Surficial Geology and Hydrogeology of the Groton 7.5 Minute Quadrangle, Vermont

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On the cover: Falls over granite outcrop on the Wells River, downstream of Ricker Pond, Groton State Forest.

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Executive Summary

Bedrock outcrops are abundant in large portions of the study area. In addition to the bedrock outcrops visited as part of this and other geologic mapping projects, Plate 1 also shows points where interpretation of lidar topographic data can be used to infer shallow bedrock. These were an aid to construction of the depth to bedrock map (Plate 2).

Glacial till is the most widespread surficial material in the study area. It is generally a moderately dense to loose, fine-sand matrix till with abundant locally-derived granite clasts.

Striations and grooves in bedrock indicate that ice motion directions ranged from 132 to 182°. Where cross-cutting relationships have been observed in nearby study areas, the more southerly striations are younger than the southeasterly ones. Crag and tail landforms visible on the lidar-derived topography show orientations of approximately 165 to 175°.

Two areas of short, irregular till ridges were identified in lowlands to the south of the Wells River. The larger of these is located about one kilometer south of Melvin Hill in Newbury and the other is about 1.5 kilometers west of Burnham Hill in Topsham. These are similar to features interpreted as Rögen Moraines in the Knox Mountains study area to the north (Springston and Kim, 2008).

Several features mapped as till benches are found in the south-central part of the study area near Burnham and Pine Mountains in Topsham. These are distinct benches oriented parallel to contours with level or gently sloping tops and are underlain by till. Similar features on both flanks of Mount Mansfield in the Green Mountains of northern Vermont have been interpreted to be a type of lateral moraine by Wright (2019). A non-genetic term is used here as their origin is still under investigation.

Ice-contact sand and gravel deposits are limited to the vicinity of Ricker Pond, in the northwest corner of the study area, where there are several short esker segments formed in subglacial meltwater stream courses.

Several sets of well-defined meltwater channels are cut into till slopes located south of the Wells River in Groton and northern Topsham. Their consistent location on north-facing slopes suggests that they formed at or under an ice-margin that was down-wasting off the hillsides as it retreated northward towards the Wells River.

An arm of glacial Lake Hitchcock extends westward through the central parts of the study area into Groton. A more accurate shoreline projection was created as part of this project using delta topset-foreset contact elevations throughout the Connecticut River valley and the new lidar topographic data. These deltas include the delta on the north side of the Wells River in South Ryegate Village in the east-central part of the study area.

Mean yields of bedrock water wells are somewhat above the statewide average (13.3 gpm versus 14.0 gpm statewide) and depths of bedrock water wells are slightly higher than the statewide average (316.2 feet versus 290.0 feet statewide).

Most of the bedrock in the quadrangle is covered by relatively thin surficial deposits, suggesting that the potential for recharge of bedrock wells is generally good. Although there is abundant opportunity for groundwater recharge over much of the quadrangle due to the relatively thin surficial deposits, the recharge areas for many wells may be relatively small and thus the wells may not be able to sustain heavy withdrawal without excessive lowering of the water levels.

There is a moderate potential for developing groundwater supplies from within the surficial deposits in the Wells River valley near the villages of Groton and South Ryegate. More detailed studies would be needed to see if a groundwater source could indeed be developed within the surficial deposits.

Introduction

General Geology

The surficial materials in the region are dominantly of glacial origin and were deposited in the late Pleistocene while the area was covered by the Laurentide ice sheet and during and shortly after the retreat of that ice. Typical of most of New England, the upland areas are covered by till that varies considerably in thickness, composition, and texture. Glacial boulders are common, with numerous granite erratics found to the south and south-southeast of the granite bodies. Bedrock exposures are abundant at the higher elevations and occur at scattered locations in the valley bottoms. Till in the stream valleys may be overlain by a variety of ice-contact sediments deposited during ice retreat. The valley bottoms are underlain by thick glacio-lacustrine deposits. The modern valley bottoms are also the locus of Holocene alluvial fan deposition, fluvial activity, and the accumulation areas for colluvium.

The bedrock geology is shown in Figure 2, adapted from Ratcliffe et al., 2011). The quadrangle is primarily underlain by the Silurian-Devonian Waits River and Gile Mountain Formations. Limited exposures of Devonian granitic rocks are found throughout the central portions of the study area and larger exposures are found on Blue Mountain in the northeast corner.

The Groton quadrangle is located in the Vermont Piedmont physiographic province (Stewart and MacClintock, 1969). Most of the study area has moderate relief, with the exception of Blue Mountain in the northeastern corner. All of the streams in the quadrangle drain ultimately into the Connecticut River. Typical views of the landscape are shown in Figures 3, 4, and 5.

Prior Work

Bedrock mapping at a scale of 1:62,500 was undertaken by White and Billings (1951).

Reconnaissance surficial geologic mapping at 1:62,500 scale was undertaken by D.P. Stewart for incorporation into the 1:250,000 scale Surficial Geologic Map of Vermont (Stewart and MacClintock, 1969, Doll, 1970). Stewart and MacClintock (1969) postulated an extensive, generally north-south moraine complex across much of eastern Vermont that they named the Danville Moraine. Mapping by Springston and Haselton in the St. Johnsbury 7.5 minute quadrangle (1999) to the northeast of the study area casts doubt on the existence of this moraine. Where examined, the areas that had been mapped as moraine were generally thin, dense, silt-matrix till. Bedrock outcrops were common in these areas.

Although supporting evidence of the extensive Danville Moraine has not been found, detailed mapping in recent years has found sets of smaller recessional moraines in the Barre East quadrangle to the west and Joes Pond quadrangles to the north (Springston, 2018; Springston, 2017) as well as sets of short till ridges that have been interpreted as Rogen moraines in the Marshfield quadrangle to the northwest (Springston and Kim, 2008). A review of the Lidar topographic data indicates similar features in the Peacham quadrangle to the north and this study identified small recessional moraine for similar features may be found in the study area, particularly in the vicinity of Pine Mountain (Figure 6).

Koteff and Larsen (1989) conducted a study of glacial Lake Hitchcock and determined elevations of topset-foreset contacts for deltas throughout the Connecticut River valley. The lake projected up into the Wells River valley as shown in Figure 6. One of their sites, the South Ryegate Delta, is shown on Plate 1 and will be discussed below.

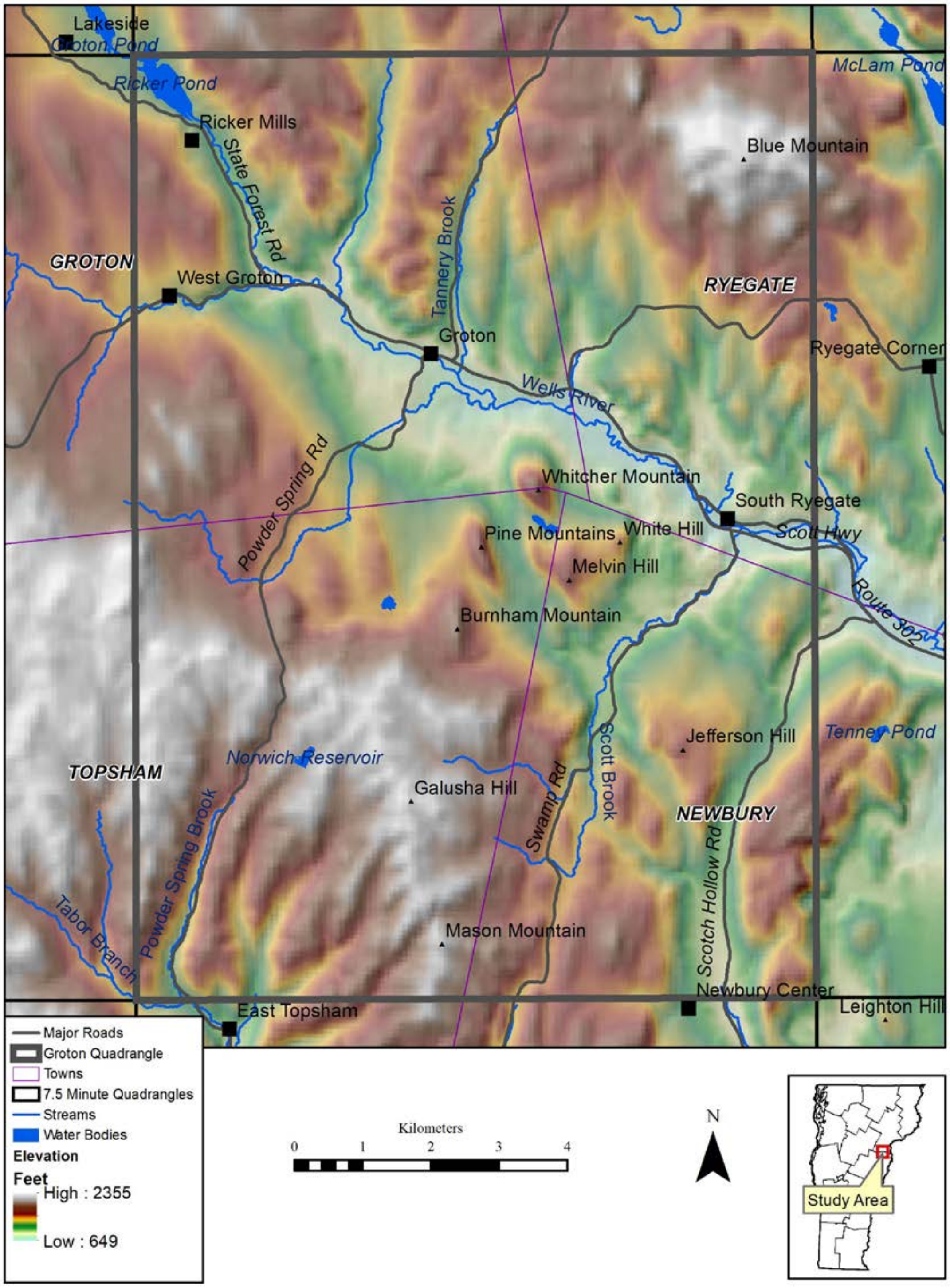


Figure 1. Location map.

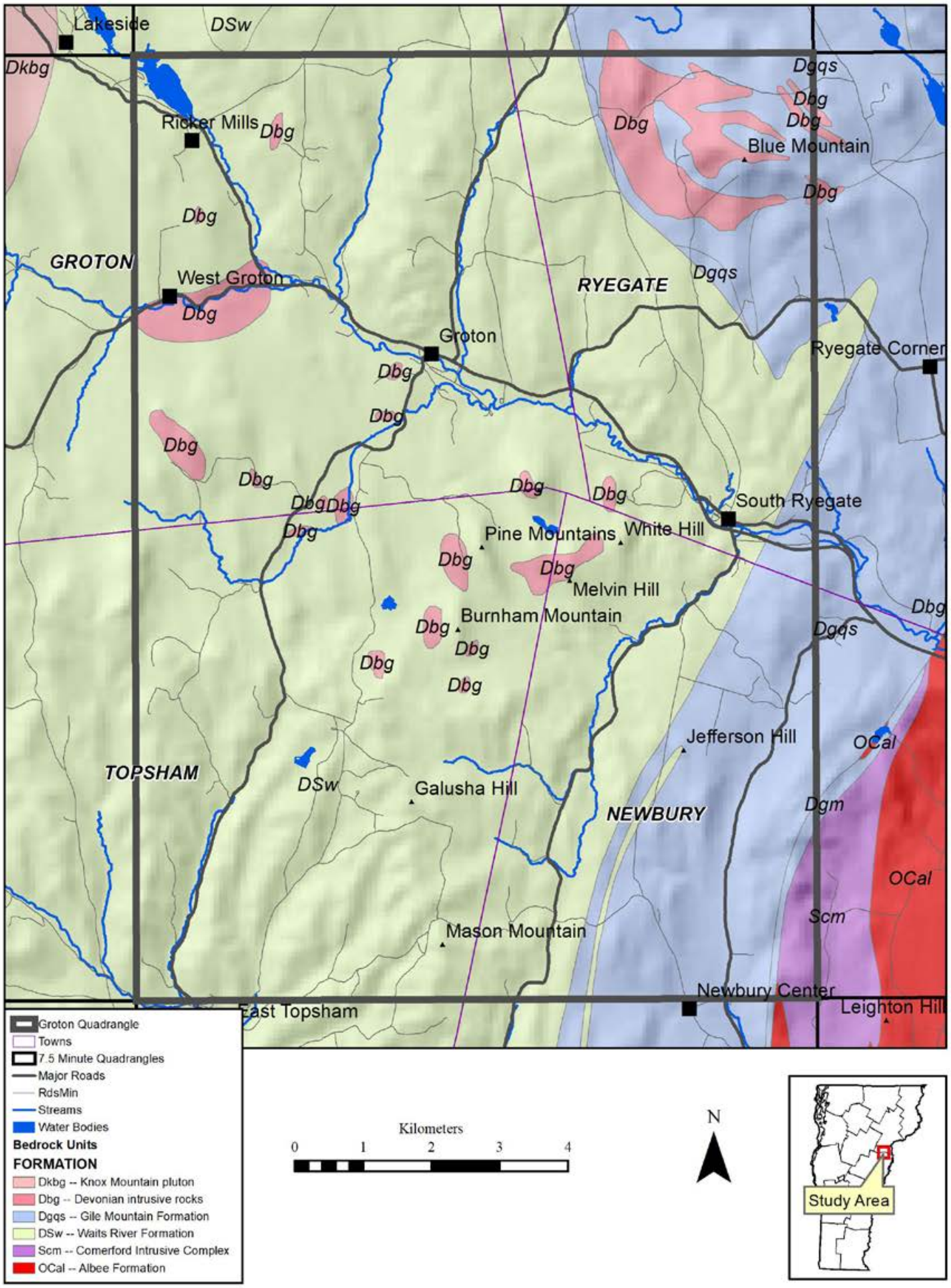


Figure 2. Bedrock geology (after Ratcliffe and others, 2011).

Figure 3. Looking west from a granite quarry on west side of Blue Mountain in Ryegate across the northern part of the quadrangle towards the Knox Mountains.

Figure 4. Looking northeast from Powder Spring Road in Groton toward Blue Mountain.

Figure 5. Rolling upland south of the Wells River, looking north. The field is underlain by very thin sandy till with scattered outcrops of rusty phyllite of the Gile Mountain Formation.

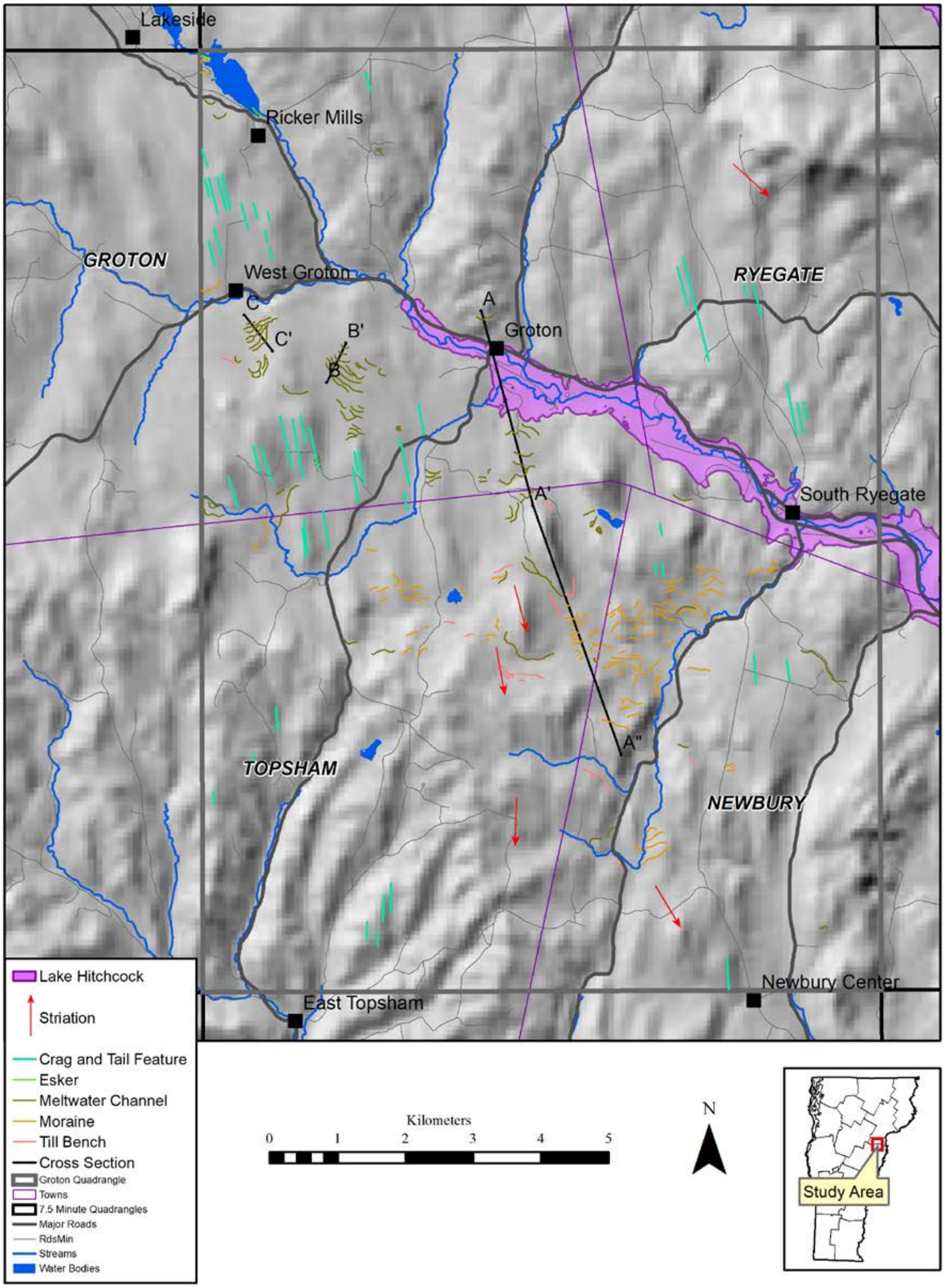


Figure 6. Glacial features and glacial Lake Hitchcock.

Methods

Field work involved visits to about 380 exposures of surficial deposits and 55 bedrock outcrops. The locations of additional bedrock outcrops were obtained from bedrock mapping by White and Billings (1951). Additional surficial geologic information was obtained by analysis of 147 water well logs. The logs were derived from databases managed by the Drinking Water and Groundwater Protection Division of the Vermont Department of Environmental Conservation. The water well locations are shown on Plate 1. As many of the older wells have uncertain locations, only wells with verified locations are used in this analysis. Newer wells with driller-reported GPS locations or E911 addresses are assumed to be close to the correct locations. Descriptions of sand and gravel resources were obtained from Highway Materials Studies undertaken by the Vermont Agency of Transportation. All of the above are also shown on Plate 1.

Bedrock Exposures

Surficial deposits are generally thin in the study area and bedrock exposures are widespread. In addition to the bedrock outcrops visited as part of this and other geologic mapping projects, Plate 1 also shows points where interpretation of lidar topographic data can be used to infer shallow bedrock. These were an aid to construction of the depth to bedrock map (Plate 2).

Most of the streams have cut down to bedrock in at least some locations and typical exposures are shown in Figures 7 and 8. A typical upland exposure is seen in Figure 9. Extensive exposures of granitic bedrock are seen on Blue Mountain (Figure 10).

Although many exposures of visible bedrock are relatively fresh, the carbonate-rich Waits River Formation is quite prone to rapid weathering and weathered bedrock (saprolite) is almost certainly much more common than the visible outcrops might indicate. A particularly fine exposure of saprolite is shown in Figure 11.

Figure 7. Falls over a granite outcrop on Wells River, downstream of Ricker Pond in Groton State Forest. Note sub-horizontal sheeting joints.

Figure 8. Bedrock exposures of the Gile Mountain Formation in the Wells River, Groton Village.

Figure 9. Typical exposure of rusty-weathering phyllite of Gile Mountain Formation overlain by very thin till. From hills south of the Wells River valley. Pack for scale.

Figure 10. Flooded granite quarry hole on west side of Blue Mountain. Note prominent sheeting joints dipping west (left).

Figure 11. Saprolite formed by weathering of gray, foliated quartzite and phyllite of the Waits River Formation. On east side of Lime Kiln Road, just south of quadrangle boundary. Station 466, UTM Coordinates: 723818, 4889382, meters, NAD 83.

Surficial Geology

Ice-movement Indicators

Striations and grooves in bedrock indicate that ice motion directions ranged from 132 to 182°, which is similar to orientations in surrounding area (Plate 1 and Figure 6). Although no cross-cutting relationships were observed in the study area, it is likely that the more southerly striations cross-cut the southeasterly striations, indicating that the southerly striations are younger. This is the pattern seen in the Barre East quadrangle to the west (Springston, 2018), the Woodbury quadrangle to the north-northwest (Springston and others, 2015) and in the St. Johnsbury quadrangle to the northeast (Springston and Haselton, 1999). This relationship has been seen at many other sites in the region and Wright (2015) has interpreted this to suggest an earlier regional ice flow trending roughly southeast, with a later more southerly re-orientation of flow.

Crag and tail landforms visible on the lidar-derived topography are common throughout the study area (Plate 1 and Figure 6). A crag and tail landform is a streamlined hill or ridge, consisting of a knob of resistant bedrock along with an elongate body of more erodible bedrock, till, or both on its lee or down-glacier side. In this area they show orientations of approximately 165 to 175°, suggesting that they formed parallel to late glacial flow.

Glacial Boulders

Glacially transported granitic boulders are widespread throughout the eastern third study area. A few prominent ones are shown on Plate 1. These were derived from the Knox Mountain pluton to the north and northwest and from the local granite bodies (Figure 2). Generally speaking, glacial boulders that were derived from one rock type but now rest on a different rock type are termed erratic boulders and some of these may have been transported a considerable distance, but many of the boulders in this study area are granitic boulders that came to were deposited on granitic bedrock, perhaps after only short transport. Photos of two prominent granitic boulders are shown in Figures 12 and 13. These and others may be good candidates for cosmogenic dating in order to determine the time of deglaciation. An example of one of the numerous stone walls is shown in Figure 14.

Figure 12. Large granite glacial boulder. These are found throughout the quadrangle, but are especially common in the area south of Groton Village in the central part of the quadrangle. Auger is one meter long. UTM Coordinates: 724291, 4894201, meters, NAD 83.

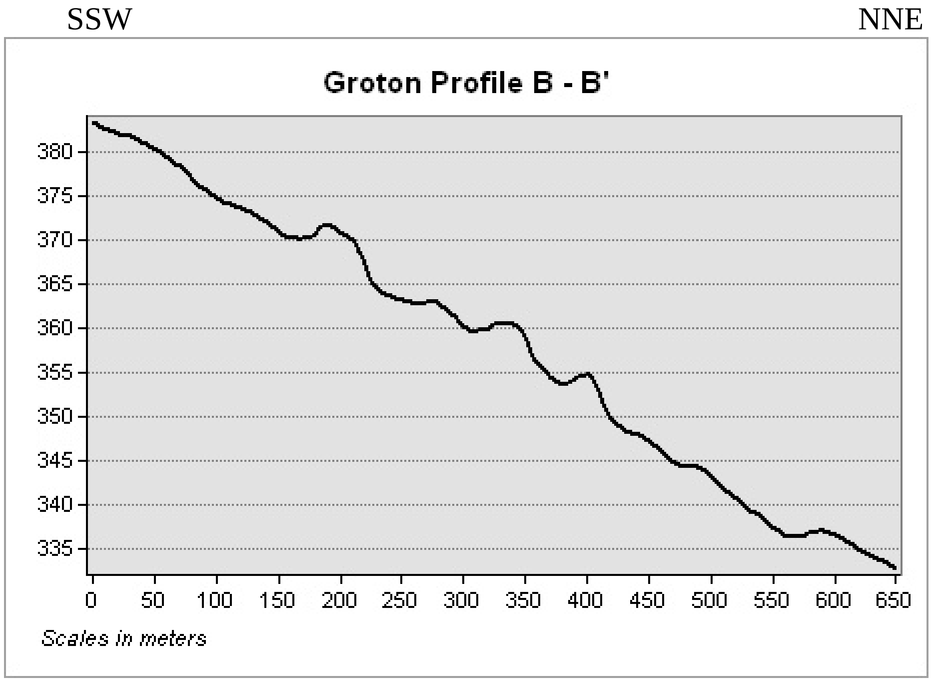
Figure 13. Large granite boulder that may be suitable for cosmogenic dating. Station 539, UTM Coordinates: 724902, 4896102, meters, NAD 83.

Figure 14. Stone wall composed almost entirely of granite. This one was constructed by building two parallel walls of granite boulders about three feet apart and filling the center with smaller rocks.

Meltwater Channels

Meltwater channels are scattered throughout the study area and are shown on Plate 1 and Figure 6. All appear to be cut into till deposits. Some occupy cols in ridges and appear to have been formed by generally south-flowing meltwater while the glacial ice margin stood at the ridge. Most, however, are found in down-stepping sets on hill slopes and appear to have formed at or perhaps under ice margins as the ice downwasted off of the hillsides. Cross Section A-A" on Plate 1 includes one of these sets and topographic profiles of two other sets are shown in Figure 16.

Figure 15. Meltwater channel in till, north-northeast of Pine Mountain in Groton.



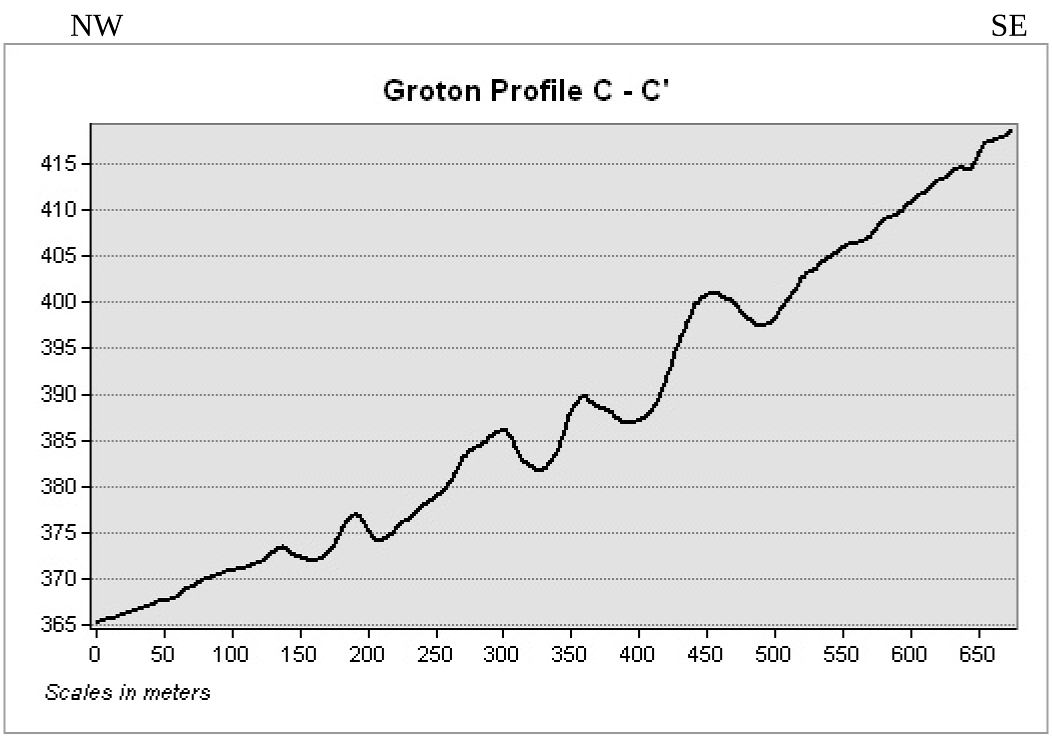


Figure 16. Topographic profiles of sets of meltwater channels. See Figure 6 for the profile lines.

Stratigraphy

Pleistocene Deposits

Although the Pleistocene Epoch ranges from about 11,700 years before present back to about 2.58 million years (Cohen and others, 2017), all of the glacial deposits in the study area are believed to belong to the last stage of the Pleistocene, the Wisconsinan Glacial Stage, which extends from about 71,000 to 11,700 years before present.

Till is very dense to loose, unsorted to very poorly sorted material deposited directly from glacial ice. It contains a wide range of grain sizes, from clay or silt up to large boulders. The matrix is commonly dominated by the silt or sand fraction. In the study area it is generally a moderately dense to loose, fine-sand matrix till with abundant locally-derived granite clasts. Typical examples are shown in Figures 17 and 18.

Figure 17. Typical moderately loose, fine-sandy till in shovel hole, west of Pine Mountain in Topsham. Notebook for scale.

Figure 18. Moderately loose, bouldery, sandy till on west side of Powder Spring Road, Topsham. Shovel for scale.

The sandy matrix of much of the till in the study area stands in contrast to the finer-grained silt matrix till that is so common in much of central Vermont. This is probably due mostly to the abundant granite-derived source material, which tends to produce a sand-rich matrix (Springston and others, 2017). An example of very dense silt-matrix till from the Barre East quadrangle is shown in Figure 19.

Where soils have developed on the sandy till within conifer forests, they commonly show a well-developed ashy gray spodic horizon due to leaching of iron and manganese coatings from the mineral grains (Figure 20).

The areas mapped as till include small areas of talus (fans or aprons of fallen rock at the bases of cliffs) and colluvium (slope-wash deposits on the lower portions of slopes).

Figure 19. Exposure of dense silt till in bed of Honey Brook in Barre Town, Barre East quadrangle.

Figure 20. Spodosol developed on sandy glacial till. Note ashy gray leached (E) horizon below dark brown A horizon and above an orange-brown B horizon. Site is in hemlock woods.

Two areas of short, irregular till ridges were identified in lowlands to the south of the Wells River (Plate 1 and Figure 6). The larger of these is located about one kilometer south of Melvin Hill in Newbury and the other is about 1.5 kilometers west of Burnham Hill in Topsham . These are similar to features interpreted as Rögen Moraines in the Knox Mountains study area to the north (Springston and Kim, 2008).

Several features mapped as till benches are found in the south-central part of the study area near Burnham and Pine Mountains in Topsham (Plate 1 and Figure 6). These are distinct benches oriented parallel to contours with level or gently sloping tops and are underlain by till. Similar features on both flanks of Mount Mansfield in the Green Mountains of northern Vermont have been interpreted to be a type of lateral moraine by Wright (2019). A non-genetic term is used here as their origin is still under investigation.

Esker Deposits. Elongate ridge of ice-contact stratified sand and gravel deposited by glacial meltwater streams in tunnels within or beneath the glacial ice. Low eskers are exposed at the inlet and outlet of Ricker Pond.

Lacustrine Deposits. The extensive lake deposits found in the Wells River valley have long been attributed to glacial Lake Hitchcock (Stewart and MacClintock, 1970 and Koteff and Larsen, 1989). Koteff and Larsen (1989) used delta topset-foreset contact elevations throughout the Connecticut River valley and its tributaries to create a trend surface. The sites included a pit in well-sorted sand and gravel on the north side of the Wells River in South Ryegate Village, which had a topset-foreset contact elevation of 244.4 meters (802 feet). As part of this study a more accurate shoreline projection was created by combining the Koteff and Larsen delta elevations and the new lidar topographic data. Using this new projection, the shoreline elevation ranges from 243.6 m (799 feet) on the eastern edge of the quadrangle to 248.5 m (815 feet) west of Groton Village.

The lacustrine deposits in the valley range from well-sorted sand, pebbly sand and/or sandy gravel deposited in shoreline, shallow water, or lake bottom environments of a glacial lake to clay, silt, and very fine to fine sand deposited in deeper waters. The finer-grained deposits are commonly laminated and often show clear indications of varves (annual sediment layers).

Holocene Deposits

The Holocene deposits are described briefly below. These are less than about 12,000 years old. Cohen and others (2017) give 11,700 years before present as the base of the Holocene

Artificial Fill. Artificially-emplaced material along road beds, embankments and in developed areas. Material varies from natural sand, gravel, or till to various artificial waste materials. Thickness varies.

Alluvium. Silt, sand, and gravel deposited by modern streams. Includes stream channel, bar, and floodplain deposits. Wetland deposits are common within these areas and are not distinguished. Thickness in tributary valleys is typically less than 3 meters, although the depth may be much greater in the valleys of the larger streams.

Alluvial Terrace Deposits. Silt, sand, and gravel deposited on terraces above the modern floodplains of streams. Composed of a variety of channel, bar, and floodplain deposits. Generally less than 5 meters thick.

Alluvial Fan Deposits. Boulder, pebble, and cobble gravel and pebbly sand deposited at sites where steep, stream gradients are sharply reduced. Common at the mouths of steep tributaries where they meet the main stream.

Wetland Deposits. Accumulations of organic matter and/or clastic sediment in low-lying areas. Includes a wide variety of wetland types. Commonly overlying other deposits such as alluvium, lacustrine sediment, or till. Only a few larger deposits are shown. A typical beaver-influenced wetland is shown in Figure 21.

Figure 21. Large wetland on the west side of Galusha Hill Road, Topsham.

Talus. Fans or aprons of fallen blocks of angular rock at the bases of bedrock cliffs. May contain colluvial (slope-wash) deposits as well. Of variable thickness.

Colluvium. Fans or aprons of slope-wash sediment that have accumulated at the base of steep slope segments. Thickness is highly variable, although usually less than 3 meters.

Hydrogeology

The distribution and quantity of groundwater have been studied by analysis of the surficial geologic data collected for this project and by analysis of water well data derived from databases managed by the Drinking Water and Groundwater Protection Division of the Vermont Department of Environmental Conservation. The water well locations are shown on Plate 1. As many of the older wells have uncertain locations, only wells with verified locations are used in this analysis. Newer wells with driller-reported GPS locations or E911 addresses are assumed to be close to the correct locations. Other well locations have been verified by use of State records of hazardous waste sites and septic systems, searches of town records, local knowledge, or online searches to verify that the listed owner has a residence at the location shown.

Bedrock well statistics are shown in Table 1 and will be discussed in the paragraphs below. Note that the percentile values and histograms for depth to bedrock, yield, and well depth are all skewed to the left. For each of these the median value serves as a better measure of central tendency than the mean.

Table 1. Descriptive statistics for all located bedrock wells in the Groton quadrangle (N = 147). Well depth and overburden (depth to bedrock) is in feet, yield is in gallons per minute. Two of the records for well depth had to be omitted due to unlikely zero values.

Variable	N	Mean	St.Dev.	Minimum	Median	Maximum
OverBurden (ft)	147	23.0	23.4	0	12.0	137
Well Depth (ft)	145	316.2	125.8	57	300.0	645
Yield (gpm)	147	13.3	19.1	0	6.0	100

Depth to Bedrock

Depth to bedrock or overburden thickness is shown on Plate 2. Depth is indicated by the contours and by the size of the green symbols at each well location. Bedrock outcrops are shown as black dots. The red lines are approximate contours at depths of 20, 40, 60, and 80 feet. A simplified map is shown in Figure 22. As shown in Table 1, the median depth to bedrock in the wells is 12.0 feet. Note that only limited areas have a depth to bedrock that is greater than about 40 feet. The depth is more certain in areas with abundant water well logs and/or bedrock outcrops and less certain in areas where this information is sparse.

Well Depth

The mean well depth is 316.2 feet. Statewide, the mean depth of bedrock wells is 290 feet (Gale and others, 2014). Thus, the wells in the quadrangle are being completed at depths that are slightly higher than the statewide average.

Well Yields

Driller's estimates of yields of bedrock wells are shown in Figure 23. Estimated yields (in gallons per minute) are indicated by the labels, as well as by the size of the green symbols. The mean well yield is 13.3 gallons per minute. Statewide, the mean yield of bedrock wells is 14 gallons per minute (Gale and others, 2014). Thus, the wells in the quadrangle have yields that are similar to the statewide average.

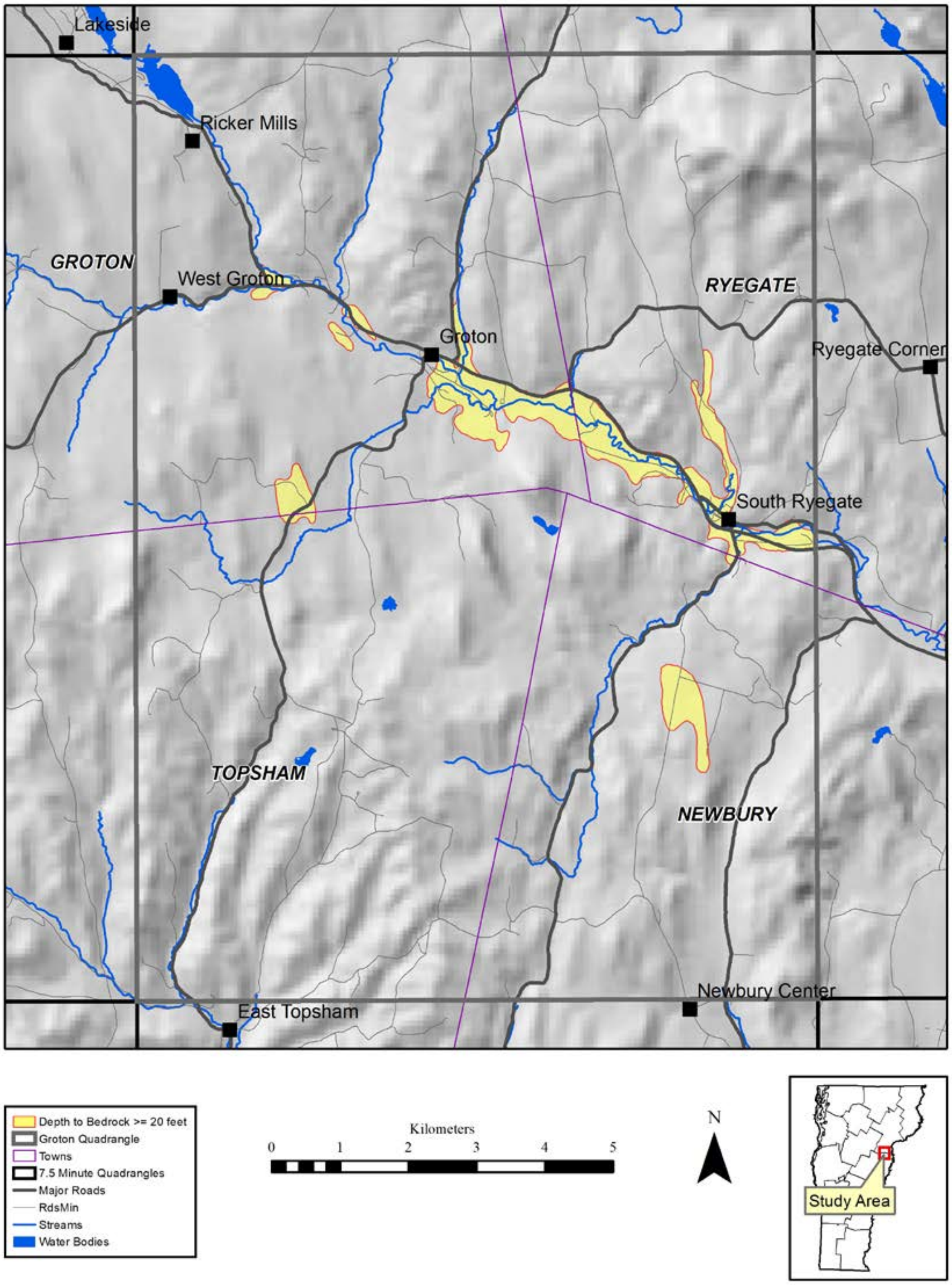


Figure 22. Depth to bedrock. For clarity, only areas within the 20 foot contours are shown. See Plate 1 for greater detail.

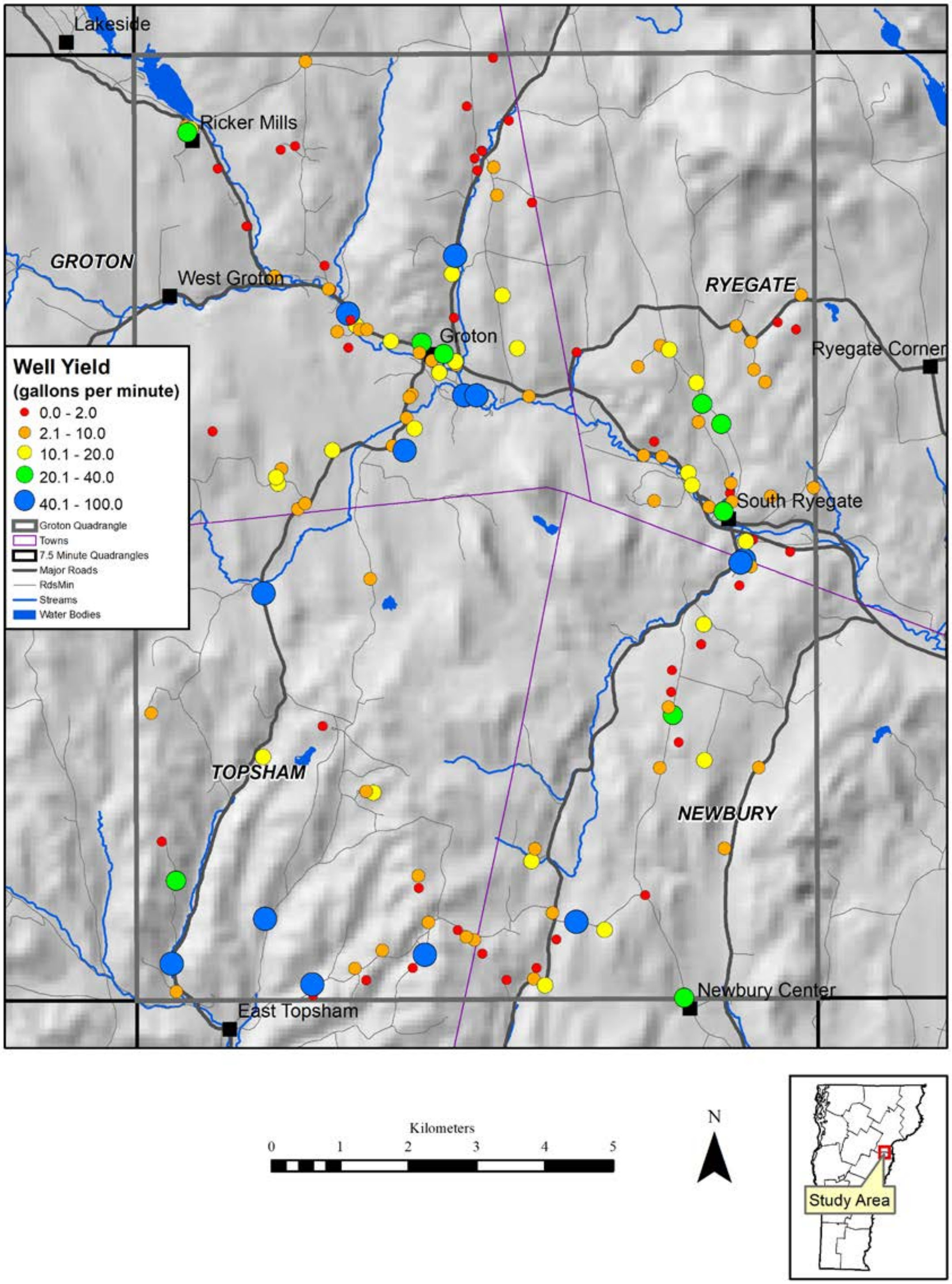


Figure 23. Driller's estimates of yield of bedrock wells, in gallons per minute.

Static Water Levels and Groundwater Flow Directions

Figure 24 shows generalized information on the height of water levels in existing wells (static water levels) and groundwater flow directions. The contours show a very generalized set of contours of static water levels and the arrows show approximate groundwater flow directions. Data on static water levels is collected during well installation and are subject to considerable seasonal variation. If the groundwater flowing through the bedrock and surficial deposits is unconfined, then the groundwater will tend to move from higher areas to lower areas and converge towards the streams, ponds, and wetlands. In that case, contours of equal elevation on the groundwater surface would be roughly parallel to the topographic contours shown on the map. However, any confining layers in the surficial deposits or within the bedrock units would result in wells that have water levels higher than the topography would indicate.

Although there is abundant opportunity for groundwater recharge over much of the quadrangle due to the relatively thin surficial deposits (see Plate 2 and Figure 22), the recharge areas for many wells may be relatively small and thus the wells may not be able to sustain heavy withdrawal without excessive lowering of the water levels.

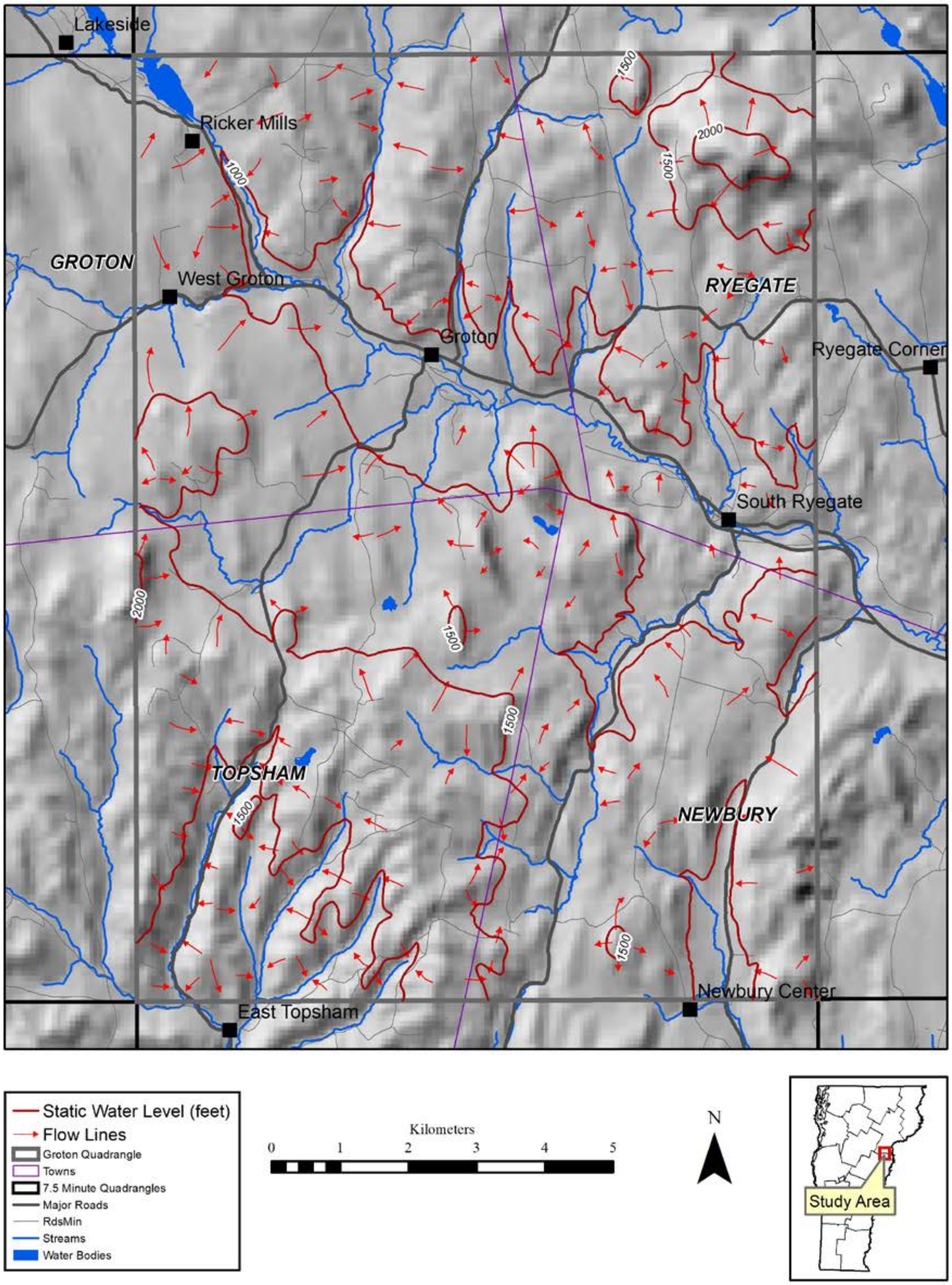


Figure 24. Generalized static water levels and groundwater flow directions.

Hydrogeologic Interpretation of Water Well Logs

A hydrogeologic classification of available water well logs was undertaken to rank how easily ground water can move through the surficial materials. The classification is made using water well logs and is based almost entirely on the coarseness of the surficial materials, with the assumption that ground water will be able to flow easier through coarser materials than through finer ones (Table 2). Interpretations based on this data will be shown on other plates in this report. As the driller's logs are not very detailed and vary widely in accuracy and completeness, these interpretations are of limited accuracy. They are perhaps most useful in areas where several nearby well logs all show similar stratigraphy.

Relatively thin, coarse-grained surface horizons that are less than about 20 feet thick are ignored in this classification as they are likely to be of little importance either as significant aquifers or as barriers to prevent or slow infiltration of ground water. In the classification below a "thick" surface horizon measures 20 feet or more.

Surficial deposits that are less than about 40 feet in **total** thickness are not considered to be good candidates for surficial aquifers. Even if such deposits can supply sufficient yields during dry seasons, they are quite likely to be at risk from contamination from surface waters.

Table 2. Hydrogeologic classification of water well logs.

0	Thick, coarse-grained, stratified deposits over till over coarse-grained stratified deposits.
1	Fine-grained stratified deposits over coarse-grained stratified deposits.
2	Fine-grained stratified deposits over coarse-grained stratified deposits over fine-grained stratified deposits or till.
3	Thick, coarse-grained, stratified deposits over fine-grained stratified deposits over coarse-grained stratified deposits.
4	Sand-matrix till over coarse-grained stratified deposits.
5	Silt-to-clay-matrix till over coarse-grained stratified deposits.
6	Thick, coarse-grained, stratified deposits.
7	Thick, coarse-grained, stratified deposits over fine-grained stratified deposits and/or till.
8	Thick section of sand-matrix till.
9	Thick section of silt-to-clay matrix till over fine-grained stratified deposits.
10	Thick section of fine-grained stratified deposits over silt-to-clay-matrix till or directly over bedrock.
11	Thick section of silt-to-clay-matrix till.
12	Thin surficial deposits or no surficial deposits overlying bedrock. Includes the very common case of thin till over bedrock. Generally less than 40 feet thick.
13	Other. Commonly, this is a thick section of surficial deposits with either no details of stratigraphy or highly variable stratigraphy.
-999	Problem record. Usually due to location being suspect.

Surficial Aquifer Potential

Figure 25 uses the hydrogeologic classification of private water well logs to estimate the surficial aquifer potential of the surficial deposits in the quadrangle. Hydrogeologic Classes 0 through 5 are interpreted as having a high surficial aquifer potential due to the presence of thick coarse-grained deposits overlain by finer grained deposits. No wells in these classes were found within the quadrangle. Classes 6 and 7 are interpreted to have a moderate surficial aquifer potential as they have thick coarse-grained deposits but these are not overlain by a fine-grained deposit that could serve to prevent direct infiltration of surface water. These are shown as orange dots. Only 20 wells were found within these classes. Classes 8 through 12 do not have a thick coarse-grained deposit and therefore have a low potential to serve as a surficial aquifer. These are shown as small red dots. Class 13 has insufficient detail for classification.

Out of the 147 water well logs examined, none were classified as having high surficial aquifer potential and only 20 were classified as having moderate potential. This suggests that there is only a moderate potential for developing substantial groundwater sources within these surficial deposits. Most of these wells are in the Wells River valley near the villages of Groton and South Ryegate (Figure 25). More detailed studies would be needed to see if a groundwater source could indeed be developed within the surficial deposits.

Recharge Potential to Surficial Aquifers

Figure 26 shows the potential for groundwater recharge to surficial aquifers based on the surficial geologic mapping. This figure is intended to show the relative permeability of the surface units (the material indicated on Plate 1) to the surficial or bedrock units that are immediately below. The general picture that emerges from this figure is that the Wells River valley is underlain by surficial materials that may be able to allow groundwater or wastewater to penetrate to depth with relative ease. This has implications for wastewater disposal in these areas insofar as any insufficiently treated wastewater might potentially be able to penetrate to considerable depths. Porosity, permeability, grain size and thickness of the surficial materials plus slope, and flow direction of groundwater are all factors to be considered in siting wastewater and protecting drinking water.

Adequacy of Groundwater Supplies

Most of the study area is underlain by thin till and can be expected to have adequate groundwater recharge to bedrock. Actual groundwater recharge will depend heavily on the topographic position of the site, the detailed stratigraphy of the surficial deposits, as well as the bedrock units present and the distribution, length, orientation, spacing, and openness of fractures in the bedrock. The bedrock characteristics are not considered here.

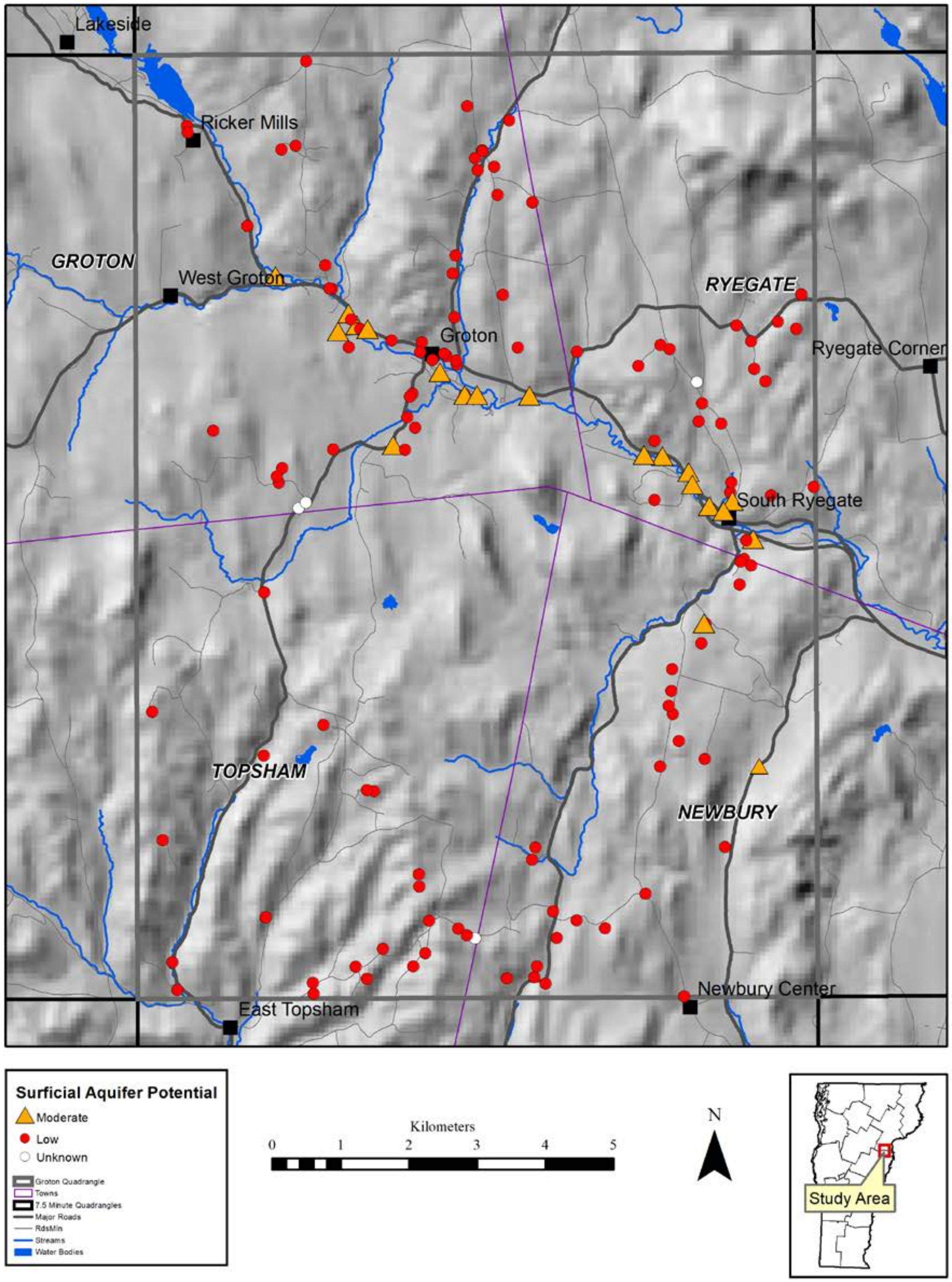


Figure 25. Surficial aquifer potential.

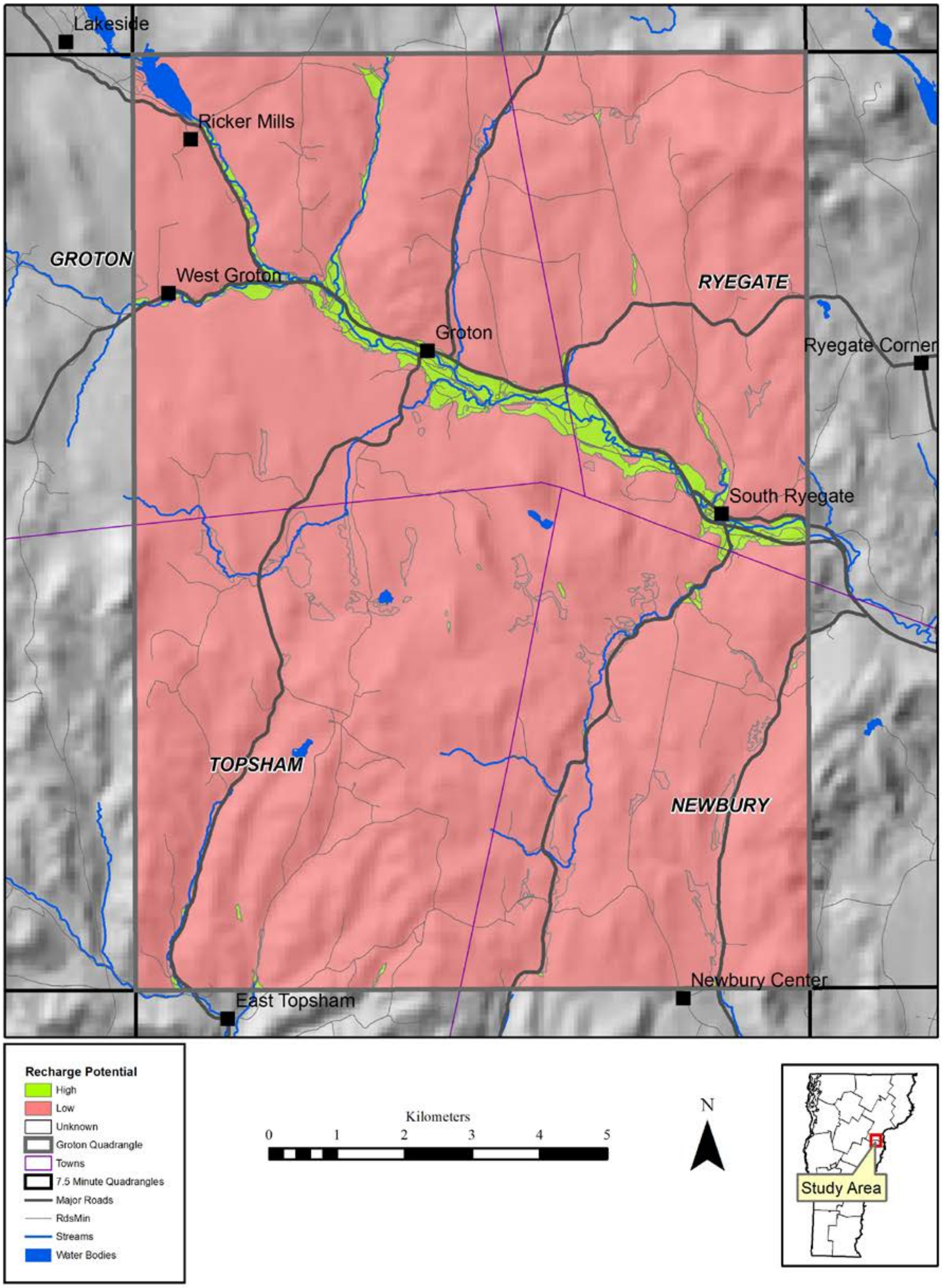


Figure 26. Recharge potential for surficial aquifers.

Summary

Glacial till is the most widespread surficial material in the study area. It is generally a moderately dense to loose, fine-sand matrix till with abundant locally-derived granite clasts.

Striations and grooves in bedrock indicate that ice motion directions ranged from 132 to 182°.

Two areas of probable Rögen Moraines were identified in lowlands to the south of the Wells River. The larger of these is located about one kilometer south of Melvin Hill in Newbury and the other is about 1.5 kilometers west of Burnham Hill in Topsham. These are similar to features mapped in the Knox Mountains study area to the north (Springston and Kim, 2008).

Several features mapped as till benches are found in the south-central part of the study area near Burnham and Pine Mountains in Topsham. These are distinct benches oriented parallel to contours with level or gently sloping tops and are underlain by till. Similar features on both flanks of Mount Mansfield in the Green Mountains of northern Vermont have been interpreted to be a type of lateral moraine by Wright (2019).

Ice-contact sand and gravel deposits are limited to the vicinity of Ricker Pond, in the northwest corner of the study area, where there are several short esker segments formed in subglacial meltwater stream courses.

Several sets of well-defined meltwater channels are cut into till slopes located south of the Wells River in Groton and northern Topsham. Their consistent location on north-facing slopes suggests that they formed at or under an ice-margin that was down-wasting off the hillsides as it retreated northward towards the Wells River.

Deposits from glacial Lake Hitchcock are widespread in the Wells River valley up to an elevation of about 815 feet.

Mean yields of bedrock water wells are similar to the statewide average (13.3 gpm versus 14.0 gpm statewide) and depths of bedrock water wells are slightly higher than the statewide average (316.2 feet versus 290.0 feet statewide).

The water level measurements from bedrock wells suggest that groundwater flow directions generally mimic the topography, with groundwater moving from recharge zones in the uplands towards discharge zones in the lowlands.

There is a moderate potential for developing groundwater supplies from within the surficial deposits in the Wells River valley near the villages of Groton and South Ryegate. However, it should be noted that none of the well logs that were examined suggested a high favorability for development of a surficial aquifer.

Most of the bedrock in the quadrangle is covered by relatively thin surficial deposits, suggesting that the potential for recharge of bedrock wells is generally good. Although there is abundant opportunity for groundwater recharge over much of the quadrangle due to the relatively thin surficial deposits, the recharge areas for many wells may be relatively small and thus the wells may not be able to sustain heavy withdrawal without excessive lowering of the water levels.

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Figure 27. A quarried granite block in an abandoned granite prospect east of Galusha Hill Road in the Pine Mountain Wildlife Management Area, Topsham.