE

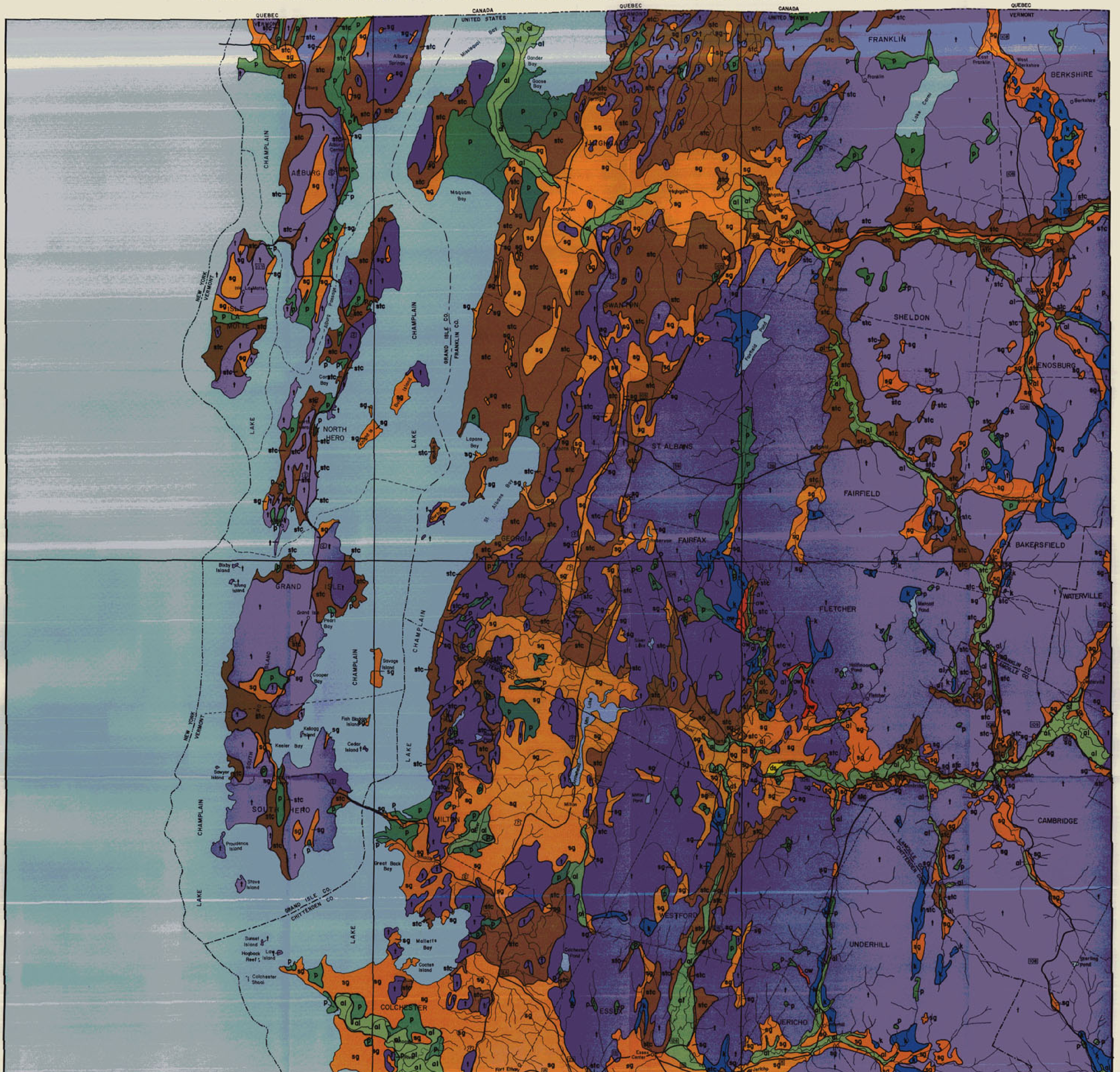

ST. ALBANS QUADRANGLE
Figure 19
CANADA
BAY
Shad I
Metcalfe I
Gander Bay
Martindale Pt
Goose Bay
Wagner I
Limekiln Pt
Phelps Bay
Rock River Bay
Rock River School
Proper Pond
North Gore School
Cutler Pond
South Gore School
Highgate Springs
H I G H G A T E
W
E
Dead Creek
Youngman
Saxe Brook
Carman Brook
Rock River
VERMONT
CENTRAL
MISSISQUOI
Cr
Carter Hill
LAKE CHAMPLAIN
AND
ST JOHNSBURY
Highgate Center
Highgate Falls
Highgate
Kelly Brook
RIVER
Swanton
Maquam
Webster School
S H E L D O N
Skeels Corners
School No 8
S W A N T O N
School No 7
Swanton Junction
Hungerford Brook
FONDA QUARRY
School No 2
Greens Corners
VALLEY
BRANCH
School No 10


ENOSBURG FALLS QUADRANGLE
Figure 20
LINE 2
LINE 1
E
W
S H E L D O N
F A I R F I E L D
Sheldon Junction
East Sheldon
Sheldon
Sheldon Hill
Waite Cem
Callan School
St Rocks
Pumpkin Village School
Leach Cem
Diamond Cem
Harrick School
Fairfield Station
Fairfield Pond
Fairfield
Creek School
Fox Hill
East Fairfield
School No 6
Bradley Cem
Gravel Pit
Soule School
Fairview Cem
Lapland Sch
Pine Hill
Leach Hill
ST ALBANS
Black Creek
Dead Creek
Goodsell Brook
Brook
Fairfield River
Elm Brook
Creek
LAKE CHAMPLAIN
ST JOHNSBURY AND
MISSISQUOI
CENTRAL VERMONT
SWANTON
L E T C H E R


MOUNT MANSFIELD QUADRANGLE
Fletcher
Mountain
East Fletcher
FRANKLIN CO
LAMOILLE CO
Taylor Brook
Armstrong Mountain
Oak Hill
Church Hill
North Cambridge
Waterville
Smiley Sch
Fletcher
Parsons Sch
Ellenwood Hill
Bald Hill
Black Hill
Bartlett Hill
Warner Hill
North Branch
RIVER
LAMOILLE
ST JOHNSBURY AN
LINE 1
LINE 2
East Cambridge Cem
River View Sch
Cambridge
Jeffersonville
Cambridge Junction
ABANDONED RR
Falls
JOHNSON
C A M B R I D G E
Brewster River
Putnam Hill
Seymour River
Buker Hill
LAMOILLE CO
CHITTENDEN CO
South Cambridge
Warner Hill
Brook
Pleasant Valley
Settlement
Morses Mill
Irish Settlement Sch
Morse Mou
Figure 21


MOUNT MANSFIELD QUADRANGLE
Figure 22
LINE 1
LINE 2
LINE 3
LINE 4
N
S
Cambridge
River View Sch
Fairfax Falls
LAMOILLE
RIVER
FRANKLIN CO
CHITTENDEN CO
Westford Plains Cem
Oak Hill
Putnam Hill
Brook
Morgan
North Underhill Cem
Westford Sch
Number Eleven Hill
Buker Hill
LAMOILLE CO
CHITTENDEN CO
Cloverdale
Morgan Hill
W E S T F O R D
Duffy Hill
Pleasant Valley
Settlement
Seymour
River
Brook
North Underhill
Irish Settlement Sch
Cem
Stewart Hill
McLean Hill
Creek Sch
Metcalf Hill
MACOMBER MOUNTAIN
Jack Lot Hill
U N D E R H I L L
Flynn Hill
Governors Right Sch
The Creek
Roaring Brook
English Settlement Sch
E S S E X
Cap Hill
Hedgehog Hill
Harvey Sch
Figure 23
Underhill
J E R I C H O
Riverside
Browns
Figure 24
River
Camp Mansfield
Stevensville Brook
Underhill Center
South Hill
Clay
Stevensville
Jericho
Halfway House
C A M

SURFICIAL MATERIAL OF THE MILTON-ST. ALBANS 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 and Marine Sands and Gravels - Marine deposits only along Lake Champlain. 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 and Marine Clays and Silts - Marine sediment only bordering Lake Champlain. Poorly drained. Medium to high plasticity.

p

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

al

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

ds

Dune Sand.

Scale

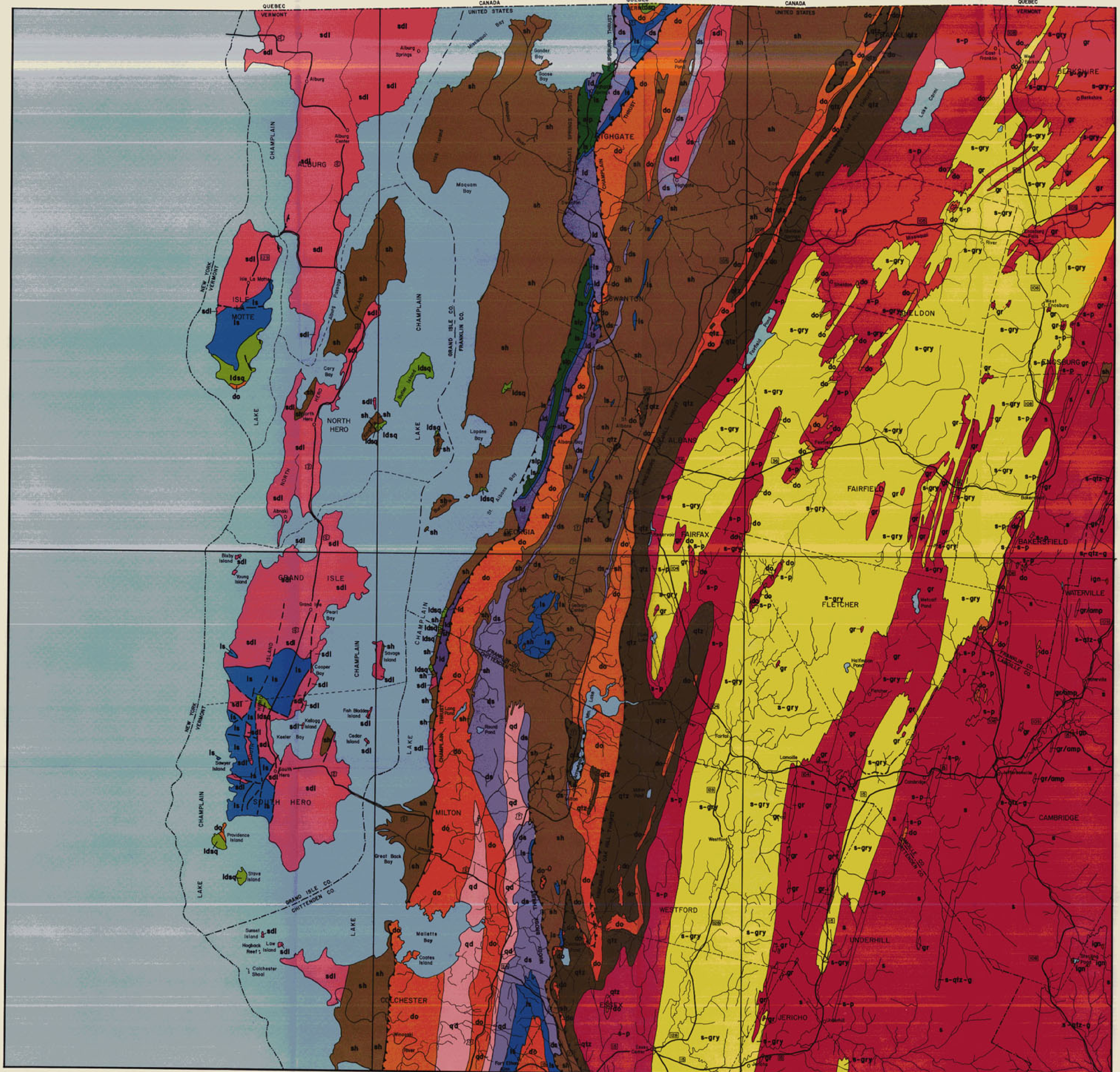
1 1/2 0 1 2
miles

true north

Geologic interpretation by David P. Stewart

Vermont Geological Survey
Charles G. Doll, State Geologist
Published 1974

BEDROCK OF THE MILTON-ST. ALBANS REGION Plate II



LEGEND

CHAMPLAIN LOWLAND

qtz

Quartzite. Very resistant to both physical and chemical weathering and erosion. Forms most of the high relief on the Champlain Lowland. Medium to fine texture, massive, usually fractured.

ls

Limestone (Marble). Medium coarse grained in the southern portion, fine grained in the north. Quite susceptible to chemical weathering and erosion. Fractures generally enlarged by solution weathering. Moderately resistant to physical weathering.

do

Dolomite (Marble). Less susceptible to chemical weathering than limestone, but solution weathering active along fractures. More resistant to physical weathering and erosion than limestone.

sh

Shale (Slate). Resistant to chemical weathering. Susceptible to physical weathering and erosion. Generally highly fractured.

ds

Dolomite and Sandstone. Sandy dolomite and dolomite conglomerate with interbeds of sandstone. Sand content increases resistance to erosion.

ld

Limestone and Dolomite. Occasional interbedded shale. Solution weathering along fractures.

qd

Quartzite and Dolomite. Quartzite with occasional relatively thick dolomite layers or alternating layers of quartzite and dolomite of about equal thickness. Includes some massive quartzite in southwest corner of map. Generally resistant to both physical and chemical weathering and erosion.

sdl

Interbedded Slate, Dolomite, Sandstone, Limestone, and Shale. Resistance to weathering varies with content of sandstone and slate.

slp

Undifferentiated Slate, Limestone, and Phyllite. Usually fractured, moderately resistant to erosion.

ldsq

Interbedded Limestone, Dolomite, Sandstone, and Quartzite. Generally resistant to erosion.

ign

Light and dark colored plutonic igneous rock.

GREEN MOUNTAINS

s-gry

Schistose Greywacke. Complex, light to dark grey color, highly metamorphosed, sandy. Generally resistant to erosion, but dark minerals susceptible to chemical weathering.

Complex, highly metamorphosed rocks of the Green Mountains consisting primarily of Phyllites, Gneisses, Schists with varying amounts of Greenstones and Amphibolites. Highly fractured.

- g - gneiss
- s - schist
- p - phyllite
- p/s - undifferentiated phyllites and schists
- s-qtz - schists with interbedded quartzite
- gr/am - undifferentiated greenstones and amphibolites
- s/gn-qtz - undifferentiated schists and gneisses with interbedded quartzite
- p/s-qtz - undifferentiated phyllites and schists with interbedded quartzite

▼▼▼▼ ▼ ▼ Thrust fault. Dashed when inferred. Sawteeth on upper plate.

— — ——— Normal fault. Dashed when inferred.

┬┬┬ ┬ ┬ Reverse fault. Dashed when inferred.

Scale

1 1/2 0 1 2

miles

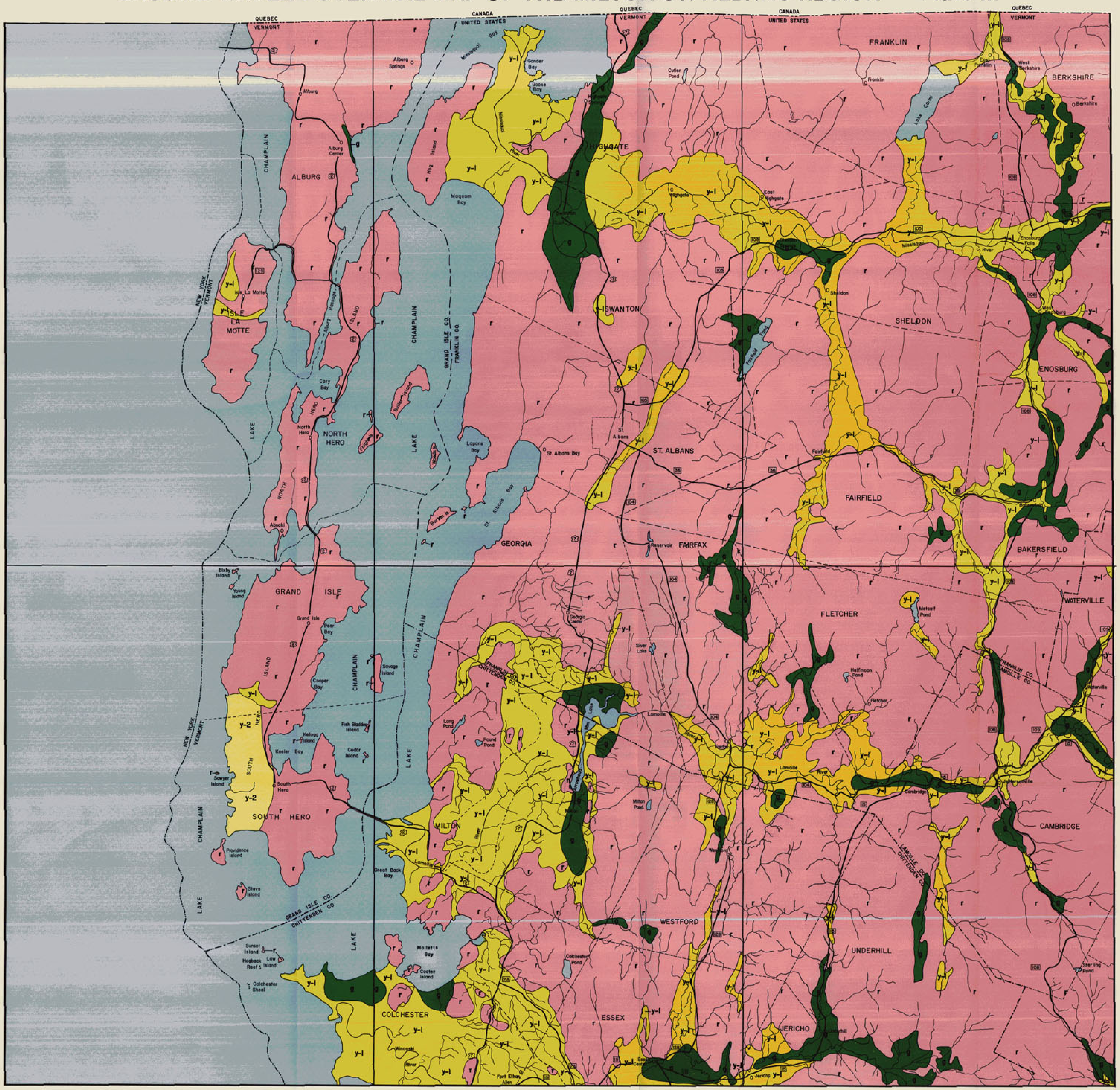
true north

Modified from the Centennial Geologic Map of Vermont (1961) by D.P. Stewart
Vermont Geological Survey
Environmental Geology No. 5

Geologic interpretation by David P. Stewart

Vermont Geological Survey
Charles G. Doll, State Geologist
Published 1974

GROUND WATER POTENTIAL MAP OF THE MILTON-ST. ALBANS 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-l

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.

y-2

Areas of low to moderate ground water potential. Water available from fractures in the rock in zones of complex faulting. No statistical data available in these areas to give estimates of the potential water yield.

r

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

Buried Valley with Inferred Boundary.

Scale

1 1/2 0 1 2
miles

true north

Geologic interpretation by David P. Stewart

Vermont Geological Survey
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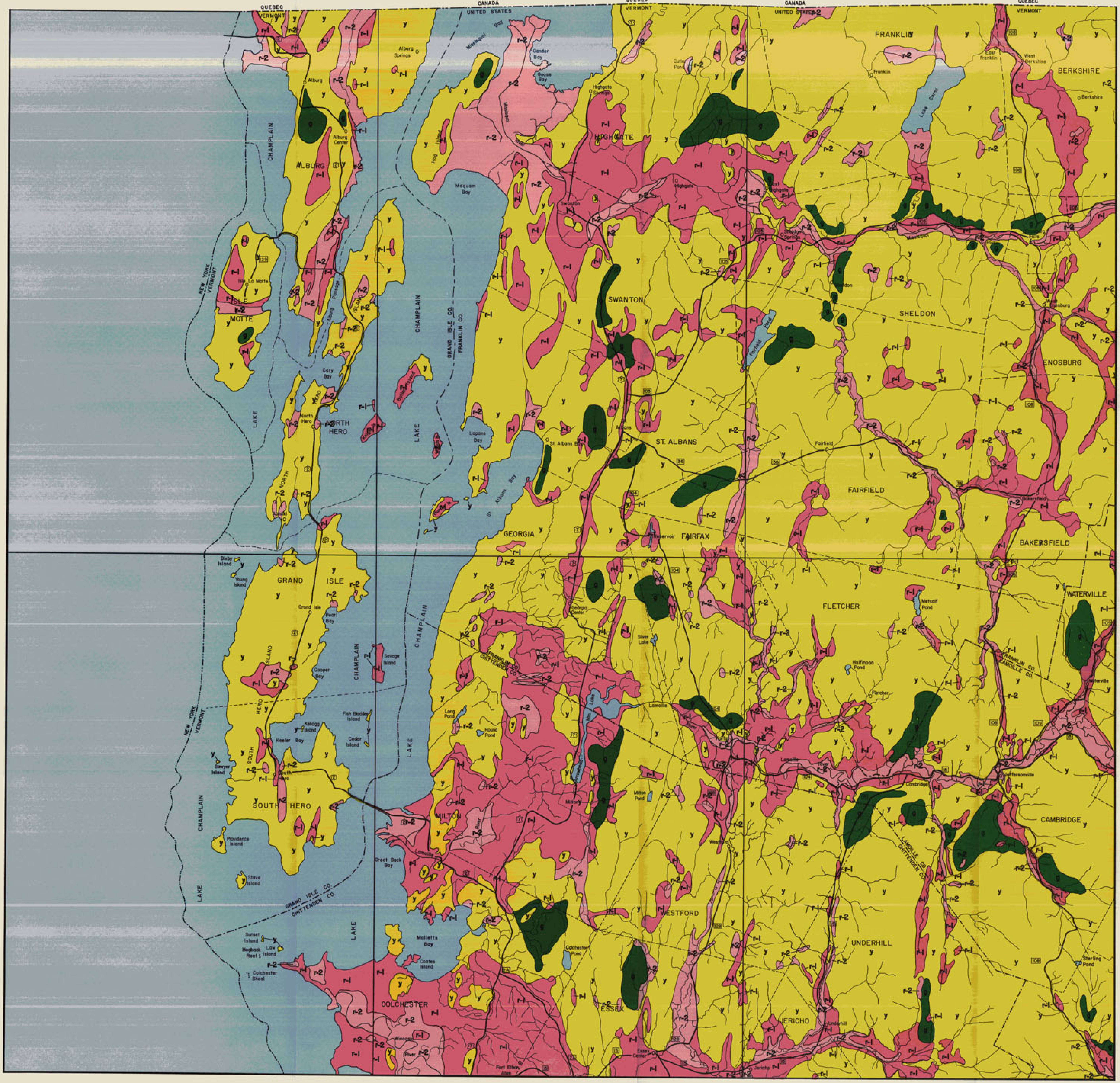
SOLID WASTE DISPOSAL CONDITIONS OF THE MILTON-ST. ALBANS REGION Plate IV



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

Geologic interpretation by David P. Stewart

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Charles G. Doll, State Geologist
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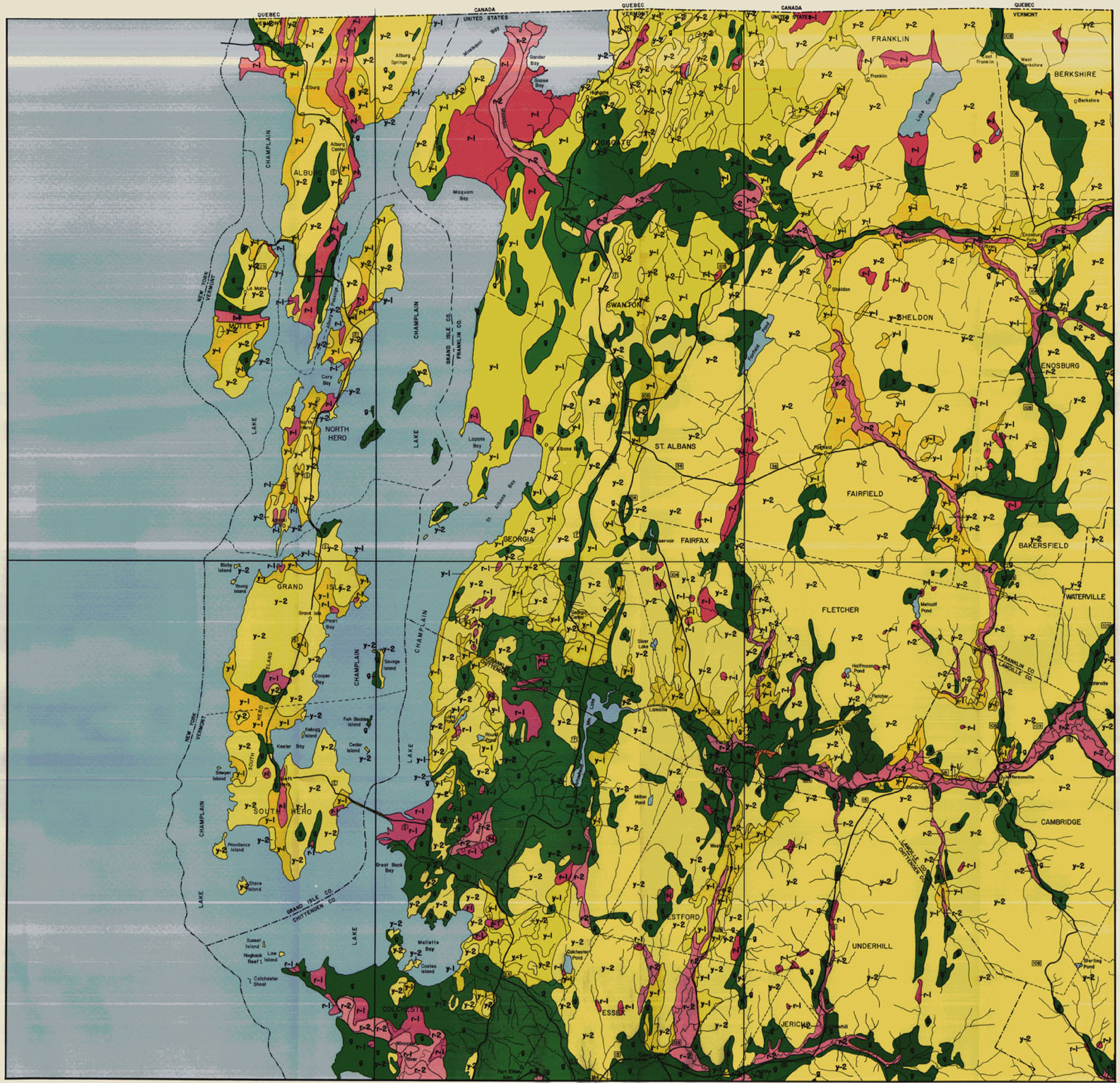
GENERAL CONSTRUCTION CONDITIONS OF THE MILTON-ST. ALBANS REGION — Plate VI



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

Geologic interpretation by David P. Stewart

Vermont Geological Survey
Charles G. Doll, State Geologist
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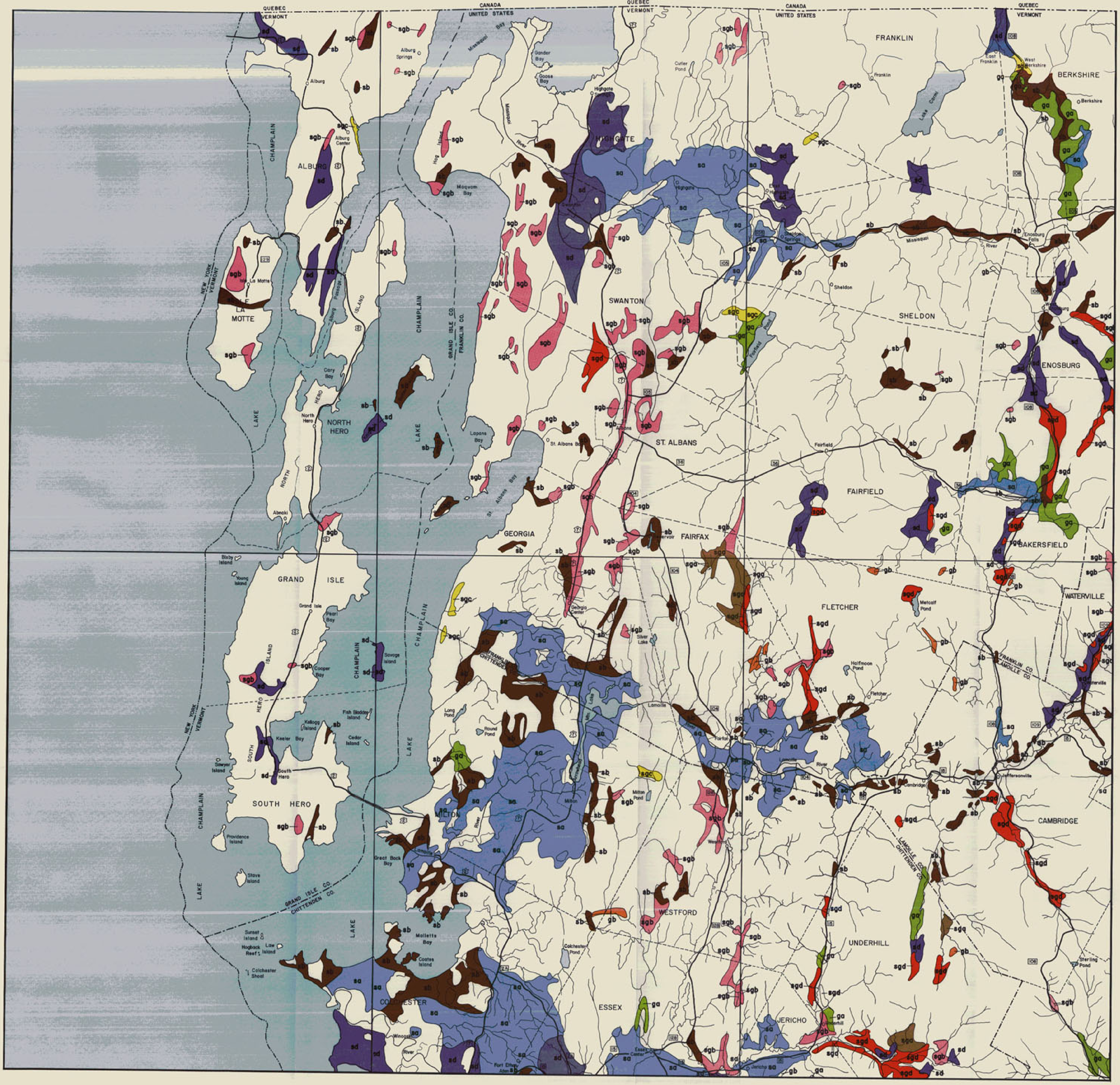
SAND AND GRAVEL RESERVES OF THE MILTON-ST. ALBANS REGION — Plate VII



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.

sd

Sand deposits of unknown quality and reserve.

Scale

1 1/2 0 1 2

miles

true north

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