Vermont Geological Survey Open File Report VG04-1

# Surficial Geology and Hydrogeology

# Of

# Manchester, Vermont

## A Technical Discussion

## With

## Executive Summary

By

**David J. De Simone, Ph.D.**
**P.O. Box 272**
**Grafton, NY 12082-0272**

**Prepared under Contract to the Vermont Geological Survey**

**Laurence R. Becker, State Geologist**
**103 South Main Street, Old Laundry Bldg.**
**Waterbury, VT 05671-0301**

**Contract DEC 08-03**

## Executive Summary

The primary objective of this investigation was to provide a modern inventory of surficial and hydrological data illustrated through a series of GIS formatted maps explained in this discussion. These maps can thus be easily modified as new data are generated and new interpretations invoked in the years ahead. This report and accompanying maps are meant to serve as a baseline for our current knowledge of the surficial geology and hydrogeology of the Manchester area. While the discussion is highly technical, there are appendices which make the data useful to the average layman, farmer, gravel resource extractor, land use planner or developer. The surficial geologic mapping units are accordingly explained in the context of their encompassing soils, slope stabilities, permeabilities, drainage, and gravel/sand resource potential. Indeed, a separate non-technical discussion and the unit descriptions mentioned above have been packaged into an accompanying report and history for Manchester residents.

The results of the mapping enabled me to decipher details of the deglaciation of the quadrangle unrecognized by previous workers. Three ice margins – Skinner Hollow, Manchester and South Dorset - were delineated on the basis of prominent kame moraines and moraines. A retreat of largely active valley glaciers is supported by the mapping and stagnation zones may have existed along the margins of these valley glaciers. Asynchronous retreat is indicated by the prominent moraines formed by the Dorset glacier which may have been due to a localized re-advance while the Danby glacier to the east apparently stagnated. Extensive deposition of a unit termed ground moraine occurred throughout the valley but especially along the western margin of the Manchester glacier and this suggests the presence of a stagnating margin attached to the edge of the actively retreating valley glacier. No significant quiet water and deep water lacustrine sediments were observed. This observation coupled with a similar paucity of lacustrine sediments to the south in the Arlington quadrangle (De Simone, 2001) strongly indicates that Glacial Lake Batten did not exist as a widespread open body of water. Numerous localized pockets of ponded waters existed in association with the ever wasting ice margin but no prominent glacial lake was recognized. I conclude that the Arlington kame moraine to the south did not dam a notable glacial lake.

Both an overburden aquifer developed in glacial gravels and bedrock aquifers developed in carbonate rock exist and represent extremely valuable sources of potable water. Yields from wells in either aquifer typically exceed 10 gallons per minute (GPM) and many yields exceed 30 GPM. The data hint that these two aquifers may be hydraulically connected. The subsurface data indicate that a basal lodgement till layer is largely absent from the valley region. Gravel is often recorded by drillers immediately atop limestone. Any overlying impermeable overburden units appear to be thin and discontinuous. The overburden water table and the carbonate aquifer piezometric surface maps are very similar. The extensive areas of kame moraine, ground moraine, kame and outwash at the surface indicate that considerable recharge of the overburden and carbonate aquifers is occurring through direct infiltration of water through these variably but relatively permeable sediments. The carbonate aquifer may be only locally isolated from the overburden aquifer by impermeable till or diamicton units.

**Contents**

| | Page |
|---|---|
| Physiography | 4 |
| Field Data Sites | 5 |
| Bedrock Geology | 5 |
| Bedrock geology and topography | 5 |
| Bedrock hydrogeologic units | 6 |
| Carbonate aquifer piezometric surface | 7 |
| Carbonate aquifer recharge potential | 7 |
| Glacial Geology | 8 |
| Late Woodfordian glaciation | 9 |
| Deglaciation | 10 |
| A. Skinner Hollow ice margin | 11 |
| B. Manchester ice margin | 11 |
| C. South Dorset ice margin | 12 |
| Overburden hydrogeologic units | 13 |
| Overburden water table | 13 |
| Overburden recharge potential | 14 |
| Conclusions and Recommendations | 15 |
| Appendices | 16 |
| 1. Data sources: description of numbered exposures | 16 |
| 2. Mapping unit descriptions | 18 |
| References | 21 |

## Physiography

Map 1 shows the topography of the Manchester quadrangle. Three mountainous areas bound a Y-shaped valley area on the Manchester quadrangle. Green Peak (3230ft) and Owls Head (2481ft) form an east-west ridge with steep southerly flanks and this ridge is bracketed by 2 narrow tributary valleys to the primary Vermont Valley. The peaks are underlain by resistant schist/phyllite bedrock (Map 2).The southeast corner of the quadrangle contains the flanks and ridges of the Green Mountains. Unnamed summits in this portion of the Greens range from 2230ft to 2886ft and ridges trend northeasterly. The area is underlain by resistant quartzite and gneiss (Map 2). The Taconic Highlands comprise the western quarter of the quadrangle and Mt. Equinox (3840ft) and Mother Myrick Mountain (3361ft) buttress the south and north ends of a ridge which exceed 3000ft elevation and trends generally north-south. The Taconic summits are underlain by relatively resistant schist/phyllite bedrock (Map 2).

The Dorset Valley trends northwest-southeast and contains the West Branch, a tributary to the Batten Kill. At the northwest extent of this valley in the quadrangle is a broad drainage divide area with waters that flow northwest out of the quadrangle. This divide area is largely wetlands. The Danby Valley trends north-northeast and continues the trend of the Vermont Valley. The upper Batten Kill flows southward toward the village of Manchester through the Danby Valley. The broader Vermont Valley, a prominant lowland in southern Vermont, continues the same NNE-SSW trend of the Danby Valley. The Batten Kill and West Branch join in the center of the quadrangle and the Batten Kill meanders south-southwestward out of the quadrangle.

Map 2 shows the major and minor streams in the quadrangle. Five tributaries to the Batten Kill draining the Green Mountains are notable. Lye Brook and Bourn Brook enter the valley after traversing deep, steep-sided valleys in their lower reaches. The Lye Brook Wilderness affords easy access along old rail and road trails into the former tributary drainage. Bromley, Stony, Little Mad Tom and Mad Tom brooks all flow generally south-southwestward out of the mountains. Windhall Brook and an unnamed brook to its east both drain the southern flank of Green Peak. All of the above mentioned brooks with the exception of Bourn Brook all appear to follow the primary NNE-SSW structural trend in the bedrock noted on Map 2. Bourn Brook appears to follow a secondary trend at right angles to the primary. Numerous tributaries drain the Taconic Highlands on the west. Tanner, Equinox, Munson, Myrick Pass (informally named here), Wideawake, Goodman, Gilbert and Daley brooks are the noted on Map 2 along with several unnamed brooks. The paths of these tributaries tend to be subparallel and follow, in part, the secondary structural trends in the bedrock. Springs or seeps were observed in the headwater areas of a couple of these Taconic tributaries. The setting suggests a line of such springs situated along or near to the contact between the overlying schist/phyllite and the underlying carbonate bedrock.

## Field Data Sites

Map 3 depicts the location of field data sites such as observed bedrock and overburden exposures. Sites which yielded considerable, useful data are numbered from MAN03-1 through MAN03-19. Descriptions of the numbered filed data sites can be found in Appendix 1. Smaller sites are identified by an “x” and a notation as to the type of overburden material present. Strike and dip data and lithology are noted for most outcrops.

A single rockslide was observed and considered a mappable feature. It occurs along the upper reach of Equinox Brook and can be seen along the hiking trail which leads to the summit of Mt. Equinox.

Several small slumps and one large slump are noted on Map 3. The large slump occurs in the flank of the quadrangle’s only esker system and has extended through the crest of the esker along the Batten Kill at the location of the Town of Manchester’s sewage treatment settling ponds. This slump poses a clear threat to the integrity of the sewage treatment facility. At this writing, a plan to remediate the slump is expected to begin during late summer of 2004.

The esker system noted above is depicted on Map 3 by a series of “>>>>>” showing the extent of the esker segments. The esker system extends for more than 2 miles and consists of numerous short segments which bifurcate and rejoin the main segment which is also discontinuous. At its maximum, the main esker is approximately 60 feet or more in height.

Ice flow direction indicators are shown on Map 3. The measured compass orientation of striations and grooves in bedrock is recorded alongside the head of the arrow symbol. In addition, the orientation of prominent streamline molded landform features such as drumlins, rock drumlins and related forms are depicted. A dashed line at the 1,500 foot elevation contour separates valley ice flow from upland ice flow indicators. The most obvious feature of Map 3 is the strong alignment of valley ice flow indicators parallel to valley orientation. This verifies the latest ice in these valleys was thin and actively flowing valley ice.

## Bedrock Geology

**Bedrock geology and topography:**

Hewitt’s (1961) vintage map and discussion of the bedrock geology of the region provided the basis for lithologic identification of bedrock units. However, I was interested only in the hydrogeologic characteristics of the major bedrock lithologies and distinguished only between carbonate, quartzite and schist, making no effort to assign the rocks to designated formations. Map 2 depicts these 3 major lithology groups. A major structural trend is aligned with jointing, foliation and fold axes oriented approximately north-northeast. Secondary trends are recognized at 90 and 45 degrees to the primary trend. It has already been noted that stream locations are apparently aligned with structural trends. Generally, bedding dips eastward at shallow to moderate angles as recorded on Map 3.

The schist and phyllite atop the Taconic Highlands defends the highest elevations on the quadrangle. These include Mt. Equinox, Mother Myrick Mountain and Green Peak, the latter geologically within the Taconic Highlands as well. While the quartzite and gneiss and minor schist of the Green Mountains is arguably more resistant, only a small portion of the Green Mountains extends into the quadrangle along the eastern edge through the southeastern corner and thee higher elevations of these mountains are not included. Carbonate rocks – limestone, dolostone and marble – underlie the majority of the quadrangle. In the Taconics, the carbonates extend up elevations ranging approximately from 2200-2400 feet. In the Greens, the carbonates extend only to elevations ranging from approximately 750-900 feet. The carbonate rocks are comparatively less resistant to weathering than the schist, gneiss and quartzite and thus underlie the mountain flanks and valley bottoms. This is reinforced when you examine the topography of the valley floors. Several prominent low ridges protrude above the surrounding lowlands and these occur where more resistant quartzite interlayers with the carbonate rock.

**Bedrock hydrogeologic units:**

The lithologic groups depicted on Map 2 represent the 3 bedrock hydrogeologic units I distinguished. These distinctions are useful. While lithologies other than the carbonates may yield water to wells, the majority of the wells are drilled into the carbonate rocks simply because the areas underlain by the carbonate rocks are the areas which have been developed. There were no wells drilled into the higher elevations of the Taconics where schist and phyllite may be found. I infer that this unit represents an aquitard or poor aquifer based upon its low porosity and permeability or hydraulic conductivity. Elsewhere where I have worked in Taconic lithologies this has proven to be a true inference.

There are few wells drilled into the lower flanks of the Greens in the eastern part of the quadrangle where quartzite and/or gneiss may be found. Only 9 wells were drilled into water-bearing material I interpreted as quartzite or gneiss. The average yield of these wells was only 3.7 gallons per minute (GPM) and yields ranged from 1-7 GPM. An additional 7 wells mentioned drilling through or finishing in quartzite but I suspect that from the well log the water-bearing layers may have been either gravels at shallower depths or fault zones where “schist” was reported. Yields in these wells ranged from 15-60 GPM and averaged 42 GPM. Based upon these data, I considered the quartzite-gneiss-schist unit of the Green Mountains to be an aquiclude or poor aquifer. Well logs in the lower Greens which recorded schist are in locations I believe to be at the lower contact with carbonate rock and/or are along a more permeable fault zone at this same structural setting. There were 8 such wells and their yields ranged from 10-200 GPM with an average yield of 46 GPM. However, this average is skewed by the sole yield of 200GPM. Excluding this value produces a more reasonable average “fault zone” yield of 24 GPM.

Carbonate bedrock represents the major aquifer of the quadrangle. However, well yields ranged widely from 1-200 GPM. This is likely the result of fracture density and dissolution variations from one place to another in the carbonate unit. In areas where few fractures and/or dissolution openings were encountered during drilling, yields ranged generally from 1-12 GPM. In areas where a higher fracture density with or without solution openings was encountered, the yields generally ranged from 10-200 GPM with many wells yielding water at rates greater than 30 GPM.

**Carbonate aquifer piezometric surface:**

Map 4 depicts the carbonate aquifer piezometric surface as determined from the cataloged well data. Static water level in the bedrock wells was contoured with a 30 ft contour interval. The range of error in piezometric surface elevation is estimated at +/- 5 ft. The surface drainages – Batten Kill and West Branch – are the low areas on this map suggesting that the carbonate aquifer is primarily an unconfined aquifer which discharges into the Batten Kill and West Branch along portions of these stream courses. The higher elevations of the piezometric surface along the flanks of Mt. Equinox, Mother Myrick Mountain and Green Peak indicate that some recharge is occurring through the higher schist-phyllite bedrock aquitard and the generally thin cover of overburden on the high summits. Some recharge is also apparently occurring through the high ridges eat of the Batten Kill, specifically the kame moraine ridge west of Bromley Brook and Beech Ridge to the north. These are the areas where the carbonate must be in contact with quartzite-gneiss of the Green Mountains, perhaps with a fault zone at this contact. Several of the more productive wells drilled into schist or quartzite or gneiss occur in these areas. The prominent ridge extending from Manchester Center north-northeastward through South Village Pond in East Dorset represents a high area of the piezometric surface. Recharge of the carbonate aquifer occurs through this ridge of interlayered carbonate and quartzite.

The question of the confined or unconfined nature of the carbonate aquifer must be addressed. Available subsurface well drilling data do not support the presence of widespread till which could act as a confining layer over the carbonate aquifer. Indeed, till is largely absent from valley well records. Thus, it is likely that the carbonate aquifer is an unconfined aquifer with only localized areas where a confining till layer exists. The piezometric surface must then be grossly equivalent to the water table. Later, a comparison of the overburden water table with the carbonate piezometric surface will support this notion.

C**arbonate aquifer recharge potential:**

Map 5 shows recharge potential for the carbonate aquifer. Recharge potential is ranked from I-V with I being the highest recharge potential. In the Taconic Highlands and Green Peak massif, recharge potential through the summit schist-phyllite is high as there is only a thin or absent veneer of overburden and the schist-phyllite is sufficiently fractured and foliated to transmit water downward. The occurrence of a major spring, the Upper Spring along Equinox Brook supports my belief. This very large spring issues from near the top of the carbonates, close to the contact with the overlying schist-phyllite. Elsewhere along the Taconic and Green Peak flanks, the recharge potential is rated highest where the overburden veneer is thin and the underlying bedrock is carbonate. Contrastingly, recharge potential is lowest beneath the overburden-mantled Green Mountains. The carbonate aquifer is not present here and the hydraulic connection between the Green Mountain gneiss-quartzite and the carbonates of the valley is ambiguous.

In the valley region, recharge potential is more varied. It is largely dependent upon the interplay of 2 factors – the thickness of the overburden cover, especially of till, and upon the relative permeability of the overburden material. For example, on the ridge mentioned in the preceding section which extends toward South Village Pond, the recharge potential is highest where the overburden cover is thin and less where the till overburden cover is thick. As another example, look at the area west of Manchester Center. Where the till veneer over the carbonate rock is thin, the recharge potential is highest. However, where the till mantle over the carbonate rock is thick, the recharge potential is ranked low. To the east of this low recharge potential area there is an extensive area of high recharge potential. This reflects the different nature of the overburden material. In this latter area, the overburden is mapped as a more permeable material called ground moraine which is composed of a mixture of till and more permeable gravel-sand.

Within the valley region, areas of extensive overburden mapped as kame moraine are ranked highest in recharge potential because the sediment in this type of overburden is most permeable – a mixture of gravel and sand with some till.

All of the recharge potential rankings must be used with due recognition that each area will have internal variations that cannot be discerned on the basis of the field work and analysis done by me. Thus, all areas ranked as having a recharge potential of II because of the presence of ground moraine will not be equally important in their contribution of water to the underlying carbonate aquifer. The thickness and permeability of the ground moraine unit is variable. The thickness and permeability of every overburden mapping unit is variable as well. In conclusion, the recharge potential map must be considered as a broad first step in identifying aquifer recharge areas and in establishing any possible aquifer protection zones to preserve the integrity of the carbonate aquifer.

## Glacial Geology

Surficial geologic mapping and hydrogeologic assessment of the overburden and bedrock within the Manchester, VT, 1:24,000 scale quadrangle was begun in summer of 2003 and completed in early summer of 2004. Previous mapping and discussions by Behling (1966), Shilts (1966), Shilts and Behling (1967) and Stewart and MacClintock (1969, 1970) served as an historical framework which helped direct my research to the most interesting areas.

My work over many years has updated the mapping in much of the Vermont Valley and in adjacent portions of the Taconic Mountains and Hudson Lowland and much of this mapping has been accompanied by aquifer studies (La Fleur and De Simone, 1992, 1991, De Simone and La Fleur, 1990, Dethier, De Simone and Oelkers, 1989, De Simone and La Fleur, 1988, De Simone and Dethier, 1987). The results of these applied studies and other work in the region has provided a more modern context within which we can view the regional glacial geologic history (Dethier and De Simone, 1996, Karabinos et al, 1996, De Simone and Newton, 1994, Small and De Simone, 1993, De Simone, 1992, De Simone and Dethier, 1992, De Simone and Sedgwick, 1992, De Simone, 1989, Dineen, De Simone and Hanson, 1988, De Simone and La Fleur, 1986, 1985). This is the framework that provides the basis for my continued mapping of glacial sediments in New York, Vermont and Massachusetts. Collectively and for better or worse, this body of work has colored my interpretations of field observations, provided insights into the nature of ice retreat in our region, prompted questions to be addressed and re-addressed with each new study, proven work of previous mappers, challenged the mapping and interpretations of previous workers, and hopefully added to our general understanding of regional glacial geologic history.

**Late Woodfordian glaciation:**

The Hudson-Champlain Ice Lobe of the Late Wisconsinan (Woodfordian) Laurentide Ice Sheet advanced over the region from the NNW as revealed by the upland ice flow indicators oriented approximately 167 degrees. Topographically controlled thinner valley ice flowed parallel to the trend of the Dorset Valley, Danby Valley and Vermont Valleys. Subsurface data discussed below reveal some information about the advancing Woodfordian ice sheet. The "fingers" of thin ice advancing first into the valley troughs mimic the alpine type glaciations we see today in such varied places as Alaska, the Alps and Himalayas. My own experiences with the glaciers in southeast Alaska has colored my perception of the field and subsurface evidence I see for past glaciations.

**Stratigraphic sections and overburden thickness:**

The landscape overridden by the ice sheet was one with deeper and narrower bedrock troughs as revealed in the 4 stratigraphic sections of Map 6 and the overburden thickness data depicted on Map 7. Erosion by active glacier ice transformed the bedrock troughs into the classic U-shape as shown in the stratigraphic sections. Even allowing for some artistic license by the author where data were inadequate, you can see the U-shaped troughs very clearly. The subsurface data reveal the separate Danby and Dorset Valleys persist in the subsurface through the location of Section C-C'-C". In this cross section, you can clearly see 2 distinct bedrock troughs. These troughs must merge into the Batten Kill trough sometime before the location of Section D-D' in the southern portion of the quadrangle.

Both the stratigraphic sections and the overburden thickness map reveal the areas of thickest accumulation of glacial overburden. The narrow troughs of the Dorset and Danby Valleys illustrated in sections A-A' and B-B' have only a modest accumulation of overburden. In section A-A', the overburden is considerably thicker on the east side of the valley where thin terrace gravels were deposited over a truncated till unit. The till unit is thinner over the higher elevations and thicker along the lower valley flanks. A basal gravel-sand unit appears to grade laterally into a fine grained silt-clay unit beneath the till unit. This may record a proglacial ice advance sequence when advancing Woodfordian ice dammed the northward draining Dorset Valley. Section B-B' reveals only a thin cover of overburden in the valley bottom and the predominant material appears to be gravel. Alternatively, these basal gravels may be older sediments preserved on the valley floors as the Woodfordian ice advanced over them. A sample and an age determination would help resolve among these 2 choices.

In contrast, the broader and deeper troughs through the wider Vermont Valley contain a thick accumulation of overburden. Section C-C'-C" reveals thick overburden in the valley bottom and moderately thick overburden across the lower flanks of the uplands. Much of the overburden is gravel and sand with till. This is a ground moraine unit. A very hummocky upper surface with a predominance of stratified sediment allowed me to map portions of this material as kame moraine. The distinction is not possible on the cross sections but is evident in the field where the landforms can be observed and exposures exist. Note the area of the cross section west of Bromley Brook. I have attempted to show the very kamic topography there where the kame moraine unit was mapped. Exposures reveal considerable gravel and sand with some till in this unit. Examine the deep valley troughs on the section. The western or Dorset trough contains a till unit with a gravel below. This may represent a continuous deposition of proglacial gravel on the valley floor as in Section A-A’ as the Woodfordian ice advanced. The till unit above the basal gravel may be a lodgement till or it could be a subaqueous diamicton deposited in a proglacial lake which may have persisted in the trough ahead of the advancing ice sheet. The eastern or Danby trough of the Batten Kill contains no fine grained diamicton unit. All of the overburden filling the trough appears to be gravel as interpreted from the well logs.

In Section D-D’, note the absence again of any till unit in the Batten Kill trough. The Dorset and Danby troughs have joined into a single Batten Kill trough. All of the well logs record gravel overlying bedrock. One well log on the west records 90 feet of a fine grained material which I interpret here as the lacustrine deposits of a small lake in an ice marginal kame terrace setting. I have depicted these fine grained sediments as grading laterally into gravel and sand both westward and eastward. The upper unit is gravel and I infer the small lake was filled in with kame terrace sediment. It is also possible that the fine grained sediment recorded in this well log represents a till unit overlying bedrock on the lower valley flank. If so, this would represent the deposition of a thick till wedge in the lee of Mt. Equinox, a situation I expected and anticipated but was surprised not to see more evident in the subsurface data.

Section Examine Map 7 and observe the thicker accumulation of overburden which is not filling the bedrock troughs. These thicker accumulations are along ice former ice margins where kame moraine and moraine and ground moraine sediments were deposited. In Section D-D’, there is considerable kame moraine sediment on the east side of the valley as well as the west side of the valley. In Section C-C’-C”, note again the kame moraine west of Bromley Brook and the ground moraine sediment with kame moraine just west of the Dorset trough. The accumulations of overburden here and the nature of the overburden were a tremendous aid in determining the former still-stands in the overall retreat of glacial ice from the valleys.

Lastly, note on Section C-C’-C” the thick gravel and sand unit in the center of the section, just east of West Branch. This is the dissected remains of an extensive outwash plain deposited as the ice retreated in the valley. This outwash unit and the absence of any widespread fine grained lacustrine sediment in the valley contributed to my conclusion that Glacial Lake Batten as originally envisioned did not exist. The nomenclature for the lake should thus be abandoned.

**Deglaciation:**

Valley striations were not numerous and did reveal any crossing striations. Thus, there are no hard data to verify that the latest ice flow was the thin valley parallel ice flow. However, this situation was determined conclusively by me during examination of striations in the Arlington quadrangle to the south (De Simone, 2001a, 2001b).It is therefore correct to envision an active retreat of confined valley ice from the lowlands of the quadrangle. This ice likely behaved similar to today’s alpine and outlet glaciers. Our understanding of processes at modern alpine glacier environments is thus applicable to the evidence we see for Woodfordian deglaciation in terrain similar to alpine or outlet glacier settings.  I shall apply my knowledge of processes at glaciers such as the Mendenhall and Herbert in southeast Alaska to interpretation of the evidence for past glaciation I mapped in the Manchester quadrangle.

A thin veneer of lodgement till accumulated over the higher elevations of the quadrangle as the Woodfordian ice sheet thinned and exposed this higher terrain. Thicker till accumulated on the lower flanks as the ice sheet continued to thin. There was no evidence for higher glacial lakes which may have formed between the ice sheet and the mountain flanks. A small area of ground moraine to the east of Lye Brook can be seen on Map 8, the Surficial Geology map. If there was an exposure of this sediment, I could determine if this was indeed a melt water deposit versus an area of sandy till. The north draining Lye Brook would have been an ideal site for a high level glacial lake but this is the only tenuous evidence I discovered for its existence on the quadrangle.

As the ice sheet continued to thin, the Vermont Valley sublobe became established as a classic outlet glacier being nourished by the thick Woodfordian ice sheet to the north. The retreat of this active Vermont Valley sublobe through the Vermont Valley has long been recognized and the latest details of the deglaciation can be found in numerous reports by the author and others as mentioned in the beginning of the glacial geology section. I shall discuss the details of the deglaciation of the valley segment through the Manchester quadrangle and the reader is encouraged to examine both the Surficial Geology map, Map 8, and Map 9, the Ice Margins with Sequence of Deglacial Events map. A complete description of the mapping units employed on Map 8 can be found in Appendix 2.

A. **Skinner Hollow ice margin;** The first marginal sediment in the valley is represented by the ground moraine accumulated at higher elevations west of Historic Route 7. The sediments were deposited along the western edge of the valley glacier, a setting which was to persist as the glacier retreated through most of the quadrangle. Ground moraine sediment consists of a mixture of stratified and unstratified sediment. The stratified sediment is gravel and sand while the unstratified sediment is diamicton. The diamicton may be deposited by one or more of several processes. Till may accumulate directly beneath the retreating valley glacier or may be pushed by minor oscillations of the glacier front. Wasting ice may slough off accumulated material on the surface of the glacier and this sediment contributes to the ground moraine as a material historically mapped as ablation till. But, as gravity is the primary agent in the deposition of this sandy material, the term ablation till is inappropriate. Ground moraine is a preferred term for this sediment mixture deposited by melt water and sediment flow processes with little sediment directly deposited by the ice itself. A high elevation band of ground moraine thus accumulated from Equinox Pond southward through Skinner Hollow to Skyline Drive. Some sediment in this ground moraine undoubtedly came from Tanner and Equinox brooks as they drained the recently deglaciated mountains.

B. **Manchester ice margin;** This ice marginal position was the most enduring one during retreat of the valley glacier. Three distinct positions of the front of the glacier can be discerned based upon my interpretation of the field data. Two positions of the lateral margin can also be discerned by me. Since all of these positions are closely related both physically and temporally, I have chosen not to subdivide them into separate ice margins. The minor retreats associated with this ice margin should be discussed as a continuum of events related to a single still-stand of the glacier. No quiet water lacustrine sediments were observed and no deltas were deposited. Thus, the existence of Glacial Lake Batten is doubtful.

The Manchester moraine complex began to accumulate. The massive Bromley Brook kame moraine formed and outwash was deposited away from the moraine along the path of Bromley Brook. The toe of the glacier was in the area of Muddy Lane and the Muddy Lane kame moraine and outwash accumulated at this time. Lye, Bourn and Bromley brooks contributed water and sediment to the complex but primarily served to keep the system "flushing" to the toe of the glacier.

On the west side of the glacier, the Union Street ground moraine continued the process of accumulating this material begun with the Skinner Hollow ice margin. Ground moraine sediments accumulated both along and beneath the disintegrating glacier margin. Meteoric waters from Munson and Myrick Pass brooks contributed to the ground moraine complex.

As the glacier thinned, nourishment of the eastern Danby fork of the glacier probably began to diminish. The ridge west of the Danby ice became exposed as a nunatak and melt water and meteoric water contributed to the disintegration of the Danby valley ice. The margins of the entire valley glacier began to narrow with rapid ice decay.

**B1;** The toe of the glacier retreated to the position shown on Map 9. The preserved Richville segment of the Manchester esker system began to accumulate. The Union Street ground moraine continued to accumulate. The Bromley Brook kame moraine continued to form and included deposition of the 900 ft Barnumville kame terrace.

**B2;** The west side of the valley glacier had disintegrated and narrowed with deposition of the distinct West Branch kame moraine and the Munson Brook segment of the Manchester esker system. Much of the gravel which would become the source of ground water for the Town Well accumulated at this time. Final deposition of the Bromley Brook kame moraine occurred and included deposition of the 860 ft Barnumville kame terrace.

**C. South Dorset ice margin;** Thinning and marginal retreat separated the Vermont Valley glacier into 2 smaller glaciers, the Dorset and Danby glaciers. An extensive stagnation zone or a completely stagnant Danby glacier is envisioned at this time. Little sediment accumulated as shown on Section B-B' and in other well logs. The valley is severely pinched at East Dorset and all of the Danby ice south of this point was stagnant. Melt water contributed to the deposition of the major Manchester Center outwash from this valley, however.

The Dorset glacier accumulated the small Wideawake ground moraine on its west side. The Forrest moraine was deposited along the more active eastern toe of the glacier. There is abundant diamicton in this moraine and the deformed sediment suggests a very active ice margin. I do not see the evidence as supporting a major re-advance of this glacier. Rather, I see the accumulation of sediment in a classic moraine that results from the typical oscillations of an active margin. There are 2 ridges to this moraine and I believe both are too large to represent an annual or deGeer moraine. A major outwash complex, the Manchester Center outwash, accumulates during the duration of this ice margin. There are no deltas or fine grained lacustrine sediments recognized in this segment of the valley either. Therefore, I conclude that Glacial Lake Batten did not exist. Nowhere in my mapping of the Arlington and Manchester quadrangles have I observed evidence of a major or persistent Glacial Lake Batten. I conclude the Arlington moraine originally thought to have contained Lake Batten, did not serve as a dam to impound water.

It is very interesting to see the contrasting behavior of the Dorset and Danby glaciers at this time. The Dorset glacier is clearly active and oscillating at its margin, producing a classic and uncommonly seen moraine composed predominantly of diamicton. Meanwhile, the Danby glacier has stagnated or developed a large stagnation zone along its front. Nourishment of the 2 glaciers is probably the cause of the difference in behavior. The Dorset glacier continued to be easily nourished by the Hudson-Champlain Lobe. The Green Peak massif, however, cut off nourishment of the Danby glacier. How long this stagnation persisted will have to await the results of my mapping during the 2004 field season in the Wallingford quadrangle.

**Overburden hydrogeologic units:**

The stratigraphic sections, overburden thickness map and surficial geologic map all depict an aerially extensive and variably thick accumulation of stratified kame moraine, outwash and partly stratified ground moraine sediment throughout the valley portion of the quadrangle. Numerous water wells, including the Town Well, finish in glacial gravel and sand. The log of the Town Well reveals a stratigraphy of interlayered permeable gravel-sand units and less permeable gravel-sand-silt-clay-boulder units. The latter are probably sediment flow diamictons deposited along the ice margin interbedded with melt water sediments, all deposited in an ice marginal fan environment. Perhaps this was a subaqueous fan if there was an opportunity to locally and temporarily impound melt water at the toe of the glacier, a situation I envision as very temporary if it occurred.

The entire body of outwash, kame moraine and ground moraine sediments probably represent a single, complex unconfined overburden aquifer. This is the easiest and simplest way to embrace this large aquifer and it may be valid to do so. Yet it must be remembered that the extent of the aquifer is broad, its thickness is highly variable, and its nature is very heterogeneous. The porosity and permeability of the sediments varies both laterally and vertically within the aquifer.

**Overburden water table:**

Despite the limitations in our understanding of the overburden aquifer and any problems with the model that this aquifer is a single unit rather than a set of several separate aquifers, all of the water table data can successfully be contoured. Map 10 depicts the contours of the water table reported as the static water level in all of the wells which finished in gravel-sand sediment. The contour interval is 10 ft and the range of error in determination of water table elevation from the data is +/- 5 ft. The map reveals a very steep water table slope along the Bromley Brook kame moraine and along the eastern edge of the kame and ground moraine complex on the west side of the valley. This is especially evident just NW of the Town Well. The steep water table slope must continue southward from the Town Well but there are no data to allow contours to be drawn. While these steep water table slopes have an unsettling appearance, the data used to produce the contours are consistent and appear to be correct. The general trend of the water table is very reasonable. The water table slopes toward the Batten Kill and West Branch and generally slopes southward out of the quadrangle. The data should match nicely with the water table contours drawn on the Arlington quadrangle to the SW, allowing for the gap in mapped data for the Sunderland quadrangle.

There is a similarity between the overburden water table map and the carbonate aquifer piezometric surface map. It is interesting to ponder the possible hydraulic connection between the two aquifers. If the carbonate aquifer is as unconfined as our knowledge of the bedrock stratigraphy suggests, then the only confining layer over the carbonate aquifer would be an impermeable overburden layer. Yet, our water well log data suggest that a continuous layer of impermeable till is not present beneath the valley. Therefore, it is reasonable to assume an hydraulic connection between the overburden gravel aquifer and the carbonate bedrock aquifer. In such a case, we would expect a similarity or even a coincidence of the piezometric surface and the water table for the piezometric surface would *be* the water table. Do we see this in the data? I believe we do. Overlay Map 10 onto Map 4 and see the similarity. Both maps have a similar contour trend. And the contours are generally within a few 10's of feet of being the same. I believe the differences are meaningless and are within the range of error of the data. Testing is recommended to determine the nature and extent of the hydraulic connection between the 2 aquifers.

**Overburden recharge potential:**

Map 11 depicts an overburden aquifer recharge potential map drawn following the same procedures as for Map 5, the carbonate aquifer recharge potential map. The mountain summit areas and upper flanks have the lowest potential for recharge of the overburden aquifer. Impermeable thick till areas along the lower flanks have low recharge potential. Similarly, within the broad valley floor, areas of thick or thin till cover over low protruding rock ridges have low recharge potential. Areas of ground moraine have a high recharge potential unless there is a rock ridge between the ground moraine region and the Batten Kill or West Branch. In this instance, I assigned a moderate recharge potential due to the likely inhibition of recharge around or through the rock ridge. A moderate recharge potential was also assigned to the moraine region. Highest recharge potential exists in areas of kame moraine, outwash and undifferentiated kame. Terrace gravel-sand regions along the floodplains of the Batten Kill and West Branch are assigned a high recharge potential, slightly lower than for kamic and outwash areas due to the more poorly sorted and finer grained sediment in stream terraces.

While the recharge potential map suggests priorities in protection areas for aquifer recharge, it must be remembered that the entire aquifer is unconfined as currently understood and this means that recharge occurs to some extent through nearly all of the valley.

## Conclusions and Recommendations

The surficial geology and hydrogeology of the Manchester quadrangle is now understood in greater detail. The map products generated by this study can be used to make better decisions regarding land use planning, resource extraction, aquifer protection and natural resource protection. This technical discussion represents a highly revised interpretation of our understanding of the Woodfordian glaciation in the region and presents valuable baseline aquifer data for both glacial overburden and bedrock ground water resources.

The evaluation of subsurface data indicates the absence of a continuous till layer beneath the valley portion of the quadrangle. Till at the surface is confined to the mountain regions and on the protruding low ridges on the valley floor. Rather, a variably thick heterogeneous mixture of gravel, sand and diamicton units appear to be interbedded and occur throughout the valley bottom, especially infilling the deeper preglacial troughs.

Deglaciation proceeded without any major re-advances and a series of 3 ice margins was recognized which enables detailed re-telling of the deglacial history. Extensive ground moraine, kame moraine, and outwash deposition associated with these ice margins accounts for the mapped distribution of surficial sediments in the valley. An uncommon traditional moraine composed primarily of diamicton was also deposited along the toe of one glacier and records the active oscillation of a valley/outlet glacier as can be witnessed in modern glacial environments such as the Mendenhall and Herbert glaciers in southeast Alaska.

The absence of fine grained lacustrine sediments and deltas coupled with the presence of subaerially deposited outwash sediments strongly argues against the former existence of Glacial Lake Batten. Accordingly, the term should be abandoned.

An unconfined carbonate bedrock aquifer and an unconfined overburden glacial aquifer developed in stratified and unstratified gravelly materials exist. Both aquifers have a similar water table and may be hydraulically connected. Recharge potential maps were generated for both aquifers to allow for improved decisions in land use planning, conservation and resource protection and development.

## Appendices

**1. Data Sources: description of numbered exposures;**

MAN 03-1; interbedded gravel and sand level or dipping toward the valley floor…fluvial; generally fining upwards sequence with a coarse top…ablation till; interbedded diamicton of gravel-sand-silt with sorted sand stringers appears to be a re-sedimented fluvial gravel…flow till; finer sands are laminated, ripple cross laminated; gravels are fine to coarse; numerous boulders with crescentic marks, rounded and facetted; clasts are quartzite and carbonate; upper unit is gravel and silty sand with some boulders.

MAN 03-2; 1 m of finely bedded medium to coarse sand with pebble gravel, tabular bedding, truncation surface at top; overlying 1m of cobble and pebble gravel with a coarse sand and silt matrix; terrace sediment over outwash.

MAN 03-3; hummocky terrain; fine gravel with medium and coarse sand and an ablation till cap; possibly an esker segment; well-sorted sand…laminated and cross laminated and tabular laminations.

MAN 03-4; south dipping pebble and cobble gravel with medium and coarse sand…outwash.

MAN 03-5; unsorted to poorly sorted sand, cobble gravel and boulders...marble clasts mostly; adjacent bank with poorly bedded cobble and boulder gravel, medium and coarse sand and silt; appears similar to kame terrace/lateral moraine at the Herbert Glacier.

MAN 03-6; reclaimed excavation with one fresh bank; medium to fine grained sands interbedded with pebble to small cobble gravels; fining upwards sequence; lower gravels mostly less than 3mm with a few larger cobbles and boulders; 60% + carbonate and the remainder quartzite clasts; sands mostly less than 1mm…cross laminated with ripple drift…a couple of silty laminae extend through the pit face and show soft sediment deformation; minor faulting present which was contemporaneous with deposition; kame terrace setting?

MAN 03-7; similar interbedded sand and gravel to above pit and adjacent to it; also reclaimed;

MAN 03-8; Dailey pit in outwash sand and gravel; mostly a processing facility now;

MAN 03-9; old pit against marble outcrop; appears to be a carbonate rich ablation till overlying sand and gravel; vegetation growth on face prohibits excavation;

MAN 03 -10; Robins Lookout on Equinox Preserve; limestone bluff; strike is approximately 020 and dip is approximately 5 east; good photos!

MAN 03-11; Deer Knoll on Equinox Preserve; limestone bluff; strike is approximately 040 and dip is approximately 25 east;

MAN 03-12; Bower Spring on Trout Lilly Trail in Equinox Preserve; geology not easily observed here due to development of site; perhaps an occluded marble spring based upon only my observations.

MAN 03-13; Middle Spring along Equinox Brook on Equinox Preserve; marble spring with a flow rate I could estimate only as greater than 100 GPM; talus, rockslide debris or till in the area; shallow dip in limestone varies from 5 degrees west to 5 degrees east; tastes great!

MAN 03-14; till exposure along steep bank above Lye Brook; silt and clay with abundant cobbles and some boulders, predominantly quartzite.

MAN 03-15; Mrs. Forrest's north pit in moraine; basal diamicton with a silt and sand matrix and numerous clasts…predominantly marble with a few schist and no quartzite; compact and could be lodgement till or a sediment flow deposit; several interbedded sand and gravel layers as lenses and stringers in this basal unit; there is a wonderful and thick soil profile developed on this basal unit where it is the surface material lower in the pit; main section of the pit reveals a

diamicton…cobbles and boulders with silt and very compact; the diamicton is embedded in or surrounded by stratified sediment; laterally adjacent are sand and pebble gravel beds folded to a vertical and overturned positions; extensively faulted and folded sand and gravel overlie the entire material described above; upper gravel beds have an unconformable (sheared?) contact with underlying gravel and sand beds; upper gravel beds are also folded with the beds beneath; farther east the sand and gravel beds are less deformed and almost horizontal in position; cobble gravels infill a fault sourced depression I the east face of the pit; this appears to be a frontal to lateral moraine showing firm evidence of ice push on the sediment package from an actively oscillating ice front; no contribution of sediment from the Danby glacier as there are no quartzite clasts.
MAN 03 16; Mrs. Forrest's south pit in moraine; interbedded sand, gravel and diamicton; over-compacted sand layer atop the lower diamicton; heavily faulted and slumped sand and gravel bed atop the middle diamicton; lower diamicton largely covered; upper diamicton truncates and overlies the faulted sand and gravel bed below; gravel and sand beds cap the deposit with slight deformation; no quartzite clasts anywhere; this material is like the kame moraine seen in an ice lateral position at the Herbert Glacier in Alaska.
MAN 03-17; basal gray compact silt and clay matrix diamicton with numerous clasts; clasts are bright in that they include tan, brown and gray quartzite, black marble and schist, gray marble and a little green schist; indicates a valley sourced till; above is a gravel and sand diamicton with interlayers of bedded sand containing soft sediment deformation; this may be a sediment flow unit perhaps deposited into a local subaqueous environment…a flow till using that terminology; interbedded gravel and sand above showing channel fills of gravel, cross bedded sand; beds undulate in an anastomosing fashion; fining upwards overall in the stratified sediments; a kame moraine setting.
MAN 03-18; Upper Spring on Equinox Preserve; roughly estimate the flow rate exceeds 100 GPM but is lower than at the Middle Spring farther down Equinox Brook; material at spring consists of talus or colluvium from a debris slide…irregular angular boulders and flaggy schist rich in quartzite with no carbonate; 60-80 ft below the spring is a prominent structural or lithologic bench developed on marble; a marble outcrop can be seen along the trail only about 100 ft below spring elevation and marble becomes prominent in the till below this point; above the spring there are no carbonate outcrops or float in the sediment; appears that the spring issues from carbonate rock probably at the upper contact with schist…perhaps along a fault plane here(?).
MAN 03-19; slump along Batten Kill in esker at the Town Sewage Treatment facility; the esker has been deeply cut by a caving bank into the Batten Kill; the outside of a meander bend cuts into the base of the slope and more than 60 ft high bank is actively failing; failure is slowly and also quickly as whole tree root systems become undermined and fail en masse into the river; one large tree with its root system is ready to fall at any moment; this is a dangerous site and there are markings to indicate someone is monitoring the movement of the slope.

**2. Mapping Unit Descriptions:**

**Recent;**

**F** **Fill; variable materials used as artificial fill along rail beds, road beds, embankments and low lying areas**. The material may be demolition/construction debris, crushed stone or gravel/sand quarry sediment. Most of the fill is along the path of Rte 7 and along railroad grades, especially to elevate the rail bed above flood plain level. Soils on these disturbed lands are Udorthents and Udisamments. Embankments may be prone to failure.

**PM** **Peat & Muck**; **organic sediment, mostly silt and clay in wetlands and swamps; low lying flat lands.** These sediments are rich in decomposing organic matter including grass, leaves and wood. Soils are typically waterlogged, dark or mottled in color and deficient in oxygen. Carlisle muck is the primary soil unit with lesser areas of Copake, Raynham and Fredon soils. Water may intermittently or permanently cover the surface. Unsuitable for development.

**AL** **Alluvium**; **stream flood pains; fine sand, silt and gravel of river channel, bar, and bank areas; river bottom lands; variable permeability but usually intermediate to low; often wet sites.** These are low lying terraces within the 100 year planning flood plain and may be seasonally flooded. Soils are often wet and the water table may be encountered at very shallow depth. Organic matter may be locally abundant. The freshest deposits with little or no soil development are Udifluvents. Older deposits with soils are of the Copake, Raynham, Hero and Pootatuck types and are excellent for agricultural uses. The high water table and wet soils impeded the flow of water and render these sites less suitable for development. They may not perc adequately or there may be insufficient thickness of sediment above the water table for conventional septic systems. Embankments along rivers and streams may be prone to failure.

**FT** **Fluvial Terrace**; **old flood plains; fine sand, silt and gravel generally less than 5 meters thick overlying other material; flat to gently sloping lands; variable permeability but usually intermediate.** These are old stream terrace deposits above the flood plain. The soils are often deep, well drained loams suitable for agriculture. The water table may be sufficiently deep to allow for conventional septic systems. However, perc rates may be locally variable and wet areas are not uncommon. Groton, Raynham, Hero, Copake and Fredon soil types are found. Bank edged above streams may be prone to failure.

**AF** **Alluvial Fan**; **tributary stream deposits; gravel, silt and sand, often poorly sorted; gently to moderately sloping lands located at the base of steep slopes and at stream junctions; variable permeability but usually intermediate to low.** This sediment is both stratified and unstratified and the degree of sorting is highly variable. Larger fans along major tributaries have better sorted and more stratified deposits while small fans along minor tributaries typically have more poorly sorted and unstratified sediment. Perc rates will be highly variable as a result of the variable sediment texture. Perched water tables may occur anywhere the sediment is of lower permeability and in places these areas may be wet at the surface. Higher permeability areas should perc adequately and be suitable for conventional septic systems. All areas may be suitable for agricultural pasture and woodlot uses on these Danforth and Hero are the major soil types.

**CO** **Colluvium**; **slump, slide and avalanche debris materials composed of boulders, cobbles, gravel, sand and silt; sloping lands.** These are in slide prone areas on mountain slopes or along embankments, especially along streams. Active erosion sites such as these are unsuitable for development.

**Late Pleistocene**;

**OW** **Outwash; glacial melt water deposits of well sorted gravel and sand typically greater than 5 meters thick; gently sloping to flat lands; intermediate to high permeability; high gravel-sand resource potential.** Water percolates very rapidly through these deposits making these lands suitable for development with septic systems. Major recharge areas for the overburden aquifer and a pronounced vulnerability to contamination argue for caution in land use decisions. Groton is the major soil type.

**K** **Kame, undifferentiated; glacial deposits from streams, slumps and deposition by ice; stratified and unstratified sand, gravel and boulders with variable silt; rolling, hilly lands; intermediate to high permeability; high gravel-sand resource potential; local steep slopes pose slope stability problem.** Sediment thickness is variable and rock outcrops may occur within this unit. Percolation rates are generally satisfactory for conventional septic systems. These are aquifer recharge areas and are prone to contamination from infiltration. Groton and Danforth soils are typical.

>>> **Esker; subglacial/englacial melt water stream deposits of moderately well sorted gravel and sand with boulders; prominent elongated and curving narrow ridges with steep sides and heights reaching 60+ feet; intermediate to high permeability; high gravel-sand resource potential; steep slopes pose a major slope stability problem.** Individual eskers occur within areas of kame, kame moraine or ground moraine mapping units. Due to their steep slopes and narrow crested summits, these landform features are best left undeveloped or may be used for their gravel-sand resources. Groton soils are typical.

**KM** **Kame Moraine; ice contact melt water and sediment flow deposits of stratified and unstratified gravel and sand with silt and boulders; rolling, hilly ridged lands with local flat areas; intermediate to high permeability; high gravel-sand resource potential; local steep slopes pose slope stability problem.** Sediment thickness is variable but typically exceeds 10 meters. Percolation rates are generally satisfactory for conventional septic systems. These are aquifer recharge areas and are prone to contamination from infiltration. Groton soils are typical and are suited farming, grazing and woodlot uses. Lesser areas with Galway-Farmington soils may contain abundant silt which will decrease drainage and affect development potential with septic systems.

**GM** **Ground Moraine; ice contact sediment flow, melt water and ice deposited sediments of variable texture ranging from stratified and well sorted gravel and sand to unstratified and poorly sorted silt, sand, gravel and boulders; thickness is variable and rock outcrops may protrude; low to high permeability; limited local slope stability problems; gently rolling hills and elongate smoothed hills are possible.** Percolation rates will vary widely over short distances. There is some gravel-sand resource potential here but the possibility of hardpan sediments makes these areas of lower resource potential than kame or outwash deposits. Soils vary widely and include areas of Nellis, Amenia and Galway-Farmington types. These areas are suitable for development, farming, grazing and woodlot uses.

**KT** **Kame Terrace; ice contact melt water and sediment flow deposits of stratified and unstratified gravel, sand, boulders and some silt; flat to nearly flat lands; intermediate to high permeability; high gravel-sand resource potential; slopes at edges of these areas may pose a stability problem.** Sediment thickness is variable but typically exceeds 10 meters. Percolation rates are generally satisfactory for conventional septic systems. These are aquifer recharge areas and are prone to contamination from infiltration. Groton soils are typical and are suited farming, grazing and woodlot uses. Lesser areas with Galway-Farmington soils may contain abundant silt which will decrease drainage and affect development potential with septic systems. These are similar in characteristics to KM unit above.

**M** **Moraine; ice contact ice deposited, sediment flow and melt water materials of unstratified and stratified silt, sand, gravel and boulders; broad ridges and swales with rolling low hills; variable permeability; local slopes may pose a stability problem.** Sediment thickness is variable and rock outcrops may occur. Percolation rates will vary considerably but may be adequate for development with conventional septic systems. Some areas may not drain well and wet soils can be found here. Other areas will drain well. Nellis, Amenia, Massena and Stockbridge soils may occur.

**T** **Till; ice derived deposits of hardpan silt, boulders, gravel and sand which are unsorted and unstratified and deposited beneath the glacier; thickness greater than 3 meters but rock outcrops may be common; surface boulders or erratics are common; smoothed and streamlined hills in the valley and gently undulating slopes on the lower mountain flanks; low permeability; unstable slopes may result in excavations.** Percolation rates are poor and the ground is typically pocked with wet areas making these areas generally unsuitable for development with conventional septic systems. Perched water tables less than 3 feet down may be encountered during excavations. Galway-Farmington, Nellis and Pittsfield soil types prevail.

**TT** **Till, thin; ice derived deposits of hardpan silt, boulders, gravel and sand which are unsorted and unstratified and deposited beneath the glacier; thickness less than 3 meters with rock outcrops or ledge frequent; surface boulders or erratics are common; moderate to steep mountain slopes and summit areas; low permeability; steep slopes are unstable and slides are common.** Percolation rates in the till are poor but areas devoid of till are common and percolation through thin soil into bedrock may occur at higher rates. Steep slopes, poor percolation and high elevation make these regions unsuitable for development. Land uses are limited to forestry and woodlot management. Valley and mountain areas of thin till are carbonate aquifer recharge zones. Rawsonville-Houghtonville, Dummerston, Taconic-Macomber, Taconic-Macomber, Houghtonville, Berkshire, Tunbridge-Lyman and similar soil types prevail.

**Pre-Cambrian & Paleozoic Bedrock;**

**R** **Rock outcrop. Marble (Rmb), quartzite (Rqz), and schist (Rsc) are the types observed in the field. These include areas of predominantly outcrop with patches of till or slump or slide debris. Outcrop areas serve to recharge the bedrock units with ground water. Poor sites for septic systems prevail. Slopes are generally stable. Development potential is low. Scenic views are common**

## References


Behling, R.E., 1966, Surficial geology of the Equinox 1:62,500 quadrangle, VT: Vermont Geological Survey, open file map.

De Simone, D.J., 2001, Surficial geology and ground water resources of Arlington, VT: A report and history for town residents: Vermont Geological Survey open file report and maps.

De Simone, D.J., 2001, Surficial geology of Arlington, VT: A technical discussion: Vermont Geological Survey open file report and maps.

De Simone, D.J., 1992, Hudson lowland lake levels; *in* Dineen, R.J., De Simone, D.J., Hanson, E.L., and La Fleur, R.G., editors, the late glaciation of eastern New York State - glacial tongues & bergy bits: 55th annual Friends of the Pleistocene Guidebook to field trips.

De Simone, D.J., 1989, Glacigenic sediment and the Lake Kinderhook problem - upper Kinderhook Valley, NY and MA: Northeastern Geology, vol. 11, #4, and p184-201.

De Simone, D.J., and Baldivieso, A.P., 2001, Applied hydrogeology in the Arlington quadrangle: GSA Abstracts with programs, Northeastern sectional meeting.

De Simone, D.J., and Newton, R., 1994, glacial geomorphology and applied hydrogeology, MA-NY-VT tri-state region: 7th Keck research symposium volume, Trinity College, San Antonio, TX.

De Simone, D.J., and Dethier, D.P., 1992, Ice retreat, stagnation, and the extent of Lake Bascom in Pownal, VT: Northeastern Geology, vol. 14, #2/3, p145-155.

De Simone, D.J., and Sedgwick, P., 1992, Deglaciation of the Little Hoosic Valley: Northeastern Geology, vol. 14, #2/3, and p137-144.

De Simone, D.J., and La Fleur, R.G., 1990, surficial geology, Town of New Lebanon: maps and user manual prepared for the Town Planning Board.

De Simone, D.J., and La Fleur, R.G., 1988, surficial geology of Stephentown, NY: map and user manual prepared for the Town Planning Board.

De Simone, D.J., and Dethier, D.P., 1987, surficial geology of the Pownal and North Pownal 1:24000 quadrangles, VT: Vermont Geological Survey open file report and maps.

De Simone, D.J., and La Fleur, R.G., 1986, Glaciolacustrine phases in the northern Hudson Lowland and correlatives in western Vermont: Northeastern Geology, vol. 8, #4, p218-229.

De Simone, D.J., and La Fleur, R.G., 1985, Glacial geology and history of the northern Hudson basin, NY and VT: NYS Geological Association guidebook to field trips, trip A-10, p82-116.

Dethier, D.P., and De Simone, D.J., 1996, Late Quaternary evolution of the Berkshire-Taconic landscape; a field guide for the 9th Keck Research Symposium, 34p.

Dethier, D.P., De Simone, D.J., and Oelkers, E., 1989, the surficial deposits and hydrogeology of Williamstown, MA: report and maps prepared for the Town Planning Board.

Dineen, R.J., De Simone, D.J., and Hanson, E.L., 1988, Glacial Lake Albany and its successors in the Hudson Lowland: AMQUA 10th biennial meeting, guidebook to field trips, trip B-2, 55p.

Hewitt, P.C., 1961, The Geology of the Equinox quadrangle and vicinity, Vermont: Vermont Geological Survey, Bulletin #18.

Karabinos, P., *et al*, 1996, Structural controls on the orientation and location of major ridges and valleys in the Taconic Range, western New England and eastern New York: 9th Keck research symposium volume, Williams College, MA.

La Fleur, R.G., and De Simone, D.J., 1992, surficial geology and water resources of Hancock, MA; maps and explanatory text prepared for the Hancock Board of Health.

La Fleur, R. G., and De Simone, D.J., 1991, Water resources of New Lebanon, NY: maps and report prepared for the Town Planning Board

Shilts, W.W., 1966, The Pleistocene geology of the Bennington area, VT: Vermont Geological Survey, open file map.

Shilts, W.W., and Behling, R.E., 1967, Deglaciation of the Vermont Valley and adjacent highlands: GSA Abstracts with programs, Annual meeting.

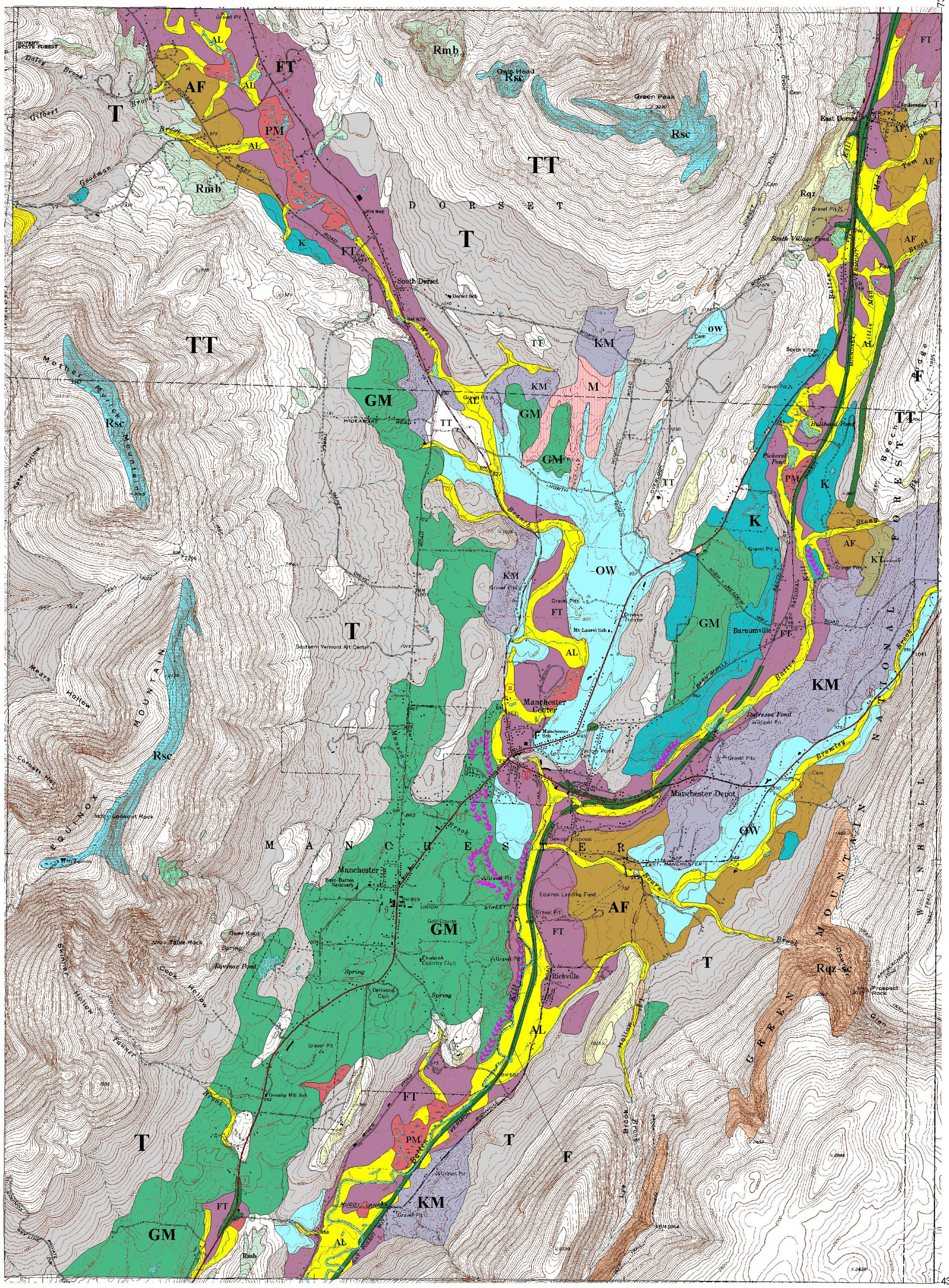
Small, E.E., and De Simone, D.J., 1993, Asynchronous ice lobe retreat and Glacial Lake Bascom: Deglaciation of the Hoosic and Vermont Valleys, southwestern Vermont: GSA Abstracts with programs, Northeastern sectional meeting, pp.79-80.

Stewart, D.P., and MacClintock, P., 1969, the surficial geology and Pleistocene history of Vermont: Vermont Geological Survey, Bulletin #31, 251 pages.

Stewart, D.P., and MacClintock, P., 1970,Surficial geologic map of Vermont.

Vermont Geological Survey
Dept. of Environmental Conservation
Vermont Agency of Natural Resources
Waterbury, Vermont






This geologic map was funded in part by the U.S.G.S. National Cooperative Mapping Program

1 0 1 2 Kilometers

Scale- 1:24,000
Contour Interval- 20'

Map Published By:
Vermont Geological Survey
103 South Main Street
Waterbury, Vermont 05671
802/241-3608
Laurence Becker- State Geologist
map produced: September 9, 2004

# Surficial Geology of the Manchester Quadrangle

Author: David De Simone

Digitized by: Caroline Orsi and Jonathan Kim

## Surficial Deposits

### Late Pleistocene Glacial Deposits

- **OW** Outwash; Glacial Meltwater Deposits; Gravel and Sand; Gently-Sloping to Flat Lands
- **K** Undifferentiated Kame; Gravel, Sand, and Boulders/Cobbles; Rolling Hilly Lands
- <<<<< Esker; Subglacial/Englacial Meltwater Stream Channel Deposits; Gravel and Sand; Prominent Elongate ridges
- **KM** Kame Moraine; Ice-Contact Meltwater and Ice- Derived Deposits; Gravel, Sand, and Glacial Till; Rolling, Hilly, Ridged Lands
- **GM** Ground Moraine; Ice Contact Stagnation, Meltwater, and Ice Flow Derived Deposits; Gravel and Sand; Streamlined to Kamic to Flat Lands
- **KT** Kame Terrace; Ice Contact Meltwater and Sediment Flow Deposits; Gravel, Sand, and Silt; Flat to Nearly Flat Lands
- **M** Moraine; Ice Contact Ice-Derived Meltwater, and Sediment Flow Deposits; Till, Gravel, Sand, and Boulders; Broad Elongate Ridges
- **T** Till; Ice-Derived Deposits; Subglacial; Hardpan Silt, Gravel, and Sand with Boulders; Hillslopes and Streamlined Hills
- **TT** Till, Thin; As Above, but with Frequent Rock Outcrops; < 3 meters thick over Ledge; Hillslopes and Summit Areas

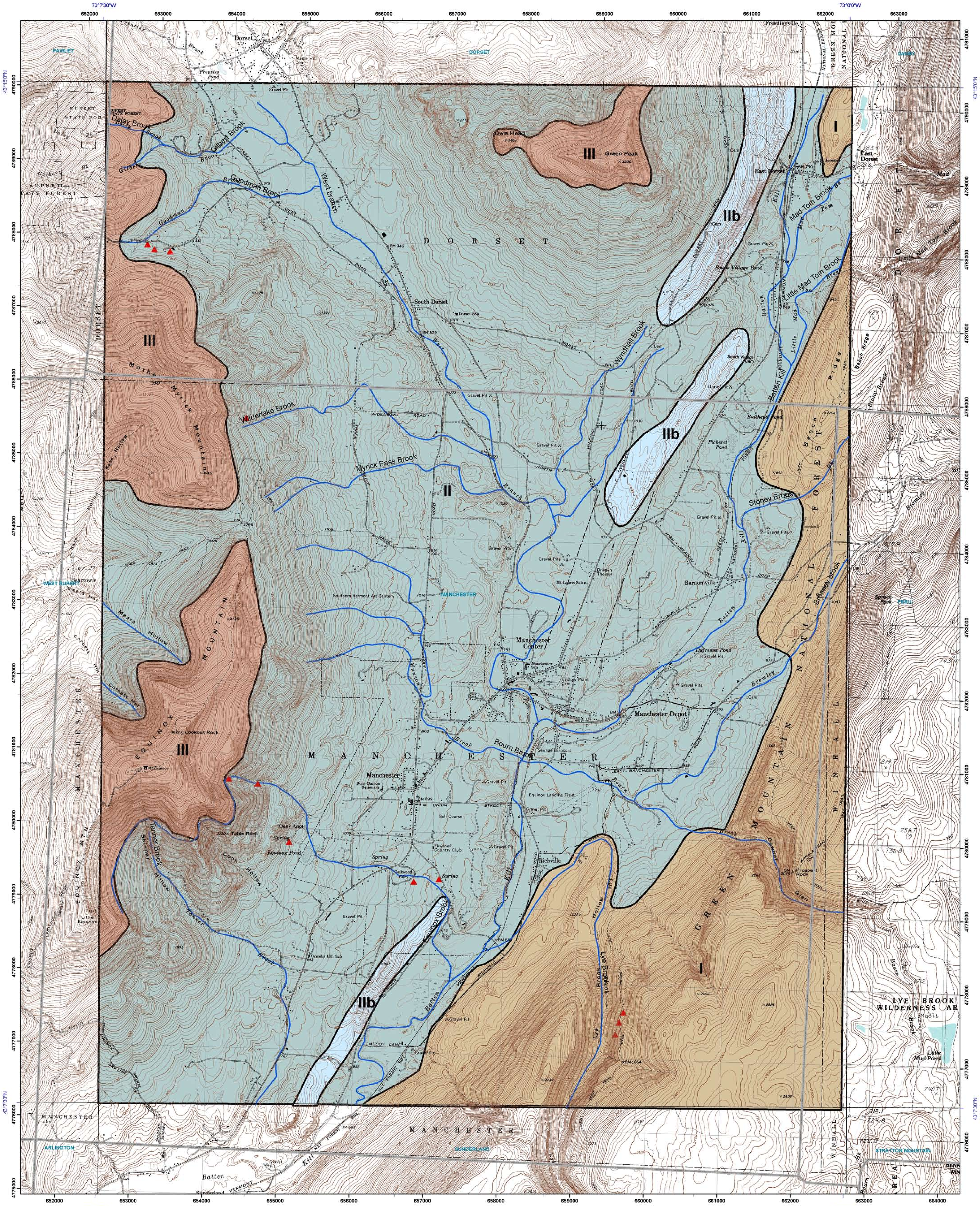
### R ecent Deposits

- **F** Fill; Artificial, Rail and Road Beds
- **PM** Peat and Muck; Swamp/Wetland; Silt and Clay; Low-Lying Flat Lands
- **AL** Alluvium; Stream Flood Plains; Fine Sand, Silt, and Gravel, River Bottom Lands
- **FT** Fluvial Terrace; Old Flood Plains; Sand, Silt, and Gravel; Flat Lands
- **AF** Alluvial Fan; Tributary Stream Deposits; Gravel, Silt, and Sand; Gently - Moderately Sloping Lands
- **CO** Colluvium; Slump, Slide, and Avalanche Debris; Boulders, Cobbles, Gravel, Sand, and Silt; Sloping Lands

### Precambrian and Paleozoic Bedrock

- **Rmb** Rock Outcrop, Marble (all Carbonate Rocks Termed Marble Here)
- **Rqz** Rock Outcrop, Quartzite
- **Rsc** Rock Outcrop, Schist
- **Rqz-sc** Rock Outcrop, Quartzite and Schist

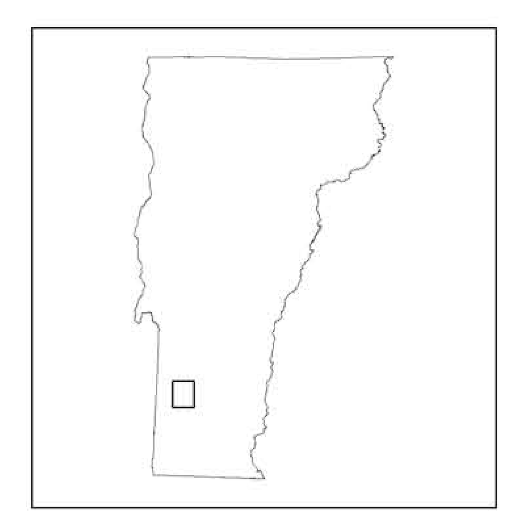
Map Plate 2- Primary surface streams, springs and seeps, and distribution of bedrock hydrogeologic units




## LEGEND

### Bedrock Hydogeologic Unit

| | |
|---|---|
| I | Schist, gneiss and quartzite- Aquiclude or poor aquifer |
| II | Carbonate rock - Aquifer |
| III | Carbonate rock with quartzite beds- Aquifer |
| IIb | Phyllite and schist - Aquitard or poor aquifer |
| ▲ | Springs and Seeps |
| - - - - - | Structural trend in bedrock |
| —— | Stream path |
| ☐ | VT Town Boundaries |
| ☐ | USGS Quadrangle Boundaries |



Map Location

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR.
This geologic map was funded in part by the USGS National Cooperative Mapping Program.


# PRIMARY SURFACE STREAMS, SPRINGS AND SEEPS, AND DISTRIBUTION OF BEDROCK HYDROGEOLOGIC UNITS, MANCHESTER QUADRANGLE, VERMONT

by
David DeSimone
2004

Base map from U.S. Geological Survey.
Quadrangle names printed in blue.
Coordinate System: Vermont State Plane, meters, NAD 83.
Geographic coordinates shown at topo corners are in NAD 83.
Grid overlay on map is Universal Transverse Mercator, Zone 18N, NAD 27.

Digitization and Cartography by M. Gale, J. Kim and C. Orsi
Date: November 2006

Scale 1:24,000

0 0.5 1 2 Miles

0 0.5 1 Kilometers

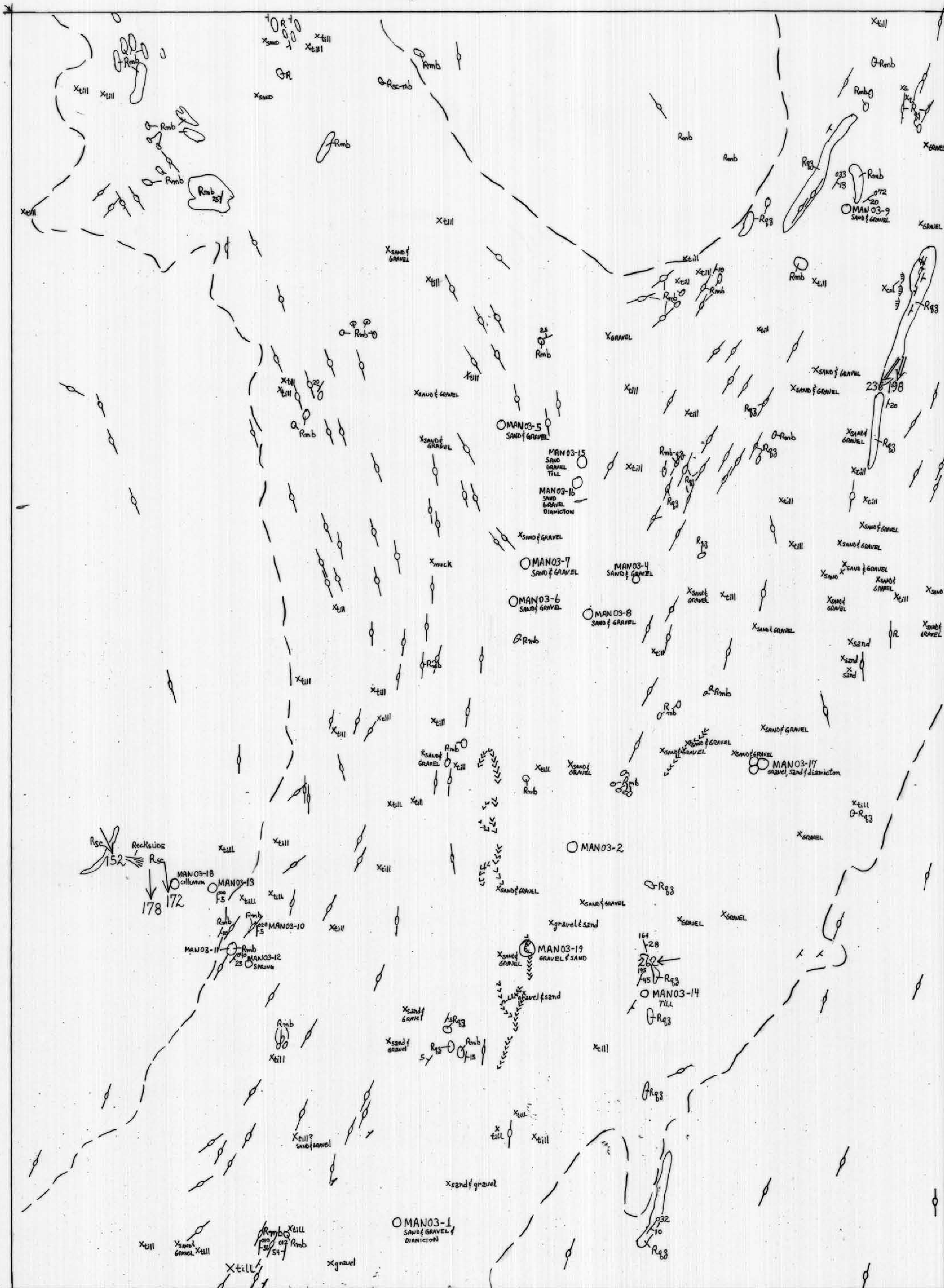
Contour Interval 20 Feet

MN N

Magnetic declination
15.5 degrees west, 1968

Published by:
Vermont Geological Survey
Laurence Becker, State Geologist
Department of Environmental Conservation
Agency of Natural Resources
103 South Main St., Logue Cottage
Waterbury, VT 05671-2420
http://www.anr.state.vt.us/dec/geo/vgs.htm

# MAP 3




FIELD DATA SITES

ESKERS, SLOPE FAILURES, ROCK OUTCROPS

MAP BY DJ DeSIMONE
2003 - 2004

MN

14°

## ICE FLOW DIRECTION INDICATORS

STREAMLINE MOLDED FORMS – ROCK DRUMLINS, DRUMLINS, ROCHE MOUTONEES, WHALEBACKS

STRIATIONS

GROOVES

DASHED LINE AT 1500 FT CONTOUR SEPARATES VALLEY ICE FLOW FROM MOUNTAIN ICE FLOW

O MAN03- FIELD DATA SITE WITH DISCUSSION IN REPORT

X( ) - FIELD EXPOSURE OR DUG PIT

R( ) - ROCK OUTCROP – mb = MARBLE, qz = QUARTZITE, SC = SCHIST

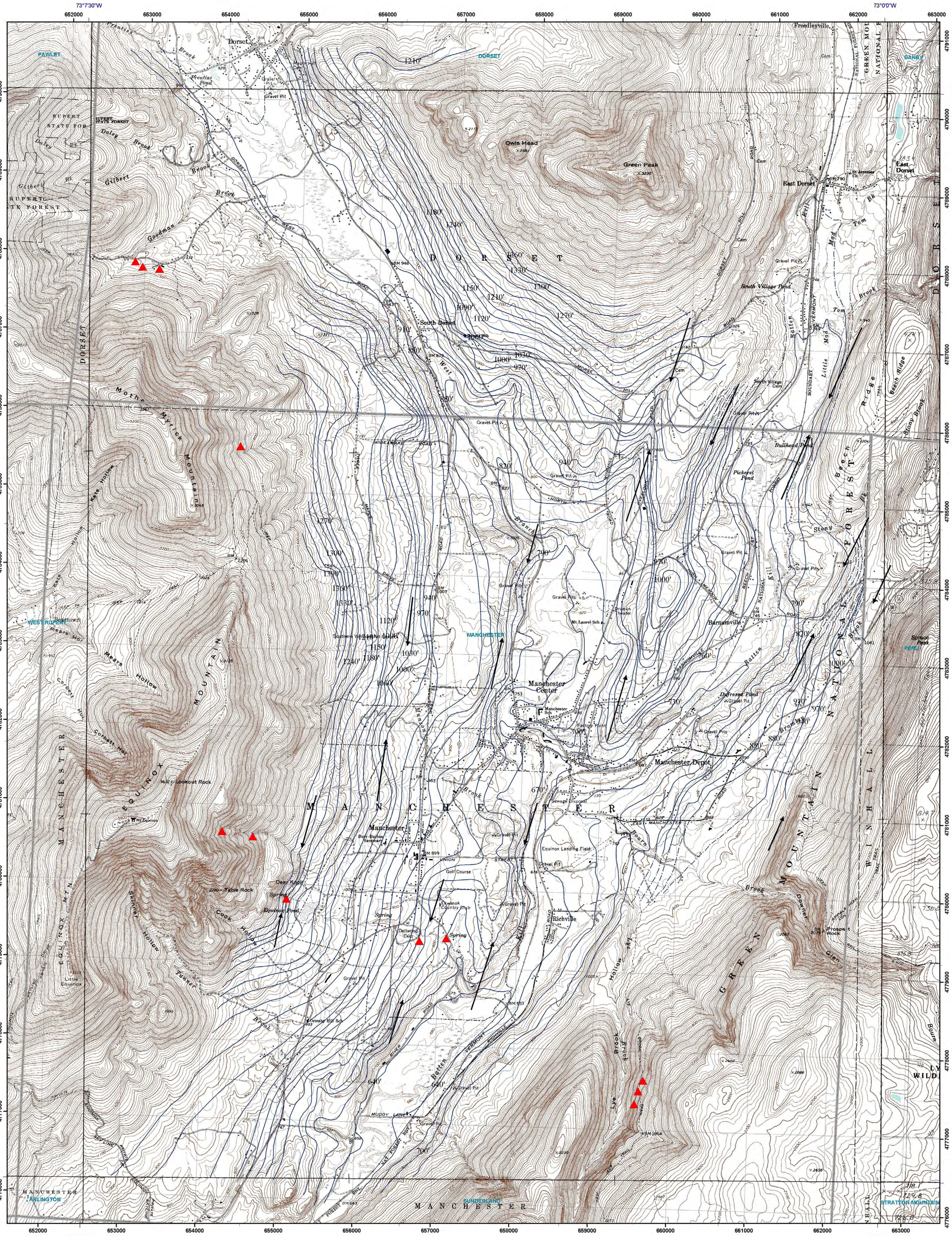
STRIKE & DIP OF BEDDING

SLOPE FAILURE – SLUMP

SLOPE FAILURE – ROCK SLIDE

>>>> ESKER

Map Plate 4 - Carbonate aquifer piezometric surface map, Manchester quadrangle, VT




## Legend

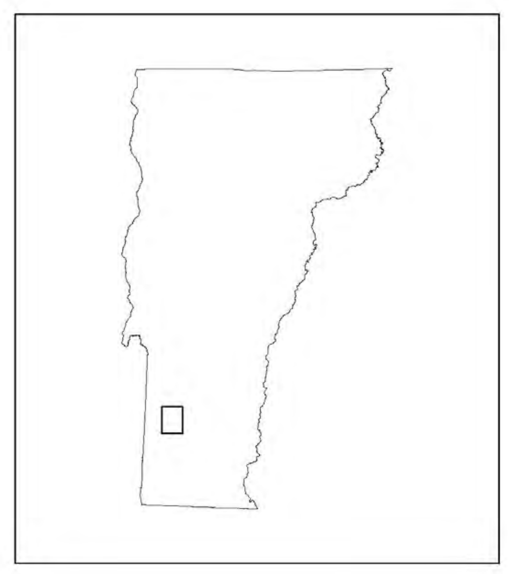
Elevation in feet; 30' contour interval (error +/- 5')

Springs observed

Possible structural and/or lithological controls on aquifer

USGS Quadrangle Boundaries

VT Town Boundaries



Map Location

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR. This geologic map was funded in part by the USGS National Cooperative Mapping Program. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Published by:
Vermont Geological Survey
Laurence Becker, State Geologist
Department of Environmental Conservation
Agency of Natural Resources
103 South Main St., Logue Cottage
Waterbury, VT 05671-2420
http://www.anr.state.vt.us/dec/geo/vgs.htm

Base map from U.S. Geological Survey.
Quadrangle names printed in blue.
Coordinate System: Vermont State Plane, meters, NAD 83.
Geographic coordinates shown at topo corners are in NAD 83.
Grid overlay on map is Universal Transverse Mercator, Zone 18N, NAD 27.

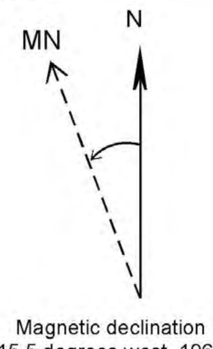
Digitization and Cartography by M. Gale, J. Kim, and C. Orsi
Date: November 2006

Scale 1:24,000

0 0.5 1 Miles

0 0.5 1 2 Kilometers

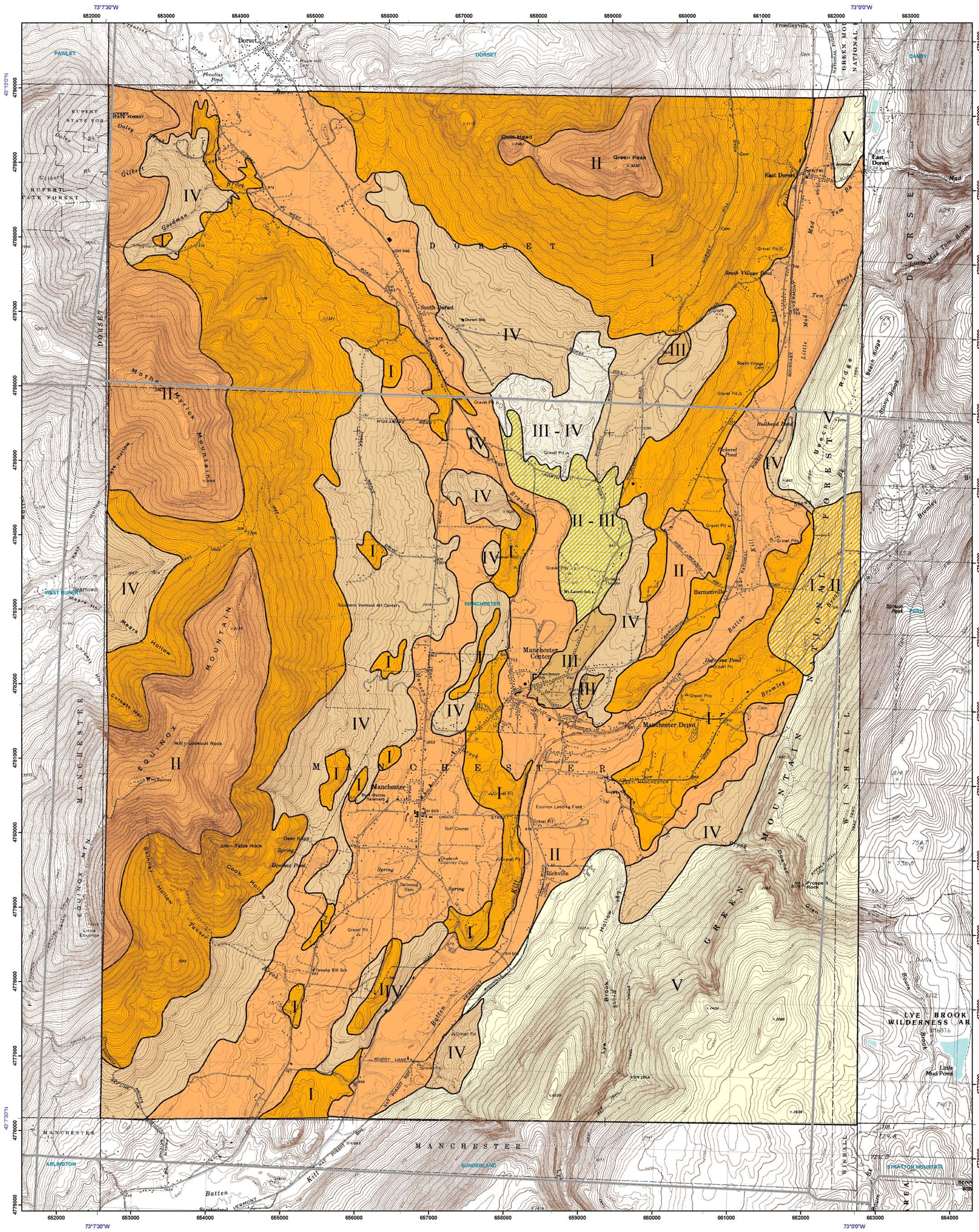
Contour Interval 20 Feet




Magnetic declination
15.5 degrees west, 1968

# CARBONATE AQUIFER PIEZOMETRIC SURFACE MAP, MANCHESTER QUADRANGLE, VERMONT

by
David DeSimone
2004




## LEGEND

### Carbonate Aquifer Recharge Potential

| | |
|---|---|
| I | Highest |
| I - II | High to highest |
| II | High |
| II - III | Moderate to high |
| III | Moderate |
| III - IV | Low to moderate |
| IV | Low |
| V | Lowest |
| | USGS Quadrangle Boundaries |
| | VT Town Boundaries |

Base map from U.S. Geological Survey.
Quadrangle names printed in blue.
Coordinate System: Vermont State Plane, meters, NAD 83.
Geographic coordinates shown at topo corners are in NAD 83.
Grid overlay on map is Universal Transverse Mercator, Zone 18N, NAD 27.

Digitization and Cartography by M. Gale, J. Kim and C. Orsi
Date: November 2006

1:24,000

0 0.5 1 Miles

0 0.5 1 2 Kilometers

Contour Interval 20 Feet

MN N

Magnetic declination
15.5 degrees west, 1968

# CARBONATE AQUIFER RECHARGE POTENTIAL MAP, MANCHESTER QUADRANGLE, VERMONT

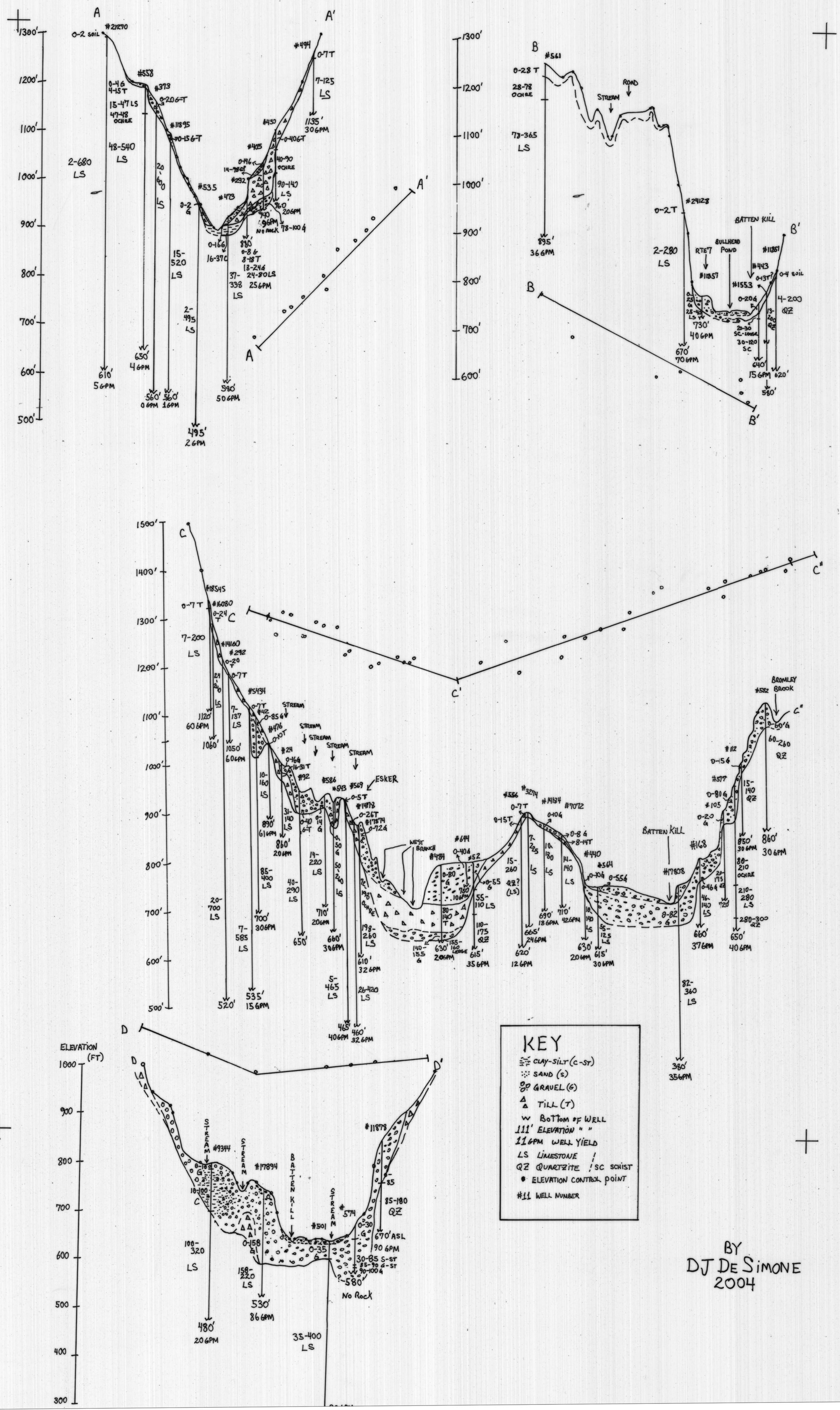
by
David DeSimone
2004

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR.
This geologic map was funded in part by the USGS National Cooperative Mapping Program.
The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

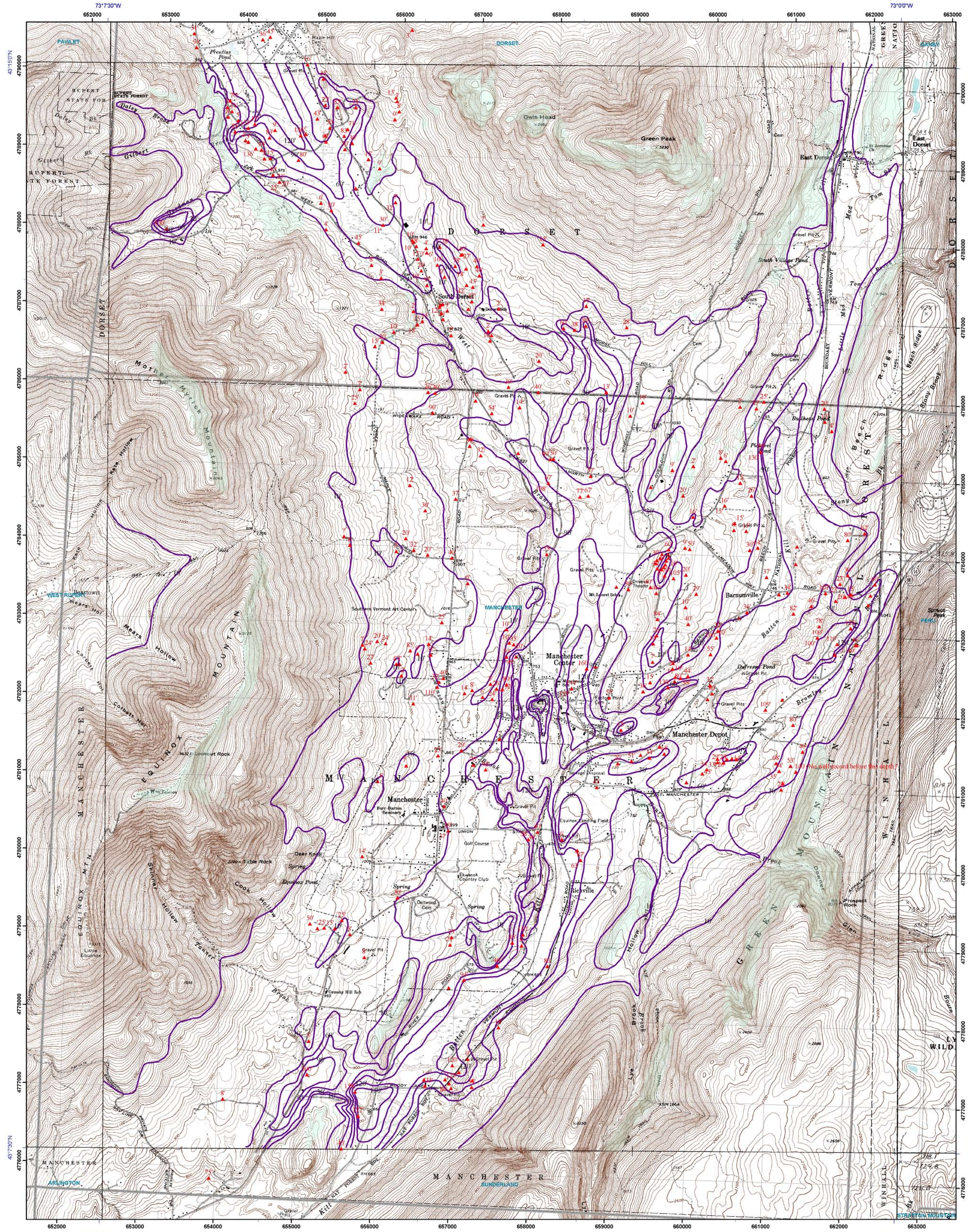
Published by:
Vermont Geological Survey
Laurence Becker, State Geologist
Department of Environmental Conservation
Agency of Natural Resources
103 South Main St., Logue Cottage
Waterbury, VT 05671-2420
http://www.anr.state.vt.us/dec/geo/vgs.htm

# MAP 6

## STRATIGRAPHIC CROSS SECTIONS




BY
DJ DeSimone
2004




1:24,000

0 0.5 1 2 3 4 Miles

0 0.5 1 2 3 4 Kilometers

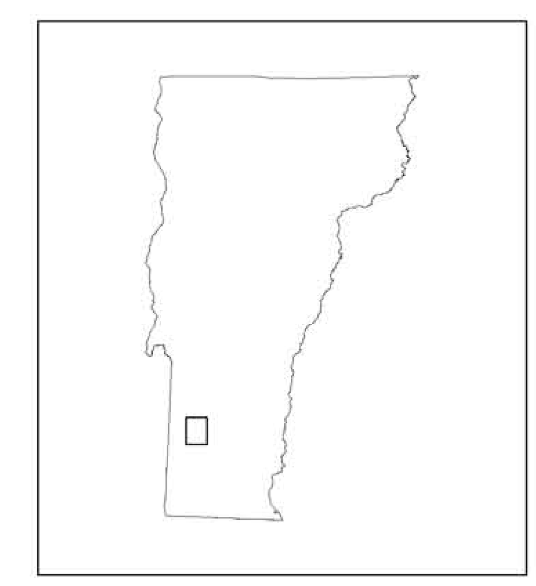
Contour Interval 20 Feet

MN N

Magnetic declination
15.5 degrees west, 1968

## Legend

- Overburden thickness contours at 30', 60', 90', 120' and 150'; Thin drift limit at 10'.
- Depth to bedrock from water well data
- Rock at surface
- USGS 24K Quadrangle Boundaries
- VT Town Boundaries



Map Location

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR. This geologic map was funded in part by the USGS National Cooperative Mapping Program.The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Published by:
Vermont Geological Survey
Laurence Becker, State Geologist
Department of Environmental Conservation
Agency of Natural Resources
103 South Main St., Logue Cottage
Waterbury, VT 05671-2420
http://www.anr.state.vt.us/dec/geo/vgs.htm

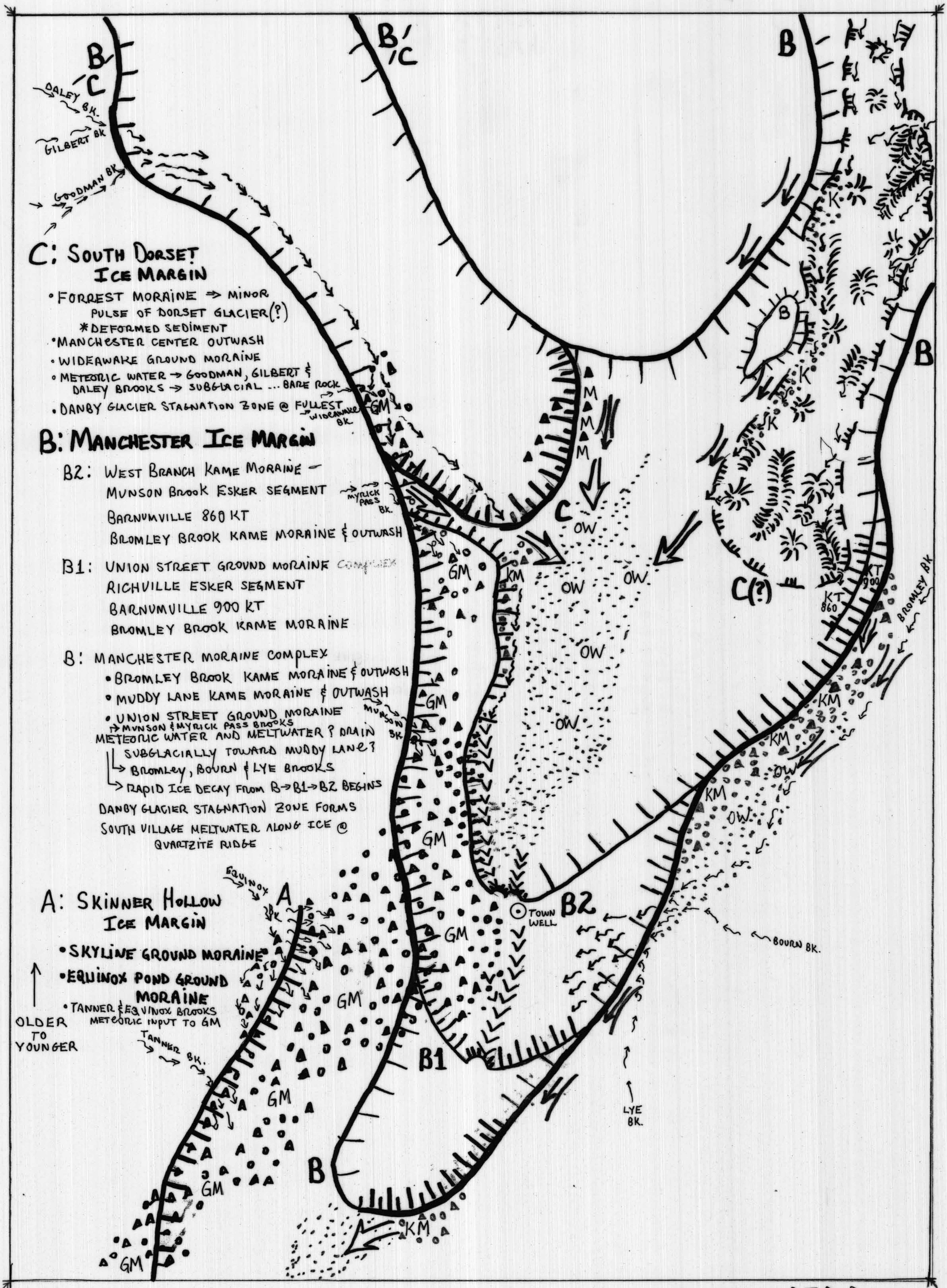
Base map from U.S. Geological Survey.
Quadrangle names printed in blue.
Coordinate System: Vermont State Plane, meters, NAD 83.
Geographic coordinates shown at topo corners are in NAD 83.
Grid overlay on map is Universal Transverse Mercator, Zone 18N, NAD 27.

Digitization and Cartography by M. Gale, J. Kim, and C. Orsi
Date: November 2006

# OVERBURDEN THICKNESS, MANCHESTER QUADRANGLE, VERMONT

by
David DeSimone
2004

# MAP 9




DRAFT MAP BY DJ DeSIMONE
2003-2004

## ICE MARGINS
WITH
## SEQUENCE OF DEGLACIAL EVENTS

CONFIDENCE OF ICE MARGINS

- KNOWN WELL FROM DEPOSITS AND/OR MELTWATER CHANNELS
- PROJECTED FROM ICE SURFACE PROFILE DATA & TOPOGRAPHY
- INFERRED STAGNATION ZONE BASED UPON DEPOSITS, MORPHOLOGY, TOPOGRAPHY AND ICE THICKNESS CONSIDERATIONS

KM ... KAME MORAINE
GM ... GROUND MORAINE
M ... MORAINE
OW ... OUTWASH
>>>>>>... ESKER ... SUBGLACIAL/ENGLACIAL MELTWATER PATH ... KNOWN FROM DEPOSITS

MELTWATER CHANNEL/PATH
MELTWATER CHANNEL/PATH ALONG ICE
METEORIC WATER FLOW PATH TOWARD ICE & BENEATH ICE
MELTWATER FLOW AWAY FROM ICE WITH OUTWASH DEPOSITION
TOWN PUBLIC WATER SUPPLY WELL

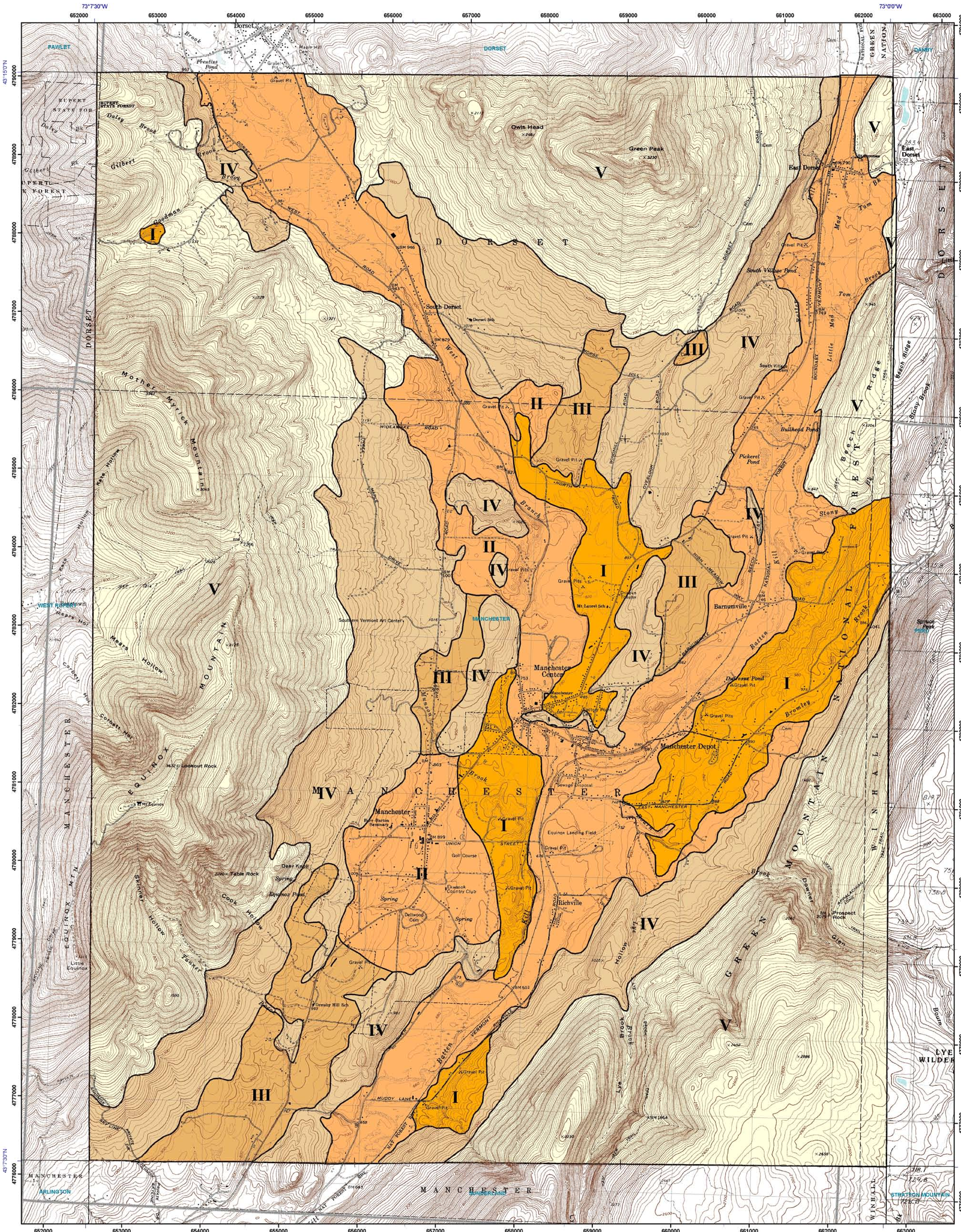
# MAP 10


WATER TABLE ELEVATION IN
OVERBURDEN AQUIFER

BY
DJ DeSimone
2004

CONTOUR INTERVAL = 10 FEET
RANGE OF ERROR IN WATER TABLE ELEVATION DATA = +/- 5 FEET

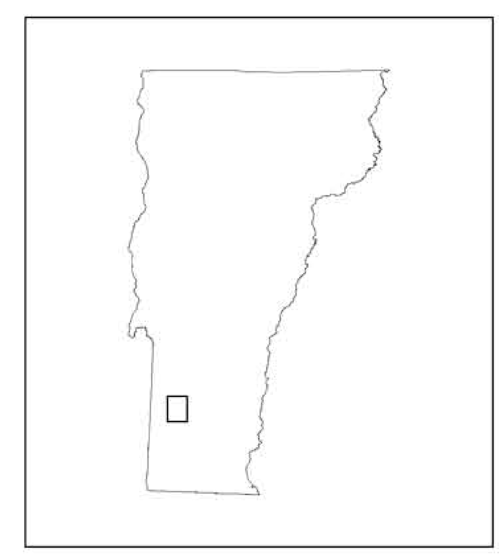
Map Plate 11- Overburden aquifer recharge potential, Manchester quadrangle, VT




LEGEND

Overburden Aquifer Recharge Potential

| | |
|---|---|
| I | Highest |
| II | High |
| III | Moderate |
| IV | Low |
| V | Lowest |
| | USGS Quadrangle Boundaries |
| | VT Town Boundaries |



Map Location

Base map from U.S. Geological Survey.
Quadrangle names printed in blue.
Coordinate System: Vermont State Plane, meters, NAD 83.
Geographic coordinates shown at topo corners are in NAD 83.
Grid overlay on map is Universal Transverse Mercator,
Zone 18N, NAD 27.

Digitization and Cartography by M. Gale, J. Kim, and C. Orsi
Date: November 2006

1:24,000

0 0.5 1 Miles

0 0.5 1 Kilometers

Contour Interval 20 Feet

MN N

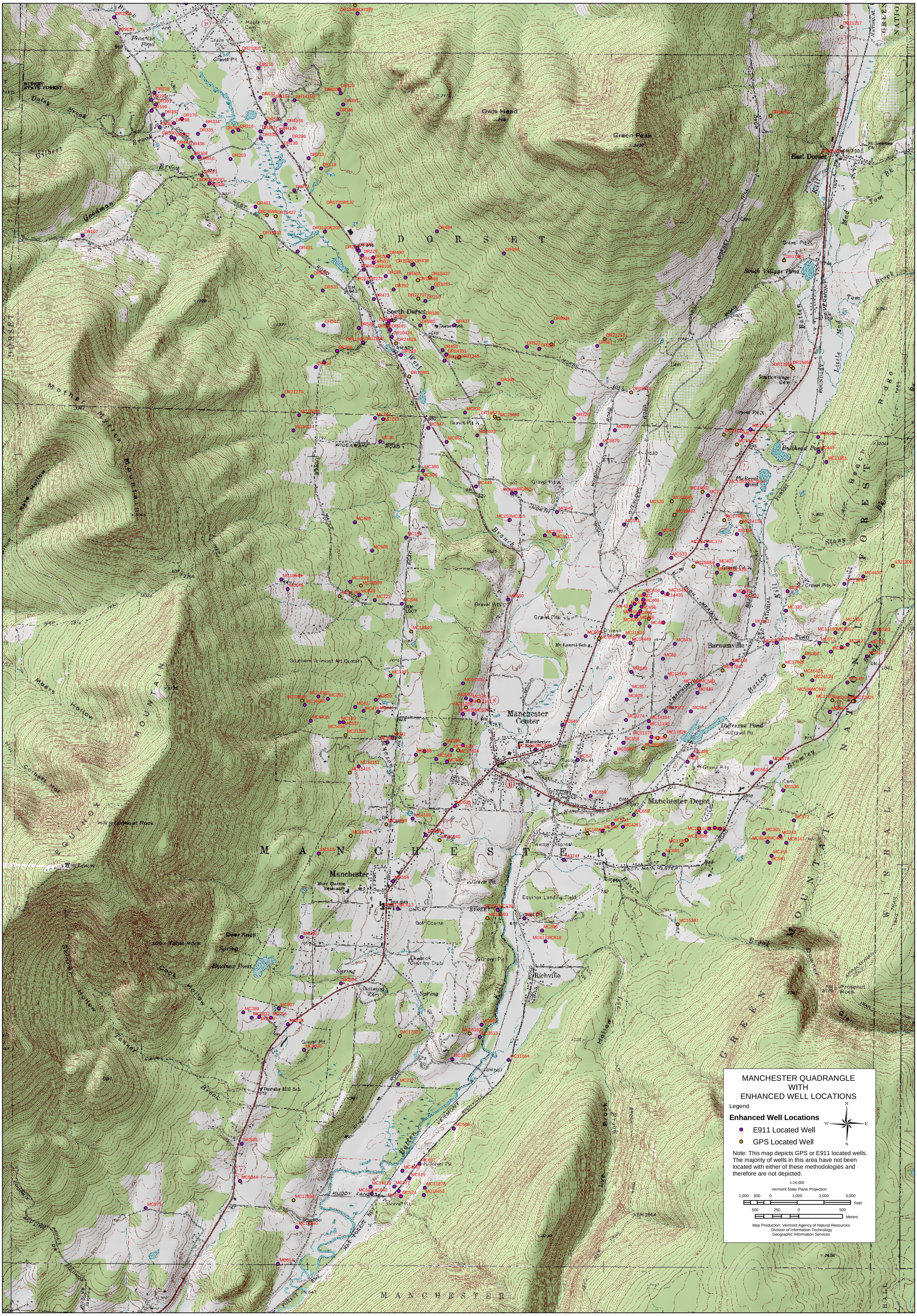
Magnetic declination
15.5 degrees west, 1968

# OVERBURDEN AQUIFER RECHARGE POTENTIAL, MANCHESTER QUADRANGLE, VERMONT

by
David DeSimone
2004

Published by:
Vermont Geological Survey
Laurence Becker, State Geologist
Department of Environmental Conservation
Agency of Natural Resources
103 South Main St., Logue Cottage
Waterbury, VT 05671-2420
http://www.anr.state.vt.us/dec/geo/vgs.htm

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR.
This geologic map was funded in part by the USGS National Cooperative Mapping Program.


MANCHESTER QUADRANGLE
WITH
ENHANCED WELL LOCATIONS
Legend
Enhanced Well Locations
E911 Located Well
GPS Located Well
N
S
E
W
Note: This map depicts GPS or E911 located wells. The majority of wells in this area have not been located with either of these methodologies and therefore are not depicted.
1:24,000
Vermont State Plane Projection
1,000 500 0 1,000 2,000 3,000
Feet
500 250 0 500
Meters
Map Production: Vermont Agency of Natural Resources
Division of Information Technology
Geographic Information Services
DORSET
MANCHESTER
Manchester Center
Manchester Depot
Manchester
South Dorset
East Dorset
Barnumville
Richville
Green Peak