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Surficial Geology and Groundwater Hydrology of Weathersfield, Vermont

Vermont Geological Survey Contract# 31879

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“Granite” erratics litter pasture immediately south of Little Ascutney mountain, Weathersfield, Vermont.

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Executive Summary/Significant Findings

The town of Weathersfield, Vermont was mapped during the summer of 2016 and the results of this work are presented here. Four University of Vermont undergraduate students assisted with the mapping effort during the month of June. Geologic contacts and landforms were mapped in considerable detail. Most of these complex contacts and landforms lie in the Black River and North Branch valleys on the western side of town and the Connecticut River valley along the eastern side. All outcrops occurring along town roads, state highways, and the Interstate were mapped. In addition to traditional field work, several areas in the North Branch river valley were surveyed using ground penetrating radar to assess the geometry of the sediments underlying this part of the valley.

At least two eskers have been mapped in the Black River/North Branch valley and a third in the Connecticut River valley. In some areas these are distinct, mappable landforms. In other areas they are exposed in gravel pits or are buried beneath younger sediments. GPR profiles have been used to help map these landforms where they are buried. To date these eskers are likely to host the single largest source of groundwater in these two major valleys.

The extent of glacial lake deposits in the area indicates that Glacial Lake Hitchcock lay at an elevation of ~600 feet (~182 m) at the latitude of Vermont State Route 131. Fluvial sediments in these valleys suggest that much of the North Branch and Black River valleys were filled with a delta system that rapidly filled the lake as the delta prograded southward towards North Springfield. These delta sediments too may host large groundwater reserves. Relatively small deltas have been mapped where east-flowing tributary streams entered the main body of Glacial Lake Hitchcock in the Connecticut River valley.

Relatively few areas in town are underlain by very fine grained lacustrine deposits (silt/clay). Quiet water lacustrine deposits primarily occur in the Connecticut River valley and consist instead of fine to very fine sand intermixed with silt. These somewhat higher energy sediments may reflect the narrowness of the lake in this area and/or sediment input into the lake from the Sugar River. These sediments frequently overlie the buried esker(s). While these sediments may not be fine enough to confine an aquifer in the eskers, they do serve to filter/adsorb many potential contaminants from entering these potential groundwater sources.

The upland areas of town are underlain by variable thicknesses of till. Much of this till contains abundant “granite” erratics sourced from Mount Ascutney and Little Ascutney Mountain. Outcrops are abundant along many of the ridges. Neither the bedrock nor the till are likely to host large, high-discharge wells, but seem more than sufficient sources of groundwater for individual household wells.

Introduction

This report describes the results of mapping surficial geologic materials and landforms at a scale of 1:24,000 in the town of Weathersfield, Vermont during the summer of 2016. Four University of Vermont undergraduate students (Will Vincett, Garrett Hazebrouck, Mitchell Miers, and Stephen Maglio) assisted with the mapping effort for 3 weeks of the field season and a fifth student (Benjamin Fisher) assisted with GIS work during the following school year. This report also describes several derivative maps generated for this project that focus on the areas groundwater hydrology.

Location and Geologic Setting

The town of Weathersfield borders the Connecticut River valley on its eastern side and is divided along it's western side by the Black River valley, a tributary to the Connecticut River (Figure 1). The town occupies parts of four 1:24,000 quadrangle maps, the Windsor, Springfield, Chester, and Cavendish Quadrangles. The bedrock geology of the area is summarized on the Vermont Bedrock Geologic Map (Ratcliffe et al., 2011). The western part of town is underlain by Proterozoic gneisses. These gneisses occur as a large structural dome and are in fault contact with a narrow sliver of Cambrian and Ordovician metasedimentary rocks. The contact between these rocks and other major geologic contacts in the area strike north-south. The Waits River Formation underlies much of the town and consists of a north-south belt of Devonian turbidites, metamorphosed during the Acadian Orogeny, that lie between the contact with the Cambrian-Ordovician rocks to the west and the Connecticut River to the east. A large Cretaceous age granite stock underlies Mount Ascutney and adjacent areas. These igneous rocks intrude the Devonian metasedimentary rocks along the northern boundary of the town. Goldthwait (in Antevs, 1922) used the very distinctive Mount Ascutney granite erratics to construct one of the first erratic dispersal fans in New England, "The Ascutney Boulder Train" fanning south from the Ascutney stock across the town of Weathersfield.

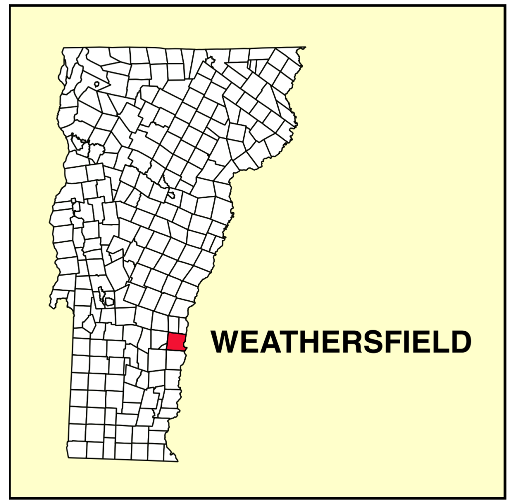

Figure 1: Map shows the location of Weathersfield, Vermont.

Most of the surficial geologic materials occurring in the region were deposited during the most recent (Wisconsinan) glaciation in glacial or periglacial environments existing during or shortly after the ice sheet retreated. A variety of surface processes (e.g. landslides, debris flows, alluvial fans, stream systems) have redistributed those materials since the ice sheet retreated ~14,500 years ago. A large glacial lake, Glacial Lake Hitchcock, occupied the Connecticut River valley and grew northward from its outlet in central Connecticut as the ice sheet retreated (Antevs, 1922; Ridge et al., 2012). Many of the surficial materials in the Connecticut River valley and its tributaries were deposited in this lacustrine environment.

Prior Work

The first systematic mapping of surficial materials in the area was completed in reconnaissance fashion by Stewart (1956–1966) using 15-minute (1:62,500-scale) base maps. This unpublished work was incorporated into the Surficial Geologic Map of Vermont (Stewart and MacClintock, 1970). Stewart's mapping shows that the Connecticut River valley in Weathersfield) is underlain by "lake sand" and a variety of deltaic deposits occur in the Black River valley. The upland areas are mantled by till with isolated overlying pockets of swamp and peat. Ice-contact sediments are not shown or shown over very limited parts of Weathersfield. No detailed mapping has occurred in Weathersfield or any of the adjacent towns on the Vermont side of the Connecticut River valley since the state surficial map was published. On the New Hampshire side of the river Hildreth (2011a, b) mapped the Claremont North quadrangle and the New Hampshire part of the Windsor quadrangle. Ridge (2000) has completed maps of the Claremont South and and New Hampshire portion of the Springfield 7.5-minute quadrangles. This detailed mapping on the New Hampshire side of the river provided some of the evidence Ridge and others (2012) utilized to construct the new North American varve chronology. The bedrock geology of the Windsor and Springfield Quadrangles has been mapped by Walsh and others (1996). The bedrock geology of the Cavendish and Chester Quadrangles were mapped by Ratcliffe (1995a, b)

Methods

Geologic mapping was conducted during the summer and fall of 2016. Field observations were recorded using a Fulcrum App created by the primary contractor. A site license to the Fulcrum Mapping Application is maintained by the UVM Geospatial Analysis Lab which enabled its use by the contractor (UVM faculty member) for no additional fee. The below map shows the locations of over 2,000 field sites visited during the course of this study. The attribute table associated with the point data shown on the below map contains the locations of each site as well as observations made at those sites.

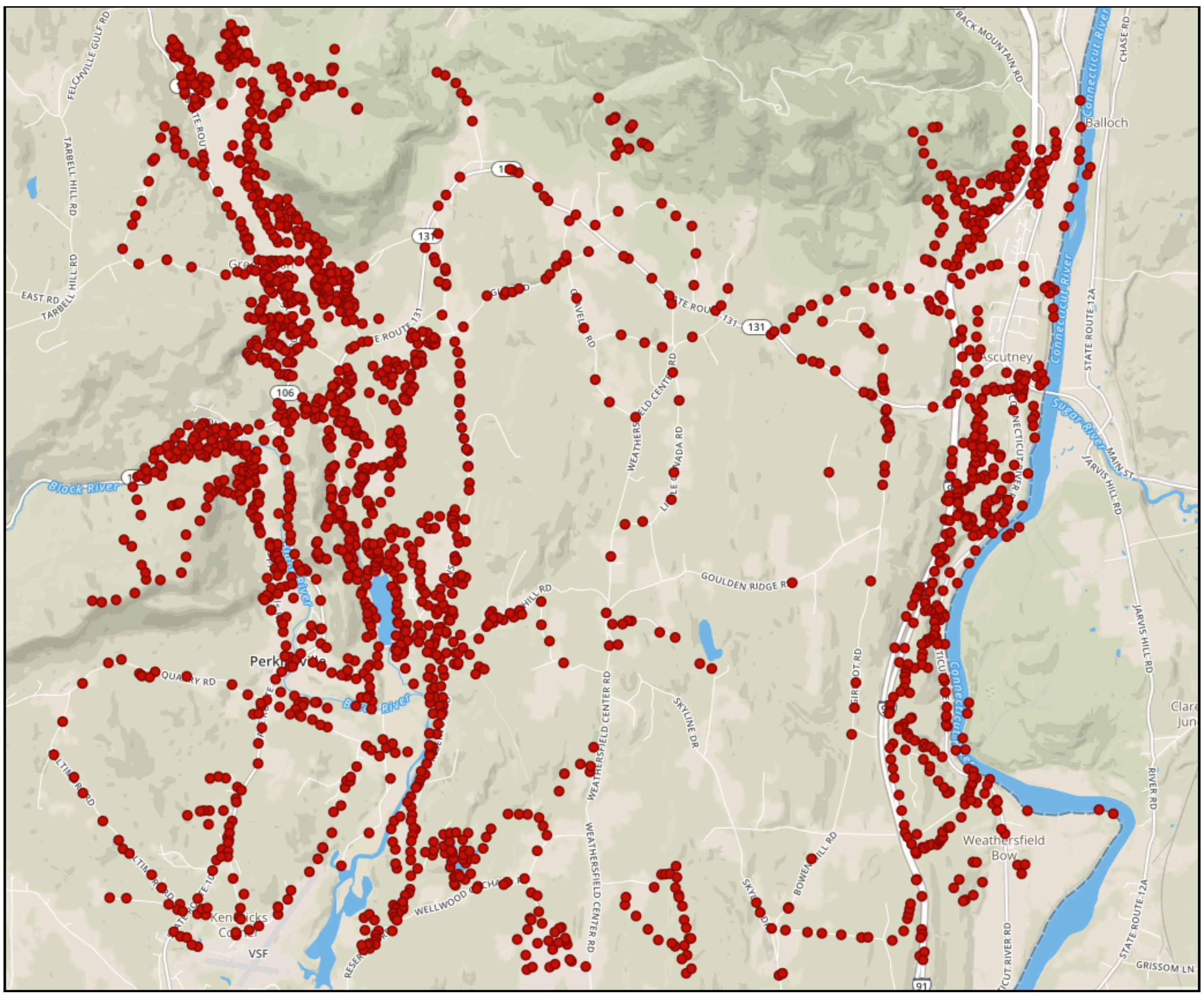

Figure 2: Red dots show the locations of over 2,000 field sites where geological observations were recorded.

A major objective of this work was to describe the three-dimensional distribution of surficial materials in the mapped area. The distribution of surficial materials, in addition to measurements of glacial striations, provide the basis for an interpretation of ice flow history across the area as well as the depositional environments that existed during and immediately following ice sheet retreat. Other landforms and associated surficial materials offer insight into processes occurring during the Holocene, long after the ice retreated.

Geologic contacts and landforms were mapped in considerable detail in the river valleys owing to the large variety of surficial materials and landforms occurring in the Black River and North Branch valleys on the western side of town and the Connecticut River valley along the eastern side. Outcrops were mapped wherever they were encountered. All outcrops occurring along town roads, state highways, and the Interstate have been mapped. In addition to traditional field work, several areas in the North Branch river valley were surveyed using Ground Penetrating Radar (GPR) to assess the geometry of the sediments underlying this part of the valley. These surveys were conducted by Seth Campbell (University of Maine) and Steve Arcone (CREEL) who volunteered both their field time and equipment as well as the time involved in processing these profiles. One University of Maine student and 4 UVM students assisted with the field GPR work.

Surficial Geologic Map

The surficial geologic map that accompanies this report shows the distribution of different types of surficial materials, the loose unconsolidated material overlying the bedrock, in the town of Weathersfield. The different surficial materials appearing on the Weathersfield Surficial Geologic Map are described below from oldest to youngest. The boundaries between these different materials are geologic contacts and are shown as solid lines on the geologic map. It's important to realize, however, that these contacts are 2D surfaces that extend out-of-sight below Earth's surface. In some areas geologic contacts could be closely located in the field and these locations were recorded and used when constructing the map. However, in most areas the location of these contacts is interpreted from field observations, distinctive landforms, and aerial imagery. Every effort was made to make these contacts as accurate as possible, but there is an element of interpretation in the placement of these contacts. The area around Weathersfield Bow was mapped in some detail by Ridge (2005) and with few exceptions the contacts he mapped have been utilized for this map.

Most of the surficial materials in the area were deposited by or adjacent to the Laurentide ice sheet as it first flowed across and then gradually thinned and retreated from the area between 14,700 and 14,400 years ago (Ridge et al., 2012). Glacial striations (scratch marks on bedrock surfaces) are not well preserved in this area, but most that were observed are oriented approximately North–South indicating that the ice sheet was flowing parallel to the Connecticut River valley when they formed. Older striations oriented from NW to SE are much less common, but were produced when the ice sheet was thicker and flowed obliquely across the mountains (Wright, 2015).

Geologic Mapping Units

<u>Bedrock Outcrops</u>

Bedrock outcrops were mapped whenever they were encountered during field traverses. No attempt was made to map all outcrops, especially in the extensive upland areas. Bedrock outcrops mapped by Walsh and others (1996) and Ratcliffe (1995a, b) were imported and included on the map. Outcrops are shown as points where the outcrop is small (e.g. Fig. 3) and as polygons.where many closely spaced outcrops occur across an area. The positions of outcrop polygons imported from the bedrock maps have been modified in areas where new bedrock location data dictate a change.

<u>Glacial Till</u>

Glacial till directly overlies the bedrock in almost all areas. Within the town, till is the ubiquitous surficial material in areas above the valley bottoms. The freshest exposures appear in landslides above streams and in excavations

Figure 4: Dense, grey glacial till exposed in the scarp of a small landslide on the western side of Little Ascutney Mountain.

where the till is gray to light brown and very dense (Fig. 4). Till in the area consists of angular to subrounded pebbles, cobbles, and boulders suspended in a fine clay/silt/sand matrix. Most of the till occurring in this area is lodgement till consisting of materials eroded, deformed, and deposited beneath the ice sheet. Close to the ground surface frost heaving, plant roots, and animal borrows have loosened the till and surface run off has eroded some of the smaller-sized sediment (the "fines") in the till. No attempt was made to systematically measure the composition of the till by either grain size or composition nor were any till fabric measurements made.

The upland areas of town are underlain by variable thicknesses of till. The till cover is thin (generally less than 2 to 3 meters) in areas where outcrops are present and thin till is extensive in areas with abundant bedrock outcrops, generally those areas outlined by the bedrock polygons or groups of closely spaced polygons on the geologic map.

In many areas south and southeast of Mount Ascutney and Little Ascutney Mountain the till contains abundant "granite" erratics sourced from these mountains (see photo on front page of this report). This is part of the "Ascutney Boulder Train," an erratic dispersal fan of igneous rocks sourced from these mountains and carried first to the southeast and then south by the overriding ice sheet (Goldthwaite, in Antevs, 1922). In some areas there are concentrations of very large "granite" erratics, e.g. along and adjacent to the power line between Amsden and Downers. These concentrations of large erratics may result from a particular event (e.g. large-scale water pressure fluctuations) or a series of events at the base of the ice sheet, closely spaced in time and space, that successfully quarried and removed a large number of erratics from the underlying bedrock.

Ice-Contact Deposits

Ice-contact deposits are fluvial (stream-deposited) sediments deposited under, adjacent to, or in front of a glacier. These streams are generally fast-moving and therefore carry and deposit coarse-grained sediment, dominantly sand and gravel.

Sediments deposited in subglacial tunnels form ridges of sand and gravel once the glacier melts away that are called eskers. Two subparallel eskers have been mapped in the Black River/North Branch valleys and a third in the Connecticut River valley. The eskers in the Black and North Branch valleys are, in many areas, distinct, mappable ridges (Fig. 5). In the North Branch valley between Little Ascutney and Ascutney Basin Roads the two eskers appear as two segmented, tree-covered ridges rising above the floodplain of the river. In the spaces between the esker segments it’s unclear if (1) the esker has been eroded by the river, (2) the esker ridge crest lies below the floodplain, or (3) if the esker was never deposited in these parts of the subglacial tunnel. Because no water wells exist in the center of this valley, the thickness of these esker sediments is unknown. South of Little Ascutney Road the eskers are largely buried. One reappears in the valley between Amsden and Stoughton Pond and and is the source of gravel in the pit at the south end of Branch Brook Road. A short segment of what may be the other esker appears at the town landfill. Farther south, along the west side of the Black River between Downers and Perkinsville, a well-developed

Figure 5: Tree-covered esker ridge west of Upper Falls Road in the Black River valley. Arrow on inset topographic map (1929) shows location of esker pictured in photo. Esker forms the eastern edge of a closed depression (to left in photo; also shown on map) known locally as the “Perkinsville Bowl.” The closed depression may have once contained a block of glacial ice that has since melted forming a glacial kettle.

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esker ridge was mapped (Fig. 5). It's unclear if this esker system once extended farther east, up the Black River valley or was connected to the subglacial drainage system coming down the North Branch valley. It's very likely these eskers extend south of Perskinsville/Stoughton Pond, but they're most likely buried by younger sediments in the area of the Springfield Reservoir and North Springfield.

The Connecticut Valley esker is only exposed in a gravel pit along the town's northern boundary (Fig. 6) and in two adjacent gravel pits along the Connecticut River in the village of Ascutney. South of Ascutney the esker isn't visible. However, the esker may still exist in some areas, albeit buried beneath younger glacial lake sediments (Fig. 6B). Elsewhere the esker may be on the New Hampshire side of the river or the Connecticut River may have partially or entirely eroded the esker away.

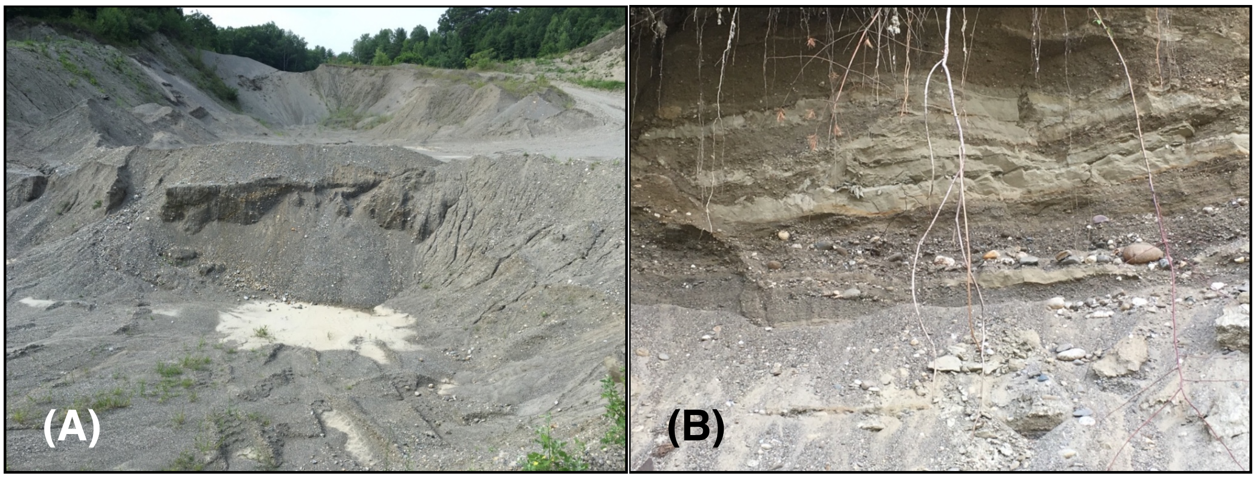

Figure 6: The Connecticut Valley esker exposed in a gravel pit north of Ascutney village immediately west of Route 5 along the town boundary with Windsor. (A) View looks south along the trend of the esker where coarse sand and pebble-cobble gravel comprising the esker has been excavated. (B) Interlayered gravel and very fine sand/silt exposed along the eastern flank of the esker. These sediments were deposited when the ice sheet had retreated just a short distance north of this point and the esker ridge was immediately submerged beneath Glacial Lake Hitchcock. The coarser-grained sediments came from the mouth of the esker tunnel (probably no more than a few 10's of meters away) during times when a lot of water was discharging from the tunnel mouth into the lake (warm summer days with lots of ice melting or rain storms). During times when little water discharged from the tunnel mouth into the lake (winter, cool dry periods) the lake was quiet enough that the fine sand and silt could settle on the flanks of the esker.

<u>Lacustrine (Glacial Lake) Deposits</u>

Glacial lake deposits include both coarser-grained sediments deposited at or near the shorelines of lakes (deltas and beaches) and finer-grained sediments deposited in the deeper quiet-water parts of lakes. Lacustrine sediments occur in both the Connecticut and Black/North Branch river valleys. The glacial lake that filled these valleys is a small part of a much larger lake that occupied much of the Connecticut River valley called Glacial Lake Hitchcock (Fig. 7). In the northern parts of these valleys lacustrine sediments occur up to elevations of ~610 feet whereas in the southern parts of these valleys lacustrine sediments are limited to elevations below 570 feet. The difference in elevation comes from isostatic tilting of the once level lake surface since the retreat of the ice sheet.

The most common deep-water sediments occurring in town are fine sand, very fine sand, and silt. These sediments occur along most of the Connecticut River valley where they are extensively exposed along the river. In the Black/ North Branch valleys these fine lacustrine sediments from Plains Road south to the town line. Across many parts of these valleys the fine-grained lacustrine sediments are overlain by a veneer of alluvium (Fluvial Terrace Deposits) deposited after the lake drained (see below). Very fine grained lacustrine deposits (silt/clay) were only mapped in the

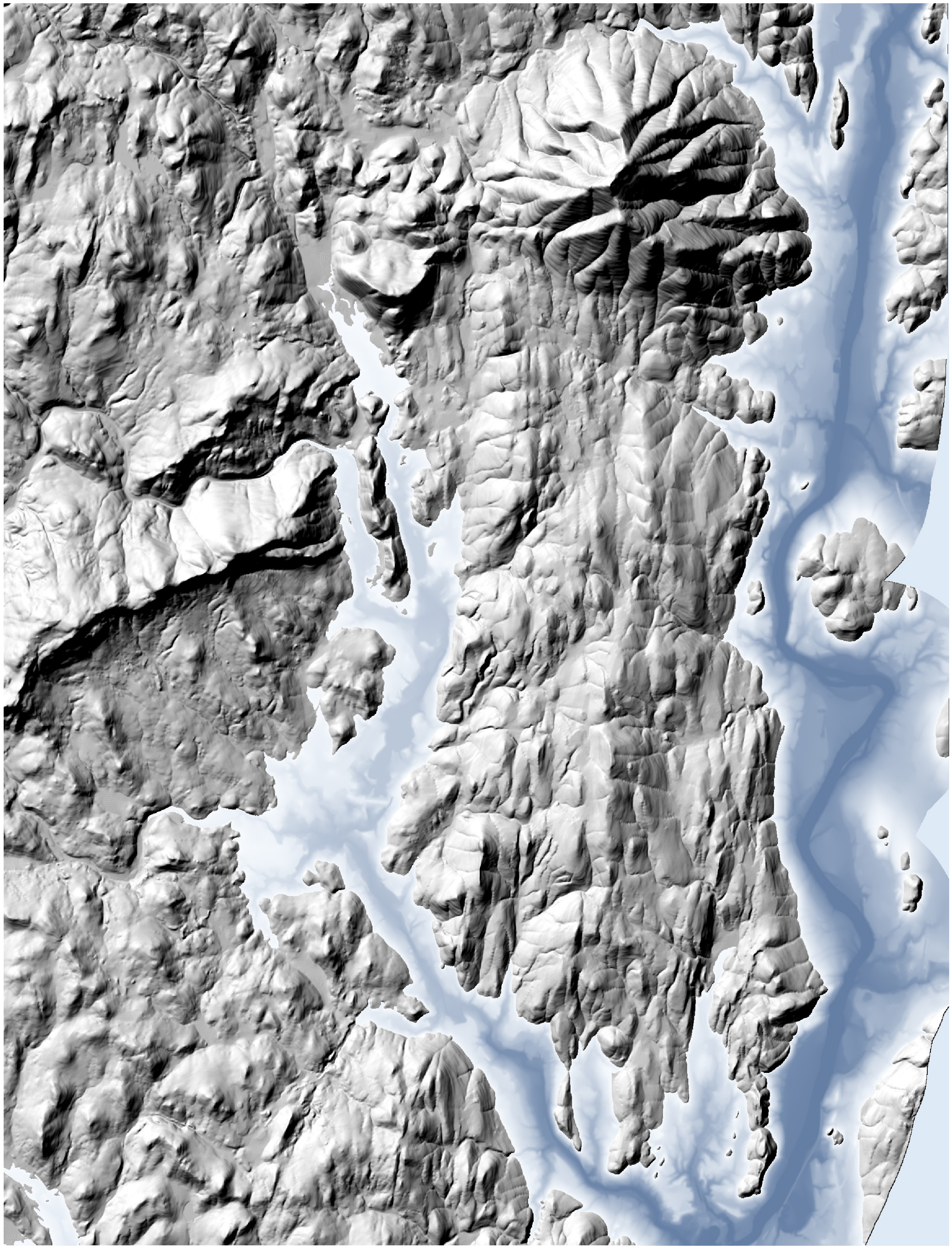

Figure 7: Extent of Glacial Lake Hitchcock in the Connecticut, Black, and North Branch River valleys. The average elevation of this lake across the area was ~600 feet (182 m). Fine-grained sediments (fine sand to clay) were deposited in the deeper parts of this lake whereas sand and gravel were deposited in deltas where streams and rivers entered the lake. Colors in lake correspond to lake depth based on current topography.

Weathersfield Bow area (Ridge, 2005). The dominance of somewhat higher energy sediments (fine sand to silt) may reflect the narrowness of the lake in this area and/or sediment input into the lake from the Sugar River (see below).

In the North Branch valley this lake was quite shallow and rapidly filled with deltaic sediments (sand and gravel). Meltwater from the receding glacier fed the ancestral North Branch river large volumes of water and sediment that were deposited in a delta system that rapidly prograded southwards to the Stoughton Pond area. A similar delta system formed where the Black River entered this lake just west of Downers and this delta also extended south to the Perkinsville area (Koteff and Larsen, 1989). When Glacial Lake Hitchcock drained, the Black and North Branch rivers incised channels through these deltaic sediments. The village of Downers and is built on part of this delta as is that part of Perkinsville that's east of the river. In the North Branch valley incision has extend as far north as Amsden where the river eroded down to bedrock which is currently keeping the river from eroding sediments upstream from here/ The inactive gravel pits in Perkinsville were excavating these delta sediments (Koteff and Larsen, 1989) as is the active gravel pit along the east side of the North Branch river, south of Amsden (Fig. 8).

Figure 8: Coarse sand and gravel exposed in a gravel pit on the east side of the North Branch River approximately 1 km south of Amsden at an elevation of ~600 feet (view looks north). Concave-up structure in the gravel is a relict river channel that formed when a river flowed south into Glacial Lake Hitchcock and indicates that this entire valley was filled with sediments when the channel was active. Since the lake drained, the North Branch river has eroded its channel through these sediments.

In the Connecticut River valley relatively small deltas have been mapped where east-flowing tributary streams entered the main body of Glacial Lake Hitchcock in the Connecticut River valley (Ridge, 2005). However, the largest tributary river in the area is the west-flowing Sugar River which formed a large delta near near Claremont, New Hampshire (Ridge, 2005). Over time this delta grew westward, into Glacial Lake Hitchcock. While the delta surface may never have reached the Vermont side of the lake, abundant sand and gravel deposits exposed in gravel pits south of Ascutney suggest that the Sugar River delta was close when these sediments were deposited.

<u>Fluvial Terrace Deposits</u>

Fluvial terrace deposits are stream sediments (alluvium) occurring on terraces well above modern streams. Most commonly these sediments were deposited when streams began flowing across the bottom of Glacial Lake Hitchcock after the lake drained. As rivers eroded channels more and more deeply through earlier-deposited sediments, older channels were abandoned. Consequently, in many areas mapped as fluvial terrace deposits there are several terrace levels and old abandoned channels are visible in many of these terraces. In most areas these fluvial terraces are underlain by a veneer of sand and gravel corresponding in thickness to the depth of the stream channel that deposited the sediment (Fig. 9). In many areas these gravels have been partially or largely mined away revealing the underlying glacial lake sediments. For geological consistency, terraces where the alluvium has been mined were still mapped as fluvial terrace deposits.

Figure 9: Coarse sand and gravel exposed in an excavation into a fluvial terrace on the north side of the Black River immediately west of Downers on Route 131. These sediments were deposited by the Black River shortly after Glacial Lake Hitchcock drained.

<u>Alluvium</u>

Alluvium refers to sediments deposited by modern rivers and streams. Generally this includes gravel deposited in the river channel, sand deposited on point bars, and sand and silt deposited on floodplains. Organic materials are a frequent component of modern alluvium. In most areas modern alluvium is in contact with fluvial terrace deposits (old alluvium). The contact between these two mapping units is an interpretation of how much area is flooded during high-water events. Satellite imagery, taken shortly after the Irene flood in August of 2011, was utilized to draw this contact on the geologic map. The thickness of alluvium is proportional to the size of the stream that deposited it, but generally corresponds to the depth of the modern stream channel. In the larger valleys alluvium directly overlies glacial lake deposits. In smaller stream valleys alluvium overlies glacial till. Alluvium was not mapped along small streams where the extent of alluvium was small and discontinuous.

Alluvial Fans

Alluvial fans are fan-shaped deposits formed where steeply-sloping streams deposit sediment flow out onto a gently-sloping valley floor, e.g. a fluvial terrace or modern floodplain. Sediments deposited in alluvial fans generally grades from coarse to fine between the apex of the fan to its toe. The absolute size range of sediment in fans depends on the source of sediment. In many upland areas fans are sourced from till remobilized as debris flows and the fans consist largely of unsorted diamict. In areas where streams are eroding channels through fine-grained lacustrine sediment, that will be the size of sediment deposited in the fan. Several alluvial fans of different sizes are shown on the geologic map. Doubtless others were overlooked in the course of field work.

Studies in northern Vermont indicate that alluvial fans similar to these have been active episodically throughout the Holocene and have often received their most recent pulse of sediment following European land clearing in the late 18th and early 19th centuries (Bierman et al, 1997, Jennings et al., 2003). Related work by Noren and others (2002) utilizing pulses of clastic sediment deposited in ponds and small lakes, indicates that pre-European settlement erosion has not been uniformly distributed throughout the Holocene and seems instead to be concentrated during periods of increased high-intensity storms. If climate shifts produce a greater frequency of “Irene-like” storms in the future, further sedimentation on the area’s alluvial fans seems likely.

Swamp/Wetlands

Wetland areas generally occupy closed basins and occur on a variety of scales across Weathersfield. Most are naturally occurring, but some exist as a consequence of dams or roads that have damed drainage. The dominant sediment in wetland areas consists of both living and partially decayed organic materials as well as inorganic sediment washed into these areas by streams and overland flow. These wetlands were mapped using satellite imagery, but the boundaries shown on the geologic map should not be used for regulatory purposes.

One notable group of wetland areas follows a valley south from the old school in Perkinsville almost to Kendricks Corner. It’s possible that this is an old channel of the Black River now partially filled with glacially-deposited materials.

Artificial Fill

Artificial fill occurring in large structures is shown on the geologic map, e.g. the Stoughton Pond dam and fill used under some parts of the interstate. However, not all areas of fill are shown on this map.

Landslides

Many small landslides were encountered during field work. Most are relatively small (5–20 m in length, <10 m in height) and all occur adjacent to streams. The small landslides are shown as points on the geologic map. Along the Black River several larger landslides were mapped and their extent is shown with small lines. Landslides that occurred during the Irene storm in 2011 and have since been obscured by construction are not shown on the map (e.g. the landslide south of Downers that took out a section of Route 106).

Geologic Cross-sections

Two approximately east-west geologic cross-sections were constructed, one in Perkinsville and the other just south of Ascutney (Figs. 10, 11). Cross-sections present an interpretation of what surficial materials lie beneath Earth’s surface and their thickness. The best information available about the type of thickness of surficial materials in most areas comes from the logs kept by drillers when completing domestic water wells. Considerable time was spent mapping the locations of as many water wells as possible in these two areas and then trying to match the well-log records maintained by the Agency of Natural Resources with these located wells. The most accurate information recorded by drillers is the “depth to bedrock” or “overburden thickness” as this is equivalent to the length of steel casing needed for a drilled well, a length carefully recorded and charged to the home owner. Otherwise, the quality of records kept by drillers of the type and thickness of the surficial material they drill through varies enormously and frequently requires some interpretation based on field evidence.

Perkinsville Cross-section

The Perkinsville cross-section extends from the hillside just west of Perkinsville, crosses the Black River, parallels Stoughton Pond Road, crosses the North Branch River below the Stoughton Pond dam, and ends a short ways up the hillside above Reservoir Road (Fig. 10; see geologic map for location). Surficial materials in this area are relatively thin (<100 ft), although the depth to bedrock below the floodplain of the North Branch River is unknown. The depth to bedrock recorded in Well 619 suggests that an older, deeper bedrock channel lies immediately west of the river's current channel. The well log for lists "clay" as the only material encountered by drillers. Based on mapping in the area it seems that this material is more likely to be till, albeit a rather thick accumulation of till. It's also possible that there is a thin mantle of till overlying "clay" deposited in a glacial lake that predates Glacial Lake Hitchcock. Till cover on the east side of the cross-section is thin and more typical of the region.

The large terrace between the two rivers is underlain by sand and gravel as is evident in both well logs and and the abandoned gravel pits. Koteff and Larsen (1989) visited these pits when they were active and interpreted the sand and gravel deposits as part of a delta system formed where the Black River entered Glacial Lake Hitchcock. Some of the sand and gravel comprising the terrace may be the southern continuation of the esker mapped a short distance north of here along Upper Falls Road.

Very fine sand and silt outcrops on the eastern side of the valley. These sediments, deposited in the deeper, quieter parts of Glacial Lake Hitchcock are abundant south of Perkinsville suggesting that the delta system produced by both the Black and North Branch Rivers never grew farther south than Perkinsville. These same quiet water sediments occur in the small valley east of Stoughton Pond indicating that this area was a relatively isolated bay in the lake.

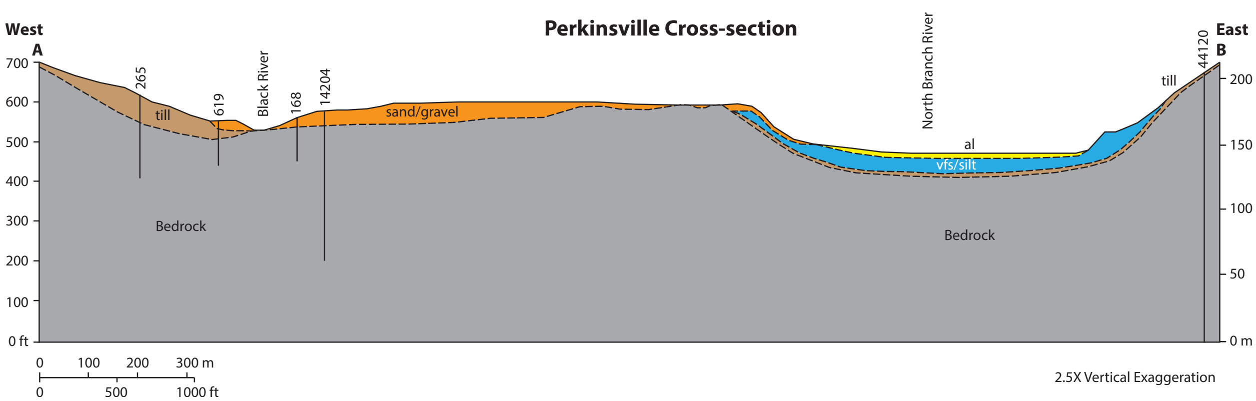

Figure 10: Cross-section depicts in interpretation of the thickness and types of surficial materials occurring near Perkinsville, Vermont. Location of cross-section is shown on the Surficial Geologic Map. Vertical black lines represent water wells and the numbers above them are the Well Report Numbers. See text for a description of the materials occurring on this cross-section.

Tenney Hill Cross-Section

The Tenney Hill cross-section begins on the hillside west of the I-91, cuts across the Tenney Hill residential neighborhood, and then drops down and crosses the Connecticut River (Fig. 11; see geologic map for location). A relatively thick section of surficial materials lies on top of bedrock in this area although the depth to bedrock beneath the Connecticut River is speculative as no wells or outcrops occur close to the river. "Clay" is reported in Well 83 and may well exist beneath the very fine sand/silt occurring adjacent to the river. These sediments were deposited in the deeper, quieter parts of Glacial Lake Hitchcock. The “sand” reported in well logs probably also includes some gravel as was visible in the old pit where Well 48332 was drilled (adjacent to the new substation). The sand and gravel may originate from one or more of the following sources: (1) The southern extension of the Connecticut Valley esker mapped from Ascutney village north, (2) Sediments deposited by the Sugar River entering Glacial Lake Hitchcock, most likely occurring as bottom-set and possibly fore-set beds of a delta, and (3) Sediments deposited by the Connecticut River as it began flowing across the bottom of Glacial Lake Hitchcock once the lake drained.

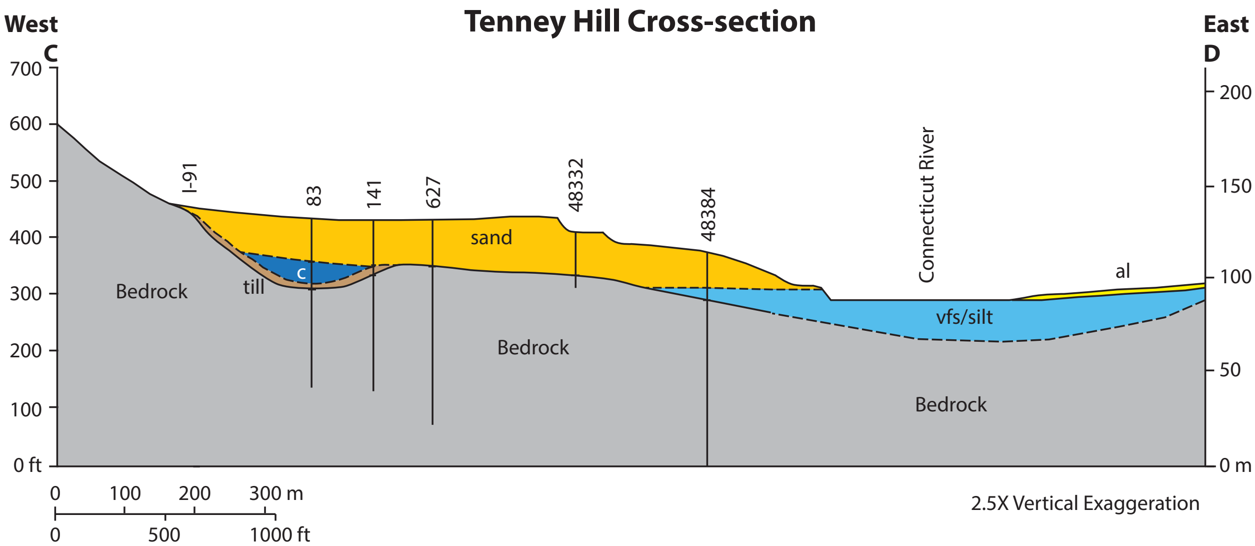

Figure 11: Cross-section depicts in interpretation of the thickness and types of surficial materials occurring west of the Connecticut River, not far south of Ascutney, Vermont. Location of cross-section is shown on the Surficial Geologic Map. Vertical black lines represent water wells and the numbers above them are the Well Report Numbers. See text for a description of the materials occurring on this cross-section.

<u>Ground Penetrating Radar</u>

Another way to assess the distribution of surficial materials below the ground surface is Ground Penetrating Radar (GPR). GPR works by projecting radar waves into the ground where they are reflected and absorbed by the underlying sediments (Fig. 12). A record of the reflections shows the layering in the underlying sediments, e.g. sand interlayered with gravel. Seth Campbell (Univeristy of Maine) and Steve Arcone (CRREL) contributed one day surveying several areas in the North Branch valley. The profile shown below (Fig. 13) was made along a section of Little Ascutney Road where the road crosses the floodplain of the North Branch River. No water wells exist in the center of the valley. Horizontal layers (beds) dominate the sediments immediately beneath the road surface and probably represent sediments deposited by the river as it has meandered back and forth across

Figure 12: Ground-penetrating radar antennas (orange) being dragged across the floodplain of the North Branch valley.

the valley, alluvium. In the center of the profile layers form an arch. These bedforms most likely are from sediments deposited in the esker which has been mapped immediately north of here. In this area the esker has been completely buried by younger sediments.

There is no strong reflector that could be interpreted as the contact between the surficial materials and the underlying bedrock. The radar signals weren't strong enough to penetrate that deep, so there is still no information about the thickness of surficial materials in this area.

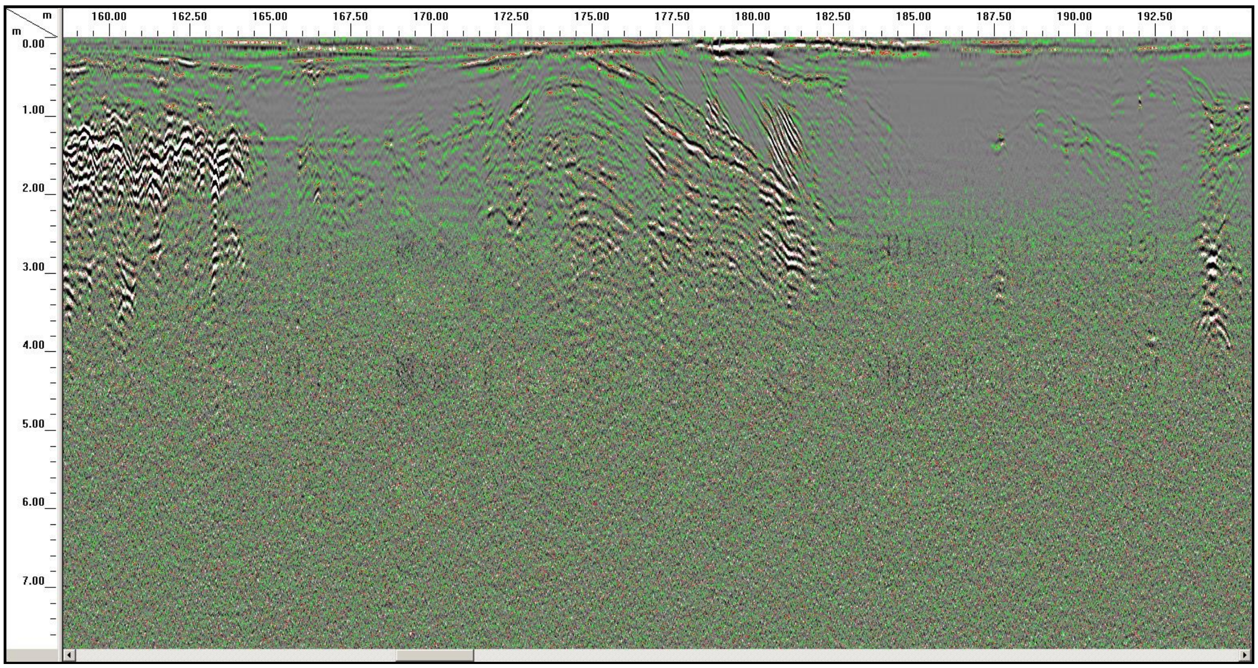

Figure 13: West–East radar profile along Little Ascutney Road. All numbers are in meters (note considerable vertical exaggeration. Zero on the horizontal scale begins near Greenbush. Near-surface layers are sub horizontal and probably are modern alluvium. Layers that are arched upwards in the center of the profile are immediately south of a mapped esker and may record that esker buried in the subsurface.

Overburden Thickness Map

The thickness of surficial materials (overburden) is shown on a separate map. The principal data used to generate this map are bedrock outcrops (which indicate that surficial materials are missing) and records of overburden thickness from domestic water wells. In most areas the overburden thickness is less than 100 feet and there are no areas where the thickness exceeds 150 feet. For this reason only one contour was drawn on the map separating areas having greater than or less than 50 feet of surficial material overlying bedrock. Note that in many areas there is little data to support the exact placement of these contours and what's shown is an interpretation.

In the upland areas widely separated wells showing more than 50 feet of overburden were generally not encircled by a contour unless there was a geological reason to think they might represent a continuous area of thick surficial materials. In most cases these well were drilled in very local pockets of thick surficial material. These may result from landslides that occurred shortly after the ice sheet retreated, alluvial fans that were missed during mapping, or accumulations of old surficial material that formed prior to the advance of the latest ice sheet.

The broadest areas of thick surficial materials occur in the major river valleys. The valleys have accumulated not only the till that's also present in the uplands, but all of the ice-contact (e.g. esker) and glacial lake sediments that accumulated as the ice sheet was retreating across this area.

Groundwater Hydrology

The town of Weathersfield relies entirely on groundwater for its drinking supply. Dug wells are used by many homeowners and tap aquifers in surficial materials close to Earth's surface. Drilled wells, both privately and publicly owned, are used by most residents. Most of these extend into bedrock and the portion of the drill hole penetrating surficial materials is cased to keep the well from collapsing and to keep groundwater in the surficial materials from entering the well. Drilled wells can also tap deeper surficial aquifers. The Fire Department wells next to the river in Ascutney are an example of that.type of well.

Many different types of bedrock underlie the town. However, they are all igneous or metamorphic rocks and have no or primary porosity, meaning there is no open space in these rocks to store water. The groundwater in these rocks is located in fractures and any drilled well in bedrock gets its water from fractures that well intersects. Generally, the volume of groundwater in fractured bedrock aquifers depends on the density of fractures but is typically less than 1% of the rock volume (Fig. 14). On the other hand, most surficial materials have a lot of primary porosity, a lot of open space between individual sediment grains, typically 25–45% of the volume of the sediments. The usefulness of water in those pore spaces depends on how easily water can move through these surficial materials. Generally, groundwater moves very slowly through fine-grained materials and much more quickly through coarse-grained materials.

Figure 14: Fractured bedrock outcrop along the east side of Route 106 immediately north of its intersection with Kendricks Corner Road. Closely spaced interconnected fractures provide the pathways groundwater flows through bedrock Weathersfield.

The largest useful groundwater reservoirs occurring in Weathersfield are found in the coarse-grained surficial materials (sand and gravel) where those materials extend below the water table. Of these, the eskers shown on the geologic map and the extensive deltaic and glacial outwash deposits underlying modern alluvium in the North Branch are the best. This type of aquifer is susceptible to contamination from human and agricultural sources. However, in some parts of Weathersfield fine-grained lacustrine sediments overlie and bury eskers and other coarse-grained sediments. While these fine sand to silt-size sediments may not be fine enough to confine an aquifer in the eskers, they do serve to filter/adsorb many potential contaminants from entering these potential groundwater sources.

What follows are descriptions of the different maps that attempt to interpret some aspects of the area's groundwater geology.

Water Table Contour Map with Flow Lines

A map contouring the elevation of the water table is included with this report. The data used to construct these contours comes from topographic maps of the area and domestic water wells where the depth to the water table was recorded. Specifically, groundwater discharges to the surface in streams, ponds, lakes, and wetlands so these are areas where the elevation of the ground surface and the elevation of the water table are equal. In areas between these groundwater discharge points the water table is, by definition, at an elevation below the ground surface. Streams are common in the upland areas implying that even in these areas the water table is relatively close to the ground surface.

Water table contours were drawn at 200 foot intervals across most of Weathersfield. In limited areas addition contours were drawn to clarify the elevation of the water table. The water table elevation at domestic water wells was determined by subtracting the depth to groundwater at each well from the ground surface elevation of those wells (calculated from the digital elevation model, DEM). These elevations are labeled on the map next to the wells. "Depth to Groundwater" was not recorded at most water wells, so most wells shown on the map have no groundwater table elevation label.

The elevation of the water table varies seasonally. It's generally highest in the early spring when groundwater is recharged by melting snow and rain. It's generally lowest at the end of the summer/early fall when the combination of lower summer rainfall and very high evapotranspiration rates from plants limits recharge. Consequently, water table contour lines on a map shift seasonally, moving up in the spring and down during the summer months. This is why many streams at higher elevations flow in the spring, but go dry during the summer.

A major north-south drainage divide separates both surface and groundwater flowing west into the Black and North Branch rivers from surface and groundwater flowing east into the Connecticut river. This divide is shown with a dashed blue line on the map. Many smaller hydrologic divides also occur separating tributary drainage basins. These aren't shown on the map, but can be inferred from the groundwater flow lines (see below).

Groundwater flows down-gradient (downhill) perpendicular to groundwater contour lines. Interpretive groundwater flow lines (arrows) are drawn on the map showing the approximate directions of groundwater flow in town. In general, most of these flow lines begin in the upland areas and end at streams where groundwater discharges to the surface. The flow lines can be used to understand the pathways groundwater has taken to reach domestic water wells. The flow lines can also be used to interpret the different types of bedrock and surficial material groundwater has flowed through. These different types of rock and surficial material are the sources of all the naturally-occurring dissolved ions in groundwater. For groundwater contaminated with human/domestic animal waste or other toxic chemicals, the flow lines can be used to search areas up-gradient from the contaminated groundwater for potential sources. Note however that the detailed groundwater flow paths needed to show point sources of groundwater contamination cannot be deciphered from this map.

Bedrock Hydrologic Unit Map

A “Bedrock Hydrologic Map” was generated using a map showing the different types of bedrock occurring in town, domestic water wells, and the yield from those water wells. Wells are shown on the map as red dots the size of which is proportional to the yield from those wells. The reported yield (GPM: Gallons Per Minute) from each individual wells is also shown.

High-yield wells (>10 GPM) occur in a variety of rock units, i.e. there does not seem to be any unique rock units that consistently produce high-yield wells. The same is true of low-yield wells (<2 GPM), i.e. low-yield wells occur across town in most rock units. These results strongly suggest that well yields in the area are largely dictated by fractures in the underlying bedrock (specifically the number, width, length, and interconnectedness of those fractures) and not the composition of the bedrock.

Extensively fractured bedrock is more susceptible to weathering and erosion than unfractured bedrock and frequently guides the location of large- and small-scale valleys that are quite linear. These linear features can be mapped and used as a guide for drilling high-yield bedrock water wells. A map of this type was not generated as part of this project.

Recharge Potential to Surficial and Bedrock Aquifers Maps

Groundwater recharge depends on (1) how easily rainfall and snow melt can infiltrate the ground surface, (2) the rate at which water can move through the surficial material or rock it infiltrates into—its permeability, (3) the amount of time that water is available to enter different groundwater systems. Infiltration is enhanced when the ground surface is permeable and rainfall and snow melt can linger on the ground surface. Coarse-grained surficial materials on level ground provide the best infiltration whereas steep bedrock surfaces provide the worst. Vegetation, burrowing animals, and frost heaving usually enhances infiltration by increasing the permeability of soils and providing a myriad of small depressions where surface water can linger. Fine-grained surficial materials usually have a low permeability. Even if vegetation allows water to infiltrate, the rate it can percolate (seep) into the material may be far slower than the rate at which new water from rainfall or snow melt is available. In fine-grained materials with low permeability, e.g. many tills and lacustrine sediments, a significant amount of water can move though these materials if enough time is available.

<u>High Recharge Potential to Surficial Aquifers</u>

Alluvium, Artificial Fill, Alluvial Fan sediments, Fluvial Terrace sediments, Deltaic sediments, Eskers, and Wetlands are all materials that readily absorb surface water. They all consist of coarse-grained surficial materials lie in valleys where slopes are gentle. Where these materials overlie moderate- to low-permeability materials, they have the capacity of soak up surface water allowing it to slowly seep into these underlying surficial materials. With the exception of the wetlands areas, these materials make excellent surficial aquifers where they extend below the water table.

<u>Moderate Recharge Potential to Surficial Aquifers</u>

Lacustrine very fine sand, fine sand, silt and most till have moderate to low permeabilities. Till mantles most upland areas usually directly overlies bedrock, so till itself is the surficial aquifer that’s being recharged. As noted earlier, animals, vegetation, and frost heaving enhance near surface infiltration and dug wells utilizing utilizing groundwater from till are common (Fig. 15).
Lacustrine fine sand occurs in the valley bottoms where slopes are gentle which enhances it’s ability to absorb water. Shallow dug wells also occur in this material. Slow movement of water through these materials can recharge coarse-grained aquifer materials beneath.

<u>Low Recharge Potential to Surficial Aquifers</u>

Lacustrine silt/clay is the only true very low permeability surficial material in the area and surface exposures are limited to the Weathersfield Bow area.

Figure 15: Shallow dug well in till adjacent to bedrock outcrop. Infiltration through the till is sufficient to supply water to shallow wells and to recharge the underlying bedrock aquifers.

High Recharge Potential to Bedrock Aquifers

A variety of materials have high recharge potential to bedrock aquifers, but they make up relatively little of Wethersfield's surface area. Wetlands and ephemeral pools/ponds (not mapped) provide a continuous source of water that can seep though any underlying surficial materials and into the bedrock (Fig. 16). Some wetlands and most ponds are groundwater discharge areas, meaning that groundwater from the surrounding and underlying surficial materials and bedrock is flowing into these water bodies, i.e. these areas are not recharging groundwater.
Other areas with a high recharge potential to bedrock aquifers where they are not in groundwater discharge areas include Artificial Fill, Alluvial Fan deposits, Deltaic deposits, and Eskers. Eskers are particularly good in that the coarse sand and gravel comprising the esker lies directly on bedrock.

Moderate Recharge Potential to Bedrock Aquifers

Materials offering moderate recharge potential to bedrock aquifers include Glacial Till, Lacustrine fine sand–silt, Fluvial Terrace deposits, and Alluvium. These materials underly a very large proportion of town. The alluvium and fluvial terrace deposits are included in this category in spite of their very high infiltration capacity because these materials frequently overlie till or lacustrine sediments with moderate to low permeabilities and because these materials frequently lie in groundwater discharge areas. Thick till in the upland areas has the potential to recharge bedrock aquifers, albeit slowly, most of the year.

Figure 16: One of several wetland areas lying between Perkinsville and Kendricks Corner. This particular wetland lies in a valley and is probably an example of a wetland that fed by groundwater rather than a recharge area to the underlying groundwater reservoir.

<u>Low Recharge Potential to Bedrock Aquifers</u>

Bedrock Outcrops do not provide good places for groundwater recharge. They do get wet when it rains and when snow melts, but that water doesn't linger on the rock surface long enough to provide significant recharge, An exception occurs when these outcrops are covered with snow and that snow begins to melt or it rains. If there isn't a layer of ice within the snow and there are fractures in the exposed rock, the snow can potentially keep that water in contact with the rock long enough for some water to enter those cracks.

Lacustrine silt and clay have very low permeability and do not provide an avenue for significant recharge to bedrock these materials mantle.

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