

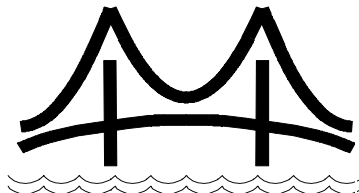
**REPORT:
AQUIFER PROTECTION STUDY
TOWN OF HURLEY,
ULSTER COUNTY, NY**

Prepared for

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Executive Summary

Aquifer Protection Study, Town of Hurley, Ulster County, NY

December 2003

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This study was initiated by the Town of Hurley Conservation Advisory Council (CAC) to define the quantity and quality of water resources with the goal of protecting such resources. The study has involved a compilation of detailed maps of federal and state-protected wetlands, soils, bedrock, surficial geologic materials, brittle structures, unconsolidated aquifers, bedrock aquifer conditions, toxic sites, and residential well data. Maps were printed on wall size sheets at a scale of 1 inch equals 13,200 feet and reduced to 8.5x11 inch page size for inclusion in the report.

Once all of the maps were compiled, then it was possible to interpret and synthesize the data into a conceptual model of hydrologic conditions to understand the interaction of surface and groundwater flow. For the 18 state-protected wetlands, as identified and mapped by NYSDEC, hydrologic conditions were interpreted using topographic, wetland, and soils maps. Areas of groundwater recharge are shown on a separate map with permeability of soils. Surficial materials and soils were correlated with unconsolidated aquifers as mapped by the US Geological Survey. Data from 114 residential wells were plotted on maps and individual bedrock aquifer areas identified and characterized. A northwest-southeast cross section, showing surface and subsurface conditions, was prepared to show topographic and flow conditions from Ohayo Mountain to Pink Hill. General areas of groundwater recharge and discharge are shown on the cross section. A generalized water budget was prepared to demonstrate the significance of the interplay of precipitation, evapotranspiration, surface water, and groundwater components.

Wetlands. Although all wetlands receive some water from precipitation, within the Town of Hurley the majority of the state-protected wetlands are maintained by lateral discharge of groundwater from adjacent bedrock and surficial materials. As a result of low permeability soil underlying most of these wetlands, the water can not infiltrate, so it is conducted downgradient as surface water. The gradients of wetlands are very low so the water moves slowly at the surface and in shallow soils and herbaceous materials. Consequently there are some large networks of wetlands within the town where one flows into another and so forth.

On the plateau south of the Ashokan Reservoir, three networks occur. Wetlands KW-2, KW-17, and KW-3 drain north and south in the vicinity of Stony Hollow into the stream that flows to the southeast down the Route 28 valley eventually entering Esopus Creek near the Kingston Traffic Circle. Stony Creek is associated with wetlands KW-6, AS-16 and AS-6 and drains to the southwest into Marbletown eventually entering Esopus Creek west of the Town of Hurley. The third wetland network is located northwest of Stony Creek and is associated with wetlands AS-4 and AS-5. Similar to Stony Creek, those wetlands and streams flow southwest into Marbletown. These wetlands on the plateau comprise surface water resources; also they are indicative of a high water table within the underlying bedrock.

In the Onondaga limestone outcrop area on the southeast side of Esopus Creek, wetlands KW-8, KW-9, and KW-18 generally drain to the north with disrupted and irregular drainage patterns entering into the Esopus. Wetlands KW-11, KW-12, and KW-20 are associated with the binnewater (no outlet) lakes within the folded limestone belt; all of which somewhere drain into the subsurface dissolution openings such as caves by way of disappearing streams and therefore they may not have surface outlets.

Soil and Groundwater Recharge. The majority of the Town is characterized as moderate recharge (0.6 to 2.0 inch/hour) as shown in green on the map. However, there are several large areas of fair and poor infiltration (0.06 to 0.2 inch/hour) as shown in orange in the wetlands, in West Hurley, in the Kenozia Lake area, in the stream valleys on the western wall of the Esopus Valley, and in some areas of the limestone belt. The best infiltration (6.0 to greater than 20 inch/hour) is found in the limestone belt, and on the northwest side along Esopus Creek as shown in magenta and blue.

Unconsolidated Aquifers. The unconsolidated aquifer map published by the US Geological Survey shows 10 different aquifers or parts of aquifers within the Town of Hurley. All of these shallow aquifers store water in unconsolidated soil and overburden materials. All except one are rated at 1 gpm. Those 9 aquifers are virtually unreliable water sources because they are shallow deposits and the yield of 1 gpm is marginal for household use. The tenth unconsolidated aquifer is marked "3" indicating a potential yield of 100 gpm. That aquifer is within the floodplain of Esopus Creek along the Route 209 corridor. The water quality may not be potable without treatment depending upon the potential presence of agricultural chemicals. Another problem with unconsolidated aquifers is that they are near the land surface and are often contaminated with bacteria. For that reason household wells over the years have increased in depth and most new wells are completed in bedrock. On the USGS Map, one area that was not identified as a potential unconsolidated aquifer is shown in blue on the soil recharge map in the valley occupied by Dug Hill Road descending the northwest valley wall of Esopus Creek. The sandy gravel loam is derived from glacial outwash deposits and has potential for storage of groundwater.

Bedrock Aquifers. Data from 115 drillers logs from the Ulster County Health Department was entered into a database and approximate well locations were plotted using centroids of the associated Section-Block-Lot. Based on location and bedrock geology, 6 areas were identified to characterize the bedrock aquifers. In each of the areas, the average depth of steel casing installed in wells was 22 to 26 feet reflecting the thickness of shallow overburden and depth to bedrock of about 20 feet throughout the town.

On the southeast side of Ohayo Mountain, in this area (purple on Geologic Map) the 18 wells had the deepest average depth of 442 feet and an average yield of 10 gpm. The static water level is the deepest of the six areas averaging 121 feet. The wells in this area are the deepest because the water table in that area is probably controlled by height of water in Ashokan Reservoir. Some of the wells have been reported to go dry, possibly as a result of the rise and fall of the reservoir or possibly poor permeability. In the case of poor permeability, the well goes dry when water in the borehole drops below the pump intake; however, groundwater levels usually recover over time and the well is

productive again. In such cases of slow recharge, a storage tank can be used to supplement the supply.

In the Hurley Ridge- West Hurley area (aqua on Geologic Map), the average well depth is the shallowest in the town at 169 feet and second highest well yield of 15 gpm. However, housing density is highest in this area and for the long-term municipal water and sewer may become necessary. Over time with so many septic fields in proximity to the residential wells, the probability for eventual bacterial contamination of the wells is quite likely. Some vacant parcels could be set aside for a potential municipal well field.

Southeast of Ashokan Reservoir, the wells in this area (aqua on Geologic Map) have the highest average yield of 17 gpm for 37 wells whereas the average total depth is only 204 feet, deeper than the Hurley average depth.

Northwest Valley Wall of Esopus Valley, this sloping area (pink on Geologic Map) has only 10 wells on record. The average depth is 375 feet and average static water level is 71 feet. Both of these parameters are second to the Ohayo Mountain area. The average well yield is 10 gpm, the same as Ohayo Mountain. The greater depths probably reflect that the water table is some distance down and back from the slope of the land.

In the Onondaga Limestone Outcrop area (yellow-green on Geologic Map), the 19 wells in this area have the following averages: yield of 13 gpm, total depth of 239 feet, and static water level of 26 feet. The static water level is the most shallow of the areas because the lowest elevations and flattest topography are found in this part of Hurley.

In the Folded Limestone Belt (blue on geologic map), only one well is recorded at Pink Hill in the very southeastern point of the Town. Because it is only one well, it may not be representative of the area.

Areas of Concern and Recommendations. Five general areas of concern are the Esopus Floodplain, Contaminated Sites, High Permeability Recharge Soil Locations, Wells in the Carbonate Bedrock, and Potential Areas for New Water Supplies

The Esopus Creek Floodplain is a significant agricultural area for cultivation of corn and field crops. The groundwater in this area must remain clean to sustain the agricultural use. Two potential threats to the water exist associated with Route 209 and other roads on the floodplain. One threat is the use of road salt and the potential to turn the groundwater to brine which the crops may not be able to tolerate. Along the highway, another threat is the potential for a chemical spill, which could render a portion of the floodplain useless for agriculture. This concern should be discussed with local farmers and if they think it is a valid issue, the State and County highway maintenance people should be approached to request that they use less or no salt on the roads adjacent to fields. In some towns, signs are put up to inform the motorists that the area is an aquifer area and salt is not used on the road.

Contaminated Sites are shown on a map from Toxic Targeting's website with symbols for the locations of solid waste (landfills), hazardous waste, hazardous substance, tank

failure and MTBE spill sites. Residual contamination is most likely still in the soils and possibly the groundwater at these sites. Documentation of each of these sites should be reviewed at NYSDEC Region 3 Offices to evaluate whether the contamination has been removed or cleaned up. If not remediated, some action should be taken to warn current landowners, potential buyers, and builders of the possibility of underground contamination at the site and under adjacent properties. Soil and groundwater testing should be required prior to building or development.

High Permeability Recharge Soil Locations are shown in magenta and blue on the soil recharge map. These areas are vulnerable to rapidly conducting any spilled liquid contaminants directly into the groundwater. Septic systems on such soils may work too rapidly and release bacteria into the groundwater. Some provision should be made address the vulnerability of these areas.

Wells in the Carbonate Bedrock. Because of the solubility of carbonate rock such as limestone and dolostone, these rock types present special conditions that require extra attention. First when wells are drilled in carbonate rocks, a rotary rig grinds the bedrock into fine powder. When water enters the borehole, the calcium carbonate and magnesium carbonate powders mix with the water to form cement. The rotating motion of the drill bit can smear the cement into the bedrock fractures that provide the water and even though the well seemed to produce water during drilling, a dry hole can result if the driller does not take care to keep the wellbore clean. When this happens, there are service companies whose personnel can open the fractures with various treatments. Second, the solubility of limestone and dolostone is the property that allows running water to create caves in such rocks. Groundwater moving through a crack or fracture can gradually dissolve away the walls and make a larger and larger opening. When a cave breaks through to the land surface, a sinkhole is formed. Similar to the high permeability soils, when contaminants are introduced into carbonate bedrock terrain, the potential for rapid dispersal exists. The green and blue areas on the Bedrock Map are carbonate terrain in the Town of Hurley. Some provision should be made address the vulnerability of these areas.

Potential Areas for New Water Supplies. As a result of examining the individual well logs, bedrock aquifer areas, the wetland distribution, the soil properties, and topography, three areas have been identified with the potential to provide significant water supplies for future residential and commercial development. All three areas have unique surface features, but each water supply is in the groundwater within bedrock. These areas include the West Hurley area close to the eastern town boundary in the vicinity of an unconsolidated aquifer on the USGS map, the Stony Creek wetland (AS-16 and AS-6) complex, and an area in the Onondaga limestone outcrop area bounded by the Town border on the south, the old railroad grade on the west, Lucas Avenue to the east and wetlands KW-8 and KW-9 to the north. These areas all show positive signs of good water yield. If municipal water systems are needed in the future, these are the potential sources. Provisions should be made to identify specific parcels and develop a well drilling and testing program to quantify the potential yield of these bedrock aquifers. To set aside these precious areas, long range planning is needed to establish a preserving and protective mechanism such as conservation easements or critical environmental areas.

TABLE OF CONTENTS

	page
Executive Summary	after title page
INTRODUCTION	1
WETLANDS	1
SURFICIAL MATERIALS	3
SOILS	5
SIGNIFICANT AREAS OF GROUNDWATER RECHARGE	5
BEDROCK	6
WATER WELL INVENTORY	7
AQUIFERS	8
Unconsolidated Aquifers	10
Bedrock Aquifers	11
WATERSHEDS AND GENERALIZED WATER BUDGET	17
AREAS of CONCERN and RECOMMENDATIONS	18
REFERENCES	21
Appendix A Index to Water Wells by SBL	
Appendix B Water Well Data by Well Number	
Appendix C Drillers' Lithologic Well Logs in Numerical Order	
Appendix D List of Drillers and Codes used in Database	

List of Tables

Table 1	Characteristics of Wetlands
Table 2	Classification of Soils by Permeability
Table 3	Characteristics of Residential Wells in Specific Geologic Areas
Table 4	Definitions of Aquifer
Table 5	Estimated Generic Water Budget

List of Figures & Plates

(Figures are 8.5 x 11 inch included with text of this report,
Plates are large format, 36 x 40 inch rolled for Town Use)

1. Freshwater Wetlands Map, Federal and State Protected
2. Surficial Geology Map
3. Map of Soil Permeability
4. Bedrock Geology Map
5. Geologic Brittle Structures Map
6. Water Supply Wells on Individual Properties
7. USGS Unconsolidated Aquifer Map
8. Geologic Cross Sections

List of Figures

Figure 9	Generalized Annual Water Budget (Month by Month)
Figure 10	Selected Toxic Sites

INTRODUCTION

This study was initiated by the Town of Hurley Conservation Advisory Council (CAC). Concern for quantity and quality of water resources in the Town was the driving force to begin compiling data and to define groundwater conditions. Mid-Hudson Geosciences prepared a proposal to provide this compilation and interpretation of hydrogeologic data identifying and classifying water resources and aquifers with respect to unconsolidated aquifers, bedrock aquifers, wetlands and surface waters within the Town of Hurley. Areas of known and potential contamination are also identified. A conceptual model of groundwater flow conditions is developed to define a basic understanding of groundwater conditions and surface water interactions. Recommendations will be made for areas of aquifer protection and measures to protect aquifers and associated water resources. Relevant maps and data will be provided for use by the CAC.

The stated objectives of the study include:

- Characterize aquifer conditions in the six bedrock terrains (areas).
- Identify areas of high yield and low yield aquifers.
- Recommend protection procedures for specific aquifers and surface waters.
- Provide data in a format that could be used for future studies.

In order to characterize hydrogeologic conditions in the Town, both surface and subsurface conditions need to be reviewed. The well data provides information on groundwater occurrence, but wetlands and stream conditions must also be addressed. For the 18 wetlands identified and mapped by NYSDEC, hydrologic conditions were interpreted; based on topographic, wetland, and soils maps. A northwest-southeast cross section, showing surface and subsurface conditions, was prepared to show topographic and flow conditions from Ohayo Mountain to Pink Hill. General areas of groundwater recharge and discharge are shown on the cross section. Areas of groundwater recharge are shown on a separate map with permeability of soils. A generalized water budget was prepared to demonstrate the significance of the interplay of precipitation, evapotranspiration, surface water, and groundwater components.

This report presents the procedures used, the data collected, the computer-plotted maps, and interpretations of hydrogeologic conditions in the Town. Also some recommendations are made for additional synthesis and interpretation of the data.

WETLANDS

There are 18 state designated wetlands within the bounds of the Town of Hurley (Figure 1). The wetlands are designated by an alphanumeric code consisting of two parts. The first part is a one or two letter designation for the 7.5 minute U.S.G.S. quadrangle, such as KW for Kingston West or AS for Ashokan. The second part is a number; the wetlands are numbered consecutively from one for each quad. The wetland designated as "AS-6" is the sixth one on the Ashokan quadrangle. If the wetland overlaps a quad boundary, the designation for the quad with the largest areal extent is used.

In order to understand the interrelationships between groundwater and surface water in the Town, it is necessary to interpret the hydrologic conditions prevailing in the wetlands. To comprehend the characteristic hydrologic setting, each of the wetlands is reviewed with respect to topographic configuration, soil types, drainage pattern, and flow direction. Table 1 summarizes the characteristics of each of the wetlands. In Ulster County, very little work has been done to classify wetlands based on hydrologic conditions. Environmental scientists have more or less assumed that they are areas of groundwater discharge or recharge. However, this study demonstrates four classes of wetlands where water is discharged, recharged, entrapped, and conducted.

As mentioned above, discharge and recharge areas are classed by the action of the groundwater, whether it is exiting or entering the subsurface in the wetland. Entrapped conditions are characterized by the accumulation of surface runoff in a depression with no outlet and underlain by low permeability materials blocking vertical infiltration. Evaporation and evapotranspiration play an important role in depleting the water from entrapping wetlands. Conducting or conductor wetlands are also underlain by a low permeability boundary, but there is an outlet for water to drain from the wetland; however, it remains wet and conductive because the incoming supply is balanced by very low flow rate of outgoing runoff.

In this study, some wetlands were found to be combinations of the four classes, such as one that entraps surface flow and discharges groundwater. Another wetland may conduct surface water and recharge groundwater. Sometimes two processes occur within the same soil type and sometimes there are two or more soil types, each facilitating different processes. Understanding the soil characteristics is essential to interpreting the hydrologic conditions prevailing in each wetland. A summary of the pertinent characteristics of each wetland or associated soil type is provided in Table 1. The soil characteristics provided in Table 1 come from the "Soil Survey of Ulster County" (USDA, 1979).

Summary of Wetlands Hydrology

The wetlands in the Town of Hurley can be classified based on whether they entrap or conduct surface waters and whether they recharge or discharge groundwater by studying the soil types and topographic configurations. Some wetlands are combinations of these classes.

The concept that most wetlands are areas of groundwater recharge is definitely not the case here. If one thinks about it, in areas where vertical recharge is a significant factor, the area should be dry because the water has percolated downward to the water table. A careful review of wetlands with respect to potential recharge reveals that wetlands KW-9, KW-11, and KW-19 are recharge areas because they supply water to streams, which disappear into the subsurface in areas underlain by soluble Onondaga Limestone. However, all of the state designated wetlands function as **discharge** sites where water from surrounding higher soils and bedrock discharges into the lowland. Some of the water in the upland wetlands south of Ashokan Reservoir may be areas of discharge due to hydrostatic pressure exerted through bedrock porosity from the water in the reservoir.

Wetlands on hillsides and at the base of the northwestern Esopus Valley wall are areas of groundwater discharge because there is sufficient hydrostatic head and permeability to allow water to discharge into the wetlands.

Several wetlands entrap surface water because runoff enters from surrounding soils, there is no outlet, and vertical permeability is slow. Some wetlands conduct surface water because there is a drainage outlet, but slow or moderate permeability keeps the soils saturated.

Although all wetlands receive some water from precipitation, within the Town of Hurley the majority of the state-protected wetlands are maintained by lateral discharge of groundwater from adjacent bedrock and surficial materials. As a result of low permeability soil underlying most of these wetlands, the water cannot infiltrate, so it is conducted downgradient as surface water. The gradients of wetlands are very low so the water moves slowly at the surface and in shallow soils and herbaceous materials. Consequently there are some large networks of wetlands within the town where one flows into another and so forth.

On the plateau south of the Ashokan Reservoir, three networks occur. Wetlands KW-2, KW-17, and KW-3 drain north and south in the vicinity of Stony Hollow into the stream that flows to the southeast down the Route 28 valley eventually entering Esopus Creek near the Kingston Traffic Circle. Stony Creek is associated with wetlands KW-6, AS-16 and AS-6 and drains to the southwest into Marbletown eventually entering Esopus Creek west of the Town of Hurley. The third wetland network is located northwest of Stony Creek and is associated with wetlands AS-4 and AS-5. Similar to Stony Creek, those wetlands and streams flow southwest into Marbletown. These wetlands on the plateau comprise surface water resources; also they are indicative of a high water table within the underlying bedrock.

In the Onondaga limestone outcrop area on the southeast side of Esopus Creek, wetlands KW-8, KW-9, and KW-18 generally drain to the north with disrupted and irregular drainage patterns entering into the Esopus. Wetlands KW-11, KW-12, and KW-20 are associated with the binnewater lakes within the folded limestone belt; all of which somewhere drain into the subsurface dissolution openings such as caves by way of disappearing streams and therefore they may not have surface outlets.

SURFICIAL MATERIALS

The New York State Geological Survey has compiled a series of 1:250,000 maps showing the distribution of surficial materials throughout the state. Ulster County and the Town of Hurley straddle the boundary between the Hudson-Mohawk Sheet and the Lower Hudson Sheet. For this study, the outlines of various materials were downloaded from the Internet and then traced to provide the areas for each material. The colored areas were then superimposed on the USGS topographic maps and printed at a scale of 1"=1500' and page size (Figure 2).

Surficial Materials consist of the material or overburden above bedrock. The materials are mapped with respect to their origin. In Ulster County much of overburden is related to Pleistocene glaciation. The surficial map shows the following materials within the Town of Hurley:

Swamp Deposits. Swamp deposits consist of peat and muck with organic silt and sand in poorly drained areas. The areas are underwater most of the time and therefore the sediments are nonoxidized. There is a potential for land instability.

Kame Deposits. A kame is defined as a mound, knob, or short irregular ridge, composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier; by a superficial stream in a low place or hole on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice. These deposits are locally cemented with calcareous cement.

Outwash Sand and Gravel. Outwash consists of sand and gravel deposited by meltwater streams in front of the end moraine or the margin of an active glacier. Sometimes these deposits are found forming a wide sloping plain called an "outwash plain" at the foot of the moraine or glacier.

Alluvial Sand and Gravel. Alluvium or alluvial sand and gravel is deposited by streams or running water and confined to floodplains in valleys. The material is oxidized and noncalcareous. These areas are subject to frequent flooding.

Lacustrine silt and clay. Lacustrine deposits originate in lakes or ponds, sometimes glacial lakes and ponds formed on top of glaciers or on the margin of glaciers. The water in the lakes or ponds is from precipitation, meltwater, and sometime streams. The fine grain size of silt and clay reflects the low energy or lack of current in the lakes or ponds. The sediments are finely laminated displaying seasonal varves. A varve is a pair of layers or laminae deposited in one year; the lower summer layer is a light-colored silt or sand and the upper thinner winter layer is a darker finer sediment consisting of organic clay.

Till. Till is defined as unstratified drift deposited directly by a glacier without reworking by meltwater and consists of a mixture of clay, silt, sand, gravel, and boulders widely ranging in size and shape. Drift is a general term for a glacial deposit. The kame, and outwash deposits are stratified compared to till which is not stratified. In Ulster County till often has a very high clay content and is sticky, hard and difficult to cultivate. Some till deposits in other parts of the Hudson Valley have significant sand content. The content of till is dependent upon the load that the glacier was carrying and deposited. Sometimes tills form broad deposits where the glacier has melted and left behind its load material. The clay content of these deposits make them relatively impermeable with respect to infiltration of water. On slopes these deposits can be unstable and landslides can be triggered.

Bedrock. A large portion of the Surficial Material Map is shown in white indicating that bedrock is at the surface or close to it. Some of these areas are the result of quarrying or

steep slopes. A lot of the area south of Ashokan Reservoir has been quarried in the past and the open rock areas are remaining.

The most significant characteristic of the surficial map is the large white area in addition to the Ashokan Reservoir. Bedrock areas with little or no overburden are shown in white. Some of that area is attributed to rock quarries, as shown on the soil map, representing an industry of the past.

The pink areas represent areas of glacial till, mostly on high ground. The wide Esopus Valley along the Route 209 corridor contains a central alluvial sand deposit and lacustrine silt and clay deposits on each side. An outwash sand and gravel deposit is mapped in the Stony Creek valley just north of the town boundary. A swamp deposit is mapped in association with wetland KW-3 in the Stony Hollow area. Two Kame deposits are shown; one in the stream valley southwest of Gallis Hill and another in West Hurley near the town boundary and the Saw Kill.

SOILS

The "Soil Survey of Ulster County, New York (USDA, 1979)" includes 8 sheets covering the Town of Hurley. The soil maps in the survey are superimposed on air photos. Separate sheets of the survey are available without the air photo overlay. Those sheets were obtained for the Town of Hurley. They were scanned into raster images and pieced together in the computer to form a complete map for the town (Figure 3). The map was plotted at a scale of 1 inch = 1500 feet to coincide with the other maps used in this project.

The significance of soil maps with respect to water resources is that certain soil types may have characteristics associated with areas of groundwater recharge and discharge. Also soil characteristics may create wetland conditions. For those reasons, the printed composite map (Figure 3) was hand colored based on permeability (Table 2).

This map (Figure 3) currently outlines the rock quarries. The majority of the town has moderately to rapidly permeable soils, shown in green. The highest permeability soils are in the central part of Old Hurley shown in magenta. Some blue areas mark the moderately to rapid permeability areas of permeability in the Esopus Valley, in the steep Dug Hill Road area closest to Hurley Mountain Road; in the Rolling Meadows to St Charles Hall area (locale shown on quad maps), and a few other smaller areas.

SIGNIFICANT AREAS OF GROUNDWATER RECHARGE

Recharge is controlled by the vertical permeability of earth materials, both surficial (unconsolidated) sediments and bedrock. There is some vertical infiltration of precipitation and runoff through most overburden materials and each soil type has a measurable and predictable vertical permeability. The soil permeability map (Figure 3) shows areas within specified ranges of permeability, based on soil type. High permeability soils tend to

develop on water-sorted glacial deposits in contrast to low permeability (hydric) soils which develop on unsorted glacial till. In the Town of Hurley, the areas shown in magenta and blue are the areas of greatest permeability and have the greatest potential for downward vertical infiltration in conjunction with the wetland areas identified as supplying recharge to bedrock.

Relationship of Wetlands to Recharge Areas

Generally, recharge areas are dry because they conduct water away from the surface. Occasionally a wetland is also a recharge area because a recharge area receives runoff faster than it is able to disperse the water downward by vertical recharge through the soil substratum. Also, some low areas can form wetlands by transmitting water upward through the permeable soils due to hydrostatic pressure from proximal uplands.

BEDROCK

The topography divides the Town into specific characteristic terrains or geologic provinces with general southwest to northeast linear trends reflecting the underlying bedrock (Figure 4). The stratigraphic sequence is described here from youngest to oldest, from top down:

Dgo	Genessee Group, locally the Oneonta Formation shale and sandstone Bedrock of Tonshi and Ohayo Mountains above 1000 feet elevation and north of the Ashokan Reservoir.
Dhmo	Hamilton Group, Moscow Formation shale and sandstone, on the northside of Ashokan Reservoir below 1000 feet elevation.
Dhpl	Hamilton Group, Plattekill and Ashokan Formations shale and sandstone, on the Morgan Hill upland south of the Ashokan Reservoir.
Dhm	Undifferentiated lower Hamilton Group shale and sandstone, forming the steep slopes north of Hurley Mountain Road and southeast of Morgan Hill.
Dou	Onondaga Limestone underlying the Esopus Creek floodplain and southeast beyond Lucas Turnpike (Ulster County Route 1).
DS	Undifferentiated Lower Devonian and Silurian folded and faulted carbonate rocks outcropping in the very southeast corner of the Town.

These bedrock formations or strata are nearly flat-lying (similar to a layer cake), so that when drilling a water well north of the Ashokan Reservoir, you would begin drilling in the local bedrock layer and gradually drill on down into the deeper strata in succession as shown below in well logs and cross sections.

The different types of bedrock within each of the six terrain areas have individual characteristics for recharge, storage, and migration of groundwater. Other environmental features that influence the water-bearing conditions include wetlands, surface waters, and soil type. One particular surface water feature that may have some

influence on a significant area of the Town is water level fluctuation in the Ashokan Reservoir. Because the Reservoir does not have a liner, water can move into and out of the underlying and surrounding bedrock. In a similar manner, the periodic discharge from the Reservoir regulates stream flow in the Esopus Creek and may influence water levels in the nearby bedrock aquifers. Annual rainfall drives the hydrologic cycle by recharging groundwater and surface water bodies.

Another map prepared by the NY Geological Survey shows the brittle structures (Figure 5). These structures are usually linear features such as faults, fold axes, fracture zones, or other undefined "lineaments." Sometimes water resources or drainage patterns are associated with these large regional features. In the case of Hurley, there are very few features except for a few lineaments associated with major stream valleys.

WATER WELL INVENTORY

The water well inventory consists of data from several sources. Four approaches were undertaken to obtain information about water wells: collection of data from the Ulster County Health Department well record files, compilation of surveys sent to homeowners, inquiries for well data from drillers, and comparison of County files with Town building permits.

The initial round of data collection was completed in 1989 from the Ulster County Health Department water well files, the Real Property Tax Department, and Town of Hurley Assessors. An initial set of maps was printed in 1990. In subsequent years, the files were updated. Once the data is compiled in a computer database, it can be displayed in formats via computer programs to facilitate synthesis and interpretation. In this particular case, computer-generated maps were created to display the spatial distribution of individual well parameters. Through the interpretation of these maps of well depths, casing depths, well yields, and static water levels; in conjunction with review of stratigraphic information, aquifer conditions can be mapped.

Collection of Well Data from County Files

Data were entered into a database on a portable computer at the Ulster County Health Department, Environmental Sanitation Division. The following items were entered from the individual driller's water well logs:

- County Code
- Town Code
- Date drilling started
- Date drilling ended
- Unique identification number
- Name of property owner or developer
- Address of property
- Total depth of well in feet
- Static water level in feet below ground surface
- Casing depth in feet

Casing diameter in inches
Yield in gallons per minute
Driller's name (abbreviated)
Soil type or lithology and depth of
each stratigraphic unit penetrated in borehole

Additional Data from Town Assessors

Tax Identification numbers consisting of Section, Block, and Lot (SBL) numbers and centroid coordinates (in State Plane Coordinates) were determined for all wells in the database. Because the Ulster County Health Department did not have SBL numbers for the wells, a search was made to find the proper Tax Identification code associated with the land parcel on which the well was drilled, using the owner, address, and dates provided in the well files. During 1992 and 1993, the County tried to get the SBL numbers, but in many cases, they had the wrong number. All of the SBL numbers were reviewed with records from the Town of Hurley Assessors in the process of searching for the centroid coordinates. To plot wells on maps, it is necessary to have rectangular coordinates for each well. Since the actual coordinates are not readily available, the centroid coordinates of each parcel were obtained from the tax assessor rolls.

All data files were read into a database program (PC-File v.5.1). That program is shareware, does not require a license, and is compatible with "dBASE III". Subsequently, the file has been transformed into Microsoft Access format.

Computer Mapping

For computer mapping, a base map from US Geological Survey 7.5 minute topographic quadrangles was chosen because the CAC soil maps and NYSDEC wetlands maps are at the same scale of 1:24000. The coordinates used for mapping are defined by the State Plane Coordinate system which uses units of feet measured north or south and east or west of a fixed origin (0,0). The coordinates in the Town of Hurley are generally some 500,000 feet west and 600,000 feet north of the origin. The X- and Y- coordinates are referred to as "Easting" and "Northing". In the database, the centroids of parcels are recorded to the nearest 10 feet and the maps are scaled in tens of feet. State Plane Coordinates are marked in tiny numbers on the edges of the topographic base map. The boundary of the Town of Hurley was digitized and stored in the computer file to print on the computer-generated maps for alignment with other maps.

To facilitate mapping, the database from PC-File is converted into an ASCII data file for the mapping subroutines within AutoCAD to read the data files and plot well symbols and data in their respective locations on the maps. A map was prepared showing a list of data next to a small triangle plotted at the well location (Figure 6).

AQUIFERS

The purpose of this section is to define an aquifer and explain some of the not-so-obvious

techniques and pitfalls in attempting to map an aquifer.

Definition of Aquifer

Four definitions of the term "aquifer" are quoted in Table 4 from four widely-used technical references. All of these definitions stress that the groundwater is used for some purpose, while including descriptions of other characteristic terms or quantitative factors such as saturation, porosity, permeability, hydraulic gradient, and yield.

Water-Bearing Zone versus Aquifer

The occurrence of groundwater is usually divided into two cases by hydrogeologists: water-bearing zones and aquifers. Water-bearing zones are zones that may be sampled by a monitoring well or the water level detected in a piezometer, but may not produce appreciable volumes of water for use. Aquifers are water-bearing zones that have sufficient production to supply a home, business, or community.

Porosity & Saturation

Porosity is the measurable storage space where groundwater occurs within the sediments or rock. There are several types of porosity based on the origin of the pores and pore space. The most common type is intergranular pore space between grains such as sand and gravel. In bedrock, there is fracture porosity, which is the space in the openings within fractures where the rock has cracked open from stress.

The water table marks the top of the saturated zone. Pore space that is below the water table is fully saturated with respect to water. Pore space above the water table may contain some moisture, but is not saturated.

Mapping Aquifers

Water resources come from two sources, surface water and groundwater. Mapping surface water resources is relatively straightforward because their upper surface can be seen from the air on photos and they are confined by earth materials on the sides and bottoms, except for openings to another body of water or the ocean. The third dimension of surface water bodies can be measured directly by various methods of sounding, and the rate of movement can be measured directly with a flowmeter. Complex variations of these methods must be used to map occurrences of groundwater because they are more obscure, they are hidden from view, and their presence is only detected at discrete points (such as wells).

Local Aquifers

The aquifers in the Town of Hurley consist of two types: unconsolidated surficial and bedrock. Generally the unconsolidated surficial aquifers are found in sand and gravel deposits associated with glacial or alluvial deposits, or a combination of the two. The

bedrock aquifers are associated with fractures, bedding plane partings, joints, and cleavage, that is, any openings in the bedrock, which can conduct water.

To estimate the availability of water in the local aquifers requires developing an understanding of the hydrogeologic conditions. Groundwater resources are dependent upon the bedrock, surficial sediments, and soils to provide the porosity for storage and the permeability to transmit water. Surface water resources are dependent on geologic materials lining lakes, ponds, wetlands, and streams. Exchange of surface water to groundwater is called "recharge" and groundwater to surface water is "discharge." The exchange between a stream and the subsurface defines "gaining streams" and "losing streams." Normally, losing stream conditions are prevalent during spring rains and gaining stream conditions during summer drought. Recharge is a significant factor in all aquifers to maintain the supply as water is withdrawn from wells.

Unconsolidated Aquifers

The information currently available describing unconsolidated aquifers includes the Soil Survey of Ulster County (USDA, 1979), USGS maps of aquifers interpreted from soils maps (Bugliosi and Trudell, 1987; Wolcott, 1987), and the water well database created as part of this study (Appendix A, B, C). The USGS has published a map of unconsolidated aquifer potential (Figure 7) based on topographic and soil conditions.

The unconsolidated aquifer map published by the US Geological Survey (Bugliosi and Trudell, 1987) shows 10 different aquifers or parts of aquifers within the Town of Hurley. Part of the USGS map (Figure 7) outlines areas of unconfined aquifers with potential yield of 1 to 100 gallons per minute. All of these shallow aquifers store water in unconsolidated soil and overburden materials. All except one are rated at 1 gpm. Those 9 aquifers are virtually unreliable water sources because they are shallow deposits and the yield of 1 gpm is marginal for household use. The tenth unconsolidated aquifer is marked "3" indicating a potential yield of 100 gpm. That aquifer is within the floodplain of Esopus Creek along the Route 209 corridor. The water quality may not be potable without treatment depending upon the potential presence of agricultural chemicals. Another problem with unconsolidated aquifers is that they are near the land surface and are often contaminated with bacteria. For that reason household wells over the years have increased in depth and most new wells are completed in bedrock. On the USGS Map, one area that was not identified as a potential unconsolidated aquifer is shown in blue on the soil recharge map in the valley occupied by Dug Hill Road descending the northwest valley wall of Esopus Creek. The sandy gravel loam is derived from glacial outwash deposits and has potential for storage of groundwater.

Although unconsolidated deposits often provide high yields because there is high porosity and good recharge directly to the aquifer, the high permeability and shallow conditions also provide an avenue for rapid contamination if toxic materials are spilled at the surface and enter an aquifer.

Bedrock Aquifers

Bedrock aquifer conditions occur throughout the Town of Hurley beneath the soils, glacial deposits, and stream sediments. Groundwater is stored within fractures, bedding plane partings, and other pore space within the bedrock. There are some geologists who believe the best aquifer conditions are found along fracture traces that can be interpreted from aerial photographs. This hypothesis is based on the assumptions that the fractures are vertical and their surface expression is not masked by glacial deposits, soils, or man-made features. Accordingly, the intersection of two fracture traces is the best location for drilling a productive well.

The different types of bedrock within each of the six terrain areas (Figure 4) have individual characteristics for recharge, storage, and migration of groundwater. Other environmental features that influence the water-bearing conditions include wetlands, surface waters, and soil type. One particular surface water feature that may have some influence on a significant area of the Town is water level fluctuation in the Ashokan Reservoir. Because the Reservoir does not have a liner, water can move into and out of the underlying and surrounding bedrock. In a similar manner, the periodic discharge from the Reservoir regulates stream flow in the Esopus Creek and may influence water levels in the nearby bedrock aquifers. Annual rainfall drives the hydrologic cycle by recharging groundwater and surface water bodies.

For each of the bedrock terrains listed above, an evaluation of their aquifer characteristics and their interactions requires integration of information from topographic, wetland, soil, surficial, and geologic maps. Another important source of information is the Ulster County Health Department file of water well driller's logs. The logs typically include total depth, casing depth, soil and rock type, well yield, and static water level. The logs are identified by property owner names and Section, Block and Lot numbers. Although the precise location of each well is not available, the centroid for each parcel is available from the Town Assessor's Office. The well measurements (total depth, casing depth, static water level, and well yield) can be mapped using the northing and easting State Plane Coordinates for the parcel centroids. Using such maps the range of depth and well yield can be found for each of the designated terrain areas.

Well Data for Drilling Prediction

From the well map, total depth and well yield can be used as predictors of aquifer conditions in a specific area. If a well is going to be drilled for a new house, the driller or property owner can review the maps with respect to depth and yield and of nearby wells. The lithologic descriptions (Appendix C) for nearby wells can also be helpful in ascertaining if most wells produce from unconsolidated deposits or bedrock.

Data from 115 drillers logs from the Ulster County Health Department was entered into a database and approximate well locations were plotted using centroids of the associated Section-Block-Lot (Figure 6). Based on location and bedrock geology, 6

areas were identified to characterize the bedrock aquifers. Well parameters for the 6 areas were tabulated and statistical measures calculated (Table 3). In each of the areas, the average depth of steel casing installed in wells was 22 to 26 feet reflecting the thickness of shallow overburden and depth to bedrock of about 20 feet throughout the town. Well depth and yield will be noted in the following discussions characterizing the various bedrock aquifer areas. Cross sections were constructed to scale showing the geologic formations and their orientation with well logs for selected water wells (Figure 8).

#1. Southeast Side of Ohayo Mountain

This area lies in north central part and northwestern corner of the Town of Hurley on the southeastern slopes of Ohayo and Tonshi Mountains, respectively. Topographically, this area consists of very steep relief and elevations range from 800 to 1380 feet above sea level on Ohayo and 800 to 2000 feet on Tonshi Mountain.

As shown in the summary table (Table 3) in this area, based on a sample of 18 wells, the average depth of 442 feet was the deepest and an average yield of 10 gpm was the lowest compared to the other 5 areas of the Town of Hurley. The static water level is the deepest of the six areas averaging 121 feet. The logs for two wells record a total depth of 998 feet for each. Such depths suggest limited water availability and the need to drill deep for it. All of the well records are from the vicinity of Ohayo Mountain or the gap separating Ohayo from Tonshi. There are no logs on file for homes on Tonshi Mountain.

As shown on Cross Section D -- E (Figure 8) and the Geologic Map (Figure 4), the wells are drilled into the Moscow Formation of the Hamilton Group (shown in purple). Depending on elevation and depth, many of these wells penetrate the Plattekill and Ashokan Formations (shown in turquoise) and a couple of very deep wells go deeper into the Lower Hamilton Group (shown in magenta). On Tonshi Mountain, wells drilled above 1000 feet would first penetrate the Oneonta Formation of the Genesee Group (shown in gold-orange) and then go deeper into the Hamilton Group strata.

In this area, a detailed study of 14 driller's logs indicate that the bedrock in the area consists of layers of Bluestone (bluish-gray sandstone), red sandstone, gray sandstone, and interbedded layers of red, gray, green, and black shale. The color variations of the bedrock are indicative of the state of oxidation of the iron compounds. Red represents high oxidation in subarial deposition and gray, green, and black represent increasing states of reduction. The Genesee and Hamilton Groups represent sequences of subarial and marine deposition in a delta with sediments transported from a source area in the east, perhaps Dutchess County or eastern Connecticut. The sandstones may have some primary porosity (perhaps 5%) providing storage of water. However, the logs indicate that often water is found in fractures and bedding planes (secondary porosity). The driller's logs usually refer to these water-bearing zones as "seams."

A comparison of the Map of Soil Permeability (Figure 3) with the topography on the Well

Location Map (Figure 6) indicates that soil percolation, infiltration and/or recharge is moderate (shown in green). Most of the area has very thin soil cover with moderate permeability indicating a potential for good infiltration of precipitation. However, the recharge is reduced by the tendency of steep slopes to limit recharge by removing the water with rapid runoff. Also the permeability of the bedrock may be significantly lower than the soil and overburden, thereby reducing vertical recharge. Water may infiltrate through the soil and reach the top of the bedrock where it may travel downgradient along the top of the bedrock and eventually come out as a spring on the mountainside.

The wells in this area are the deepest because the water table in some parts is probably controlled by height of water in Ashokan Reservoir. Also there is a strong vertical hydraulic gradient along the mountain slope. Some of the wells have been reported to go dry, possibly as a result of the rise and fall of the reservoir or possibly poor permeability. Scarcity of water may be a result of steep hydraulic gradient by virtue of elevation and low permeability. In all cases, withdrawal can exceed recharge or demand can exceed supply. In the case of poor permeability, the well goes dry when water in the borehole drops below the pump intake; however, groundwater levels usually recover over time and the well is productive again. In such cases of slow recharge, a storage tank can supplement the supply in conjunction with the wellbore holding about 1.5 gallons per vertical foot of 6-inch diameter casing or open hole. If recovery is too slow, the well should be deepened.

#2. Hurley Ridge- West Hurley Area

The Hurley Ridge- West Hurley area lies in northeast corner of the Town of Hurley, east of Ohayo Mountain and north of Ashokan Reservoir. Topographically, this area consists of relatively low relief and elevations range from 500 to 700 feet above sea level. The elevation of Ashokan Reservoir (when full) is 597 feet; therefore some of the land surface in this area is below the elevation of the reservoir.

As shown in the summary table (Table 3), for this area, based on a sample of 24 wells, the average well depth is the shallowest at 169 feet and second highest well yield of 15 gpm when compared with the other 5 areas. As shown on Cross Section A -- B (Figure 8) and the Geologic Map (Figure 4), the wells are drilled into the Plattekill and Ashokan Formations of the Lower Hamilton Group (shown in turquoise). Only the deepest wells, those greater than about 400 feet, would penetrate the underlying Lower Hamilton Group (shown in magenta).

In this area a detailed study of 19 driller's well logs indicates that the bedrock consists of layers of red, gray, gray-green, and black shale in addition to gray sandstone, red sandstone, and bluestone (bluish-gray sandstone). The sandstone is primarily a mixture of feldspar, amphibolite/pyroxene, and quartz grains in order of diminishing concentrations. The grains are primarily sand-size although smaller amounts of smaller-size silt are undoubtedly present in the sediments along with a small fraction of fines (clay and mud particles). The sandstones may have some primary porosity (perhaps 5%) providing storage of water. However, the logs indicate that prolific water

is found often in fractures and bedding planes (secondary porosity). The driller's logs usually refer to these water-bearing zones as "seams."

As mentioned above, probably most of the time, there is a hydraulic gradient from high water in the Ashokan Reservoir, outward from the reservoir toward areas of lower elevation. Most likely there are hydraulic connections between the reservoir and surrounding bedrock through fractures and other openings. Probably, the presence of the reservoir has a positive influence by recharging some of the water withdrawn by wells. A comparison of the Map of Soil Permeability (Figure 3) with the topography on the Well Location Map (Figure 6) indicates that soil percolation, infiltration and/or recharge is slow in the center lower elevations and moderate (green) ringing the outside of the area of concern. Hence, the topographically low area, which appears to have slow infiltration of precipitation most likely, benefits from seepage from the reservoir.

However, specifically in the West Hurley area, housing density is very high and for the long-term municipal water and sewer may be appropriate. Over time with so many septic fields in proximity to the residential wells, the probability for eventual bacterial and waste contamination of the wells is quite likely. Plans should be made now for the eventual development of a public water supply system for the area. Some vacant parcels could be set aside for a potential municipal well field. Evaluation of specific properties is beyond the scope of this study. A review of the tax parcel maps and the well data is recommended to provide a comparison of land availability and nearby well yield.

#3. *Southeast of Ashokan Reservoir*

This area lies in the center of the Town of Hurley, southeast of Ashokan Reservoir on a nearly horizontal plateau. Topographically, this area consists of irregular hills and steams, ranging in elevations from 500 to 800 feet above sea level. On the three cross sections (Figure 8), the plateau is shown to be formed by the Ashokan Formation of the middle Hamilton Group (shown in turquoise) overlying the Lower Hamilton Group (shown in magenta). The slab of the Ashokan Formation capping the plateau is shown to diminish in breadth and depth from east to west in the three cross sections. The plateau is dissected by postglacial drainage systems of wetlands and streams draining southwest in Stony Creek and southeast through Stony Hollow.

As shown in the summary table (Table 3) in this area, based on a sample of 37 wells, the wells in this area have the highest average yield of 17 gpm whereas the average total depth is only 204 feet, second deeper than the West Hurley area. However, the well yields have a high standard deviation indicating there is a high degree of uncertainty with respect to predicting well yield before drilling.

As shown on the three cross sections (Figure 8) and the Geologic Map (Figure 4), most of the wells start and complete in the in the Ashokan Formation (turquoise), about half are completed in the same formation and a small proportion penetrate the deeper Lower Hamilton Group (magenta). In this area, a detailed study of 36 driller's logs indicate that

the bedrock in the area consists of primarily bluestone (bluish-gray sandstone) and associated sandstone and shale of the Ashokan Formation overlying the gray sandstone and black shale of the Lower Hamilton Group.

The sandstones may have some primary porosity (perhaps 5%) providing storage of water. However, the logs indicate that prolific water is found often in fractures and bedding planes (secondary porosity). The driller's logs usually refer to these water-bearing zones as "seams." A comparison of the Map of Soil Permeability (Figure 3) with the topography on the Well Location Map (Figure 6) indicates that soil percolation, infiltration and/or recharge is generally moderate (green) except for some linear areas of slow permeability (orange) associated with wetlands.

The most prolific water resources associated with the plateau may be associated with wetlands. As shown on Cross Section A—B (Figure 8), on the east side of the plateau, Wetland KW-2 lies well below the high water level of the Ashokan Reservoir (597 feet). Wetland KW-2 may receive discharge water after it is transmitted from the Reservoir through hydraulic connections within the Plattekill Formation. On Cross Section E—F (Figure 8), the wetlands drop in elevation going south away from the Reservoir. Wetland AS-4 is above and AS-5 is just below the full Reservoir level. However, AS-18 and AS-8 are below the full level, but some distance away. Some of the best well yields are found along the Stony Creek wetland network. The four wetlands intercepted by Cross Section E-F (Figure 8) have large drainage areas and have potential for consideration for well field locations for municipal water supplies in this century. Development of a municipal well field could provide significant quantities of water for future use.

Another resource of the plateau that could have some uses related to water is the expansive abandoned bluestone quarries (shown in white on the Soil Permeability Map, Figure 3). Those quarries may have hydrogeologic properties to allow them to be used for recreational ponds or impoundments to store water.

#4. Northwest Valley Wall of Esopus Valley,

This area lies directly northwest of the Esopus Floodplain crossing the Town of Hurley from southwest to northeast. The valley wall is comprised of Lower Hamilton Group bedrock. Topographically, this area consists of steep slopes, sculpted into a dendritic drainage pattern by streams dissecting the bedrock along their southeastern downgradient path to Esopus Creek. The original Esopus Valley was formed by an antecedent Esopus Stream flowing along the boundary of the weak soluble Onondaga Limestone on the southeast and the hard and erosion-resistant Lower Hamilton sandstone on the northwest. The stream kept undercutting the bluestone and migrating northwestward while removing the erosional sandstone rubble. The elevations of the valley wall range from 180 feet above sea level along Hurley Mountain Road to 700 feet at the top of the hills. Cross Section E—F (Figure 8) shows the steepest slope and Section A—B (Figure 8) shows the most undulating slope of the northwestern Esopus valley wall.

Based on a sample of 10 well logs, the average depth is 375 feet and average static water level is 71 feet (Table 3). Both of these parameters are second to the Ohayo Mountain area. The average well yield is 10 gpm, the same as Ohayo Mountain. The greater depths probably reflect that the water table is some distance down and back from the slope of the land. As shown on the three Cross Sections (Figure 8), the wells are drilled into the Lower Hamilton Group and if deep enough penetrate the underlying Onondaga Limestone (if the surface elevation is close to 200 feet). In this area, a detailed study of 10 driller's logs indicates that the bedrock in the area consists of gray sandstone and black shale of the Lower Hamilton Group (magenta). The deeper wells may penetrate the underlying white and black layers of the Onondaga Limestone.

The sandstones may have some primary porosity (perhaps 5%) providing storage of water. However, the logs indicate that prolific water is found often in fractures and bedding planes (secondary porosity). The driller's logs usually refer to these water-bearing zones as "seams." A comparison of the Map of Soil Permeability (Figure 3) with the topography on the Well Location Map (Figure 6) indicates that soil percolation, infiltration and/or recharge is generally moderate (green) with a few areas of slow permeability (orange). One area east of Dug Hill Road has a rapid-permeability rating and may be a significant area of groundwater recharge. Because of vulnerability to contamination, this area should be explored and protected, possibly as a Critical Environmental Area.

#5. In the Onondaga Limestone Outcrop Area

This area lies in the Esopus Floodplain and the adjacent hilly terrain to the southeast in the Town of Hurley. Topographically, this area consists of the floodplain at about 160 to 180 feet above sea level and the area southeast of Route 209 averaging 300 feet above sea level.

As shown in the summary table (Table 3) in this area, based on a sample of 19 wells, in this area have the following averages: yield of 13 gpm, total depth of 239, and static water level of 26 feet. The static water level is the lowest of the areas because the lowest elevations and flattest topography are found in this part of Hurley.

As shown on the southern end of the three Cross Sections (Figure 8) and the Geologic Map (Figure 4), the wells are drilled into the Onondaga Limestone. In this area, a detailed study of 16 driller's logs indicates that the bedrock consists of layers of black limestone and white limestone. In some cases, the water-bearing zone is associated with brown or soft limestone, which is indicative of a dissolved zone like a small cave through which water is transmitted. In the area of carbonate outcrop, the topographic map shows "disappearing" streams which are characteristic of karst terrain consisting of weathered limestone solution features.

A review of the Map of Soil Permeability (Figure 3) indicates that the pattern of soil percolation, infiltration and/or recharge is quite complex but tends to follow northeast-

southwest trends in this area. The majority of the northwestern part of the floodplain is moderate (green) while the southeastern part is rapid (blue). The area of old Hurley is very rapid (magenta). A band of rapid permeability (blue) is shown in the vicinity of Rolling Meadows and extending south-southeast. These areas of rapid and very rapid permeability atop limestone bedrock with solution cavities are most vulnerable to rapid distribution of contamination if a spill or release were to occur. The more permeability the soils and bedrock have, the faster and farther contaminants can spread in groundwater. The use of road salt and other potential contaminants should be curtailed in such areas.

If an additional source of municipal water is needed for old Hurley and the vicinity, the well logs indicate good well yield between Route 209 and the old railroad grade near the southwest boundary of the Town, opposite where old 209 south of Riverside Park enters Route 209. Three wells in that area show yields of 15, 21, and 60 gpm. Two other wells, a few thousand feet to the east on Lucas Avenue, have yields of 20 gpm. The area outlined by those good yields is most promising for a municipal well field.

#6. *In the Folded Limestone Belt*

In this small area only one well (Table 3) is recorded at Pink Hill in the very southeastern point of the Town. The folded limestone belt is shown in blue on the Geologic Map (Figure 4) and on Cross Section D—C (Figure 8). Because it is only one well, it may not be representative of the area. The hydrogeologic characteristics of the folded limestone belt are similar to the Onondaga Limestone with additional complications resulting from folding and faulting of the bedrock creating rugged terrain and complex surface and groundwater flow regimes.

WATERSHEDS AND GENERALIZED WATER BUDGET

A water budget estimates the inflow and outflow of a system such as a watershed or an aquifer. Sources of inflow include infiltration from precipitation and lateral subsurface flow. Inflow from septic systems and wastewater treatment systems are also sources of inflow. Receptacles of outflow include surface runoff, streamflow, pumping of wells, withdrawal from surface waters, and evapotranspiration. Since evapotranspiration is dependent upon temperature, precipitation, and vegetation; a water budget shows seasonal variations and is normally expressed on a monthly or weekly basis. Table 6 summarizes a generic water budget for Ulster County on a monthly basis.

In a mathematical sense, a water budget for the Town of Hurley may not be particularly useful because the Town is comprised as part of different watersheds. The area north of the Ashokan Reservoir flows into the reservoir. The Hurley Ridge area drains northeast to the Saw Kill. The area southeast of the Reservoir drains southwest to the Esopus via Stony Creek and another tributary. Actually, the upstream drainage of Stony Creek is disrupted shown by flow from wetland KW-6 eventually joining the southwest flowing stream. South of the eastern end of Ashokan Reservoir, the creeks and wetlands generally flow to the stream occupying the Route 28 valley, although some of the streams

are “disappearing streams” suggesting deep bedrock fractures or karst topography. In the southeastern part of Hurley, streams flow southeast down the wall of the Esopus Valley creating a flanging or dendritic pattern on the topographic map. On the southeast of the Esopus to the southeastern corner of the town, drainage shows a disrupted pattern with isolated wetlands, disappearing streams, and flow in opposite directions, southwest and northeast. The disrupted nature of the drainage pattern is most likely due to the presence of soluble Onondaga Limestone beneath the surface.

A budget for any watershed may be useful for a study of a specific area. However, a conceptual water budget is useful in understanding the relative volumes of water that make up the budget.

Water budgets are prepared for different purposes. The one in Table 5 was prepared to estimate annual recharge to groundwater. In this case, the estimate indicates that average annual recharge is approximately 11 inches per year in Ulster County.

The estimated annual water budget (Figure 5) shows average monthly amounts of precipitation, runoff, and evapotranspiration. A groundwater surplus occurs when precipitation is greater than the sum of runoff plus transpiration. A groundwater deficit occurs when evapotranspiration exceeds precipitation minus runoff.

AREAS of CONCERN and RECOMMENDATIONS

Five general areas of concern are the Esopus Floodplain, Contaminated Sites, High Permeability Recharge Soil Locations, Wells in the Carbonate Bedrock, and Potential Areas for New Water Supplies

The Esopus Creek Floodplain is a significant agricultural area for cultivation of corn and field crops. The groundwater in this area must remain clean to sustain the agricultural use. Two potential threats to the water exist associated with Route 209 and other roads on the floodplain. One threat is the use of road salt and the potential to turn the groundwater to brine which the crops may not be able to tolerate. Along the highway, another threat is the potential for a chemical spill, which could render a portion of the floodplain useless for agriculture. This concern should be discussed with local farmers and if they think it is a valid issue, the State and County highway maintenance people should be approached to request that they use less or no salt on the roads adjacent to fields. In some towns, signs are put up to inform the motorists that the area is an aquifer area and salt is not used on the road.

Contaminated Sites are shown on a map (Figure 10) from Toxic Targeting's website with symbols for the locations of solid waste (landfills), hazardous waste, hazardous substance, tank failure and MTBE spill sites. Residual contamination is most likely still in the soils and possibly the groundwater at these sites. Documentation of each of these sites should be reviewed at NYSDEC Region 3 Offices to evaluate whether the contamination has been removed or cleaned up. If not remediated, some action should be taken to warn current landowners, potential buyers, and builders of the possibility of

underground contamination at the site and under adjacent properties. Soil and groundwater testing should be required prior to building or development.

High Permeability Recharge Soil Locations are shown in magenta and blue on the soil recharge map. These areas are vulnerable to rapidly conducting any spilled liquid contaminants directly into the groundwater. Septic systems on such soils may work too rapidly and release bacteria into the groundwater. Some provision should be made to address the vulnerability of these areas.

Wells in the Carbonate Bedrock. Because of the solubility of carbonate rock such as limestone and dolostone, these rock types present special conditions that require extra attention. First when wells are drilled in carbonate rocks, a rotary rig will grind the bedrock into fine powder. When water enters the borehole, the calcium carbonate and magnesium carbonate powders mix with the water to form cement. The rotating motion of the drill bit can smear the cement into the bedrock fractures that provide the water and even though the well seemed to produce water during drilling, a dry hole can result if the driller does not take care to keep the wellbore clean. When this happens, there are service companies whose personnel can open the fractures with various treatments. Second, the solubility of limestone and dolostone is the property that allows running water to create caves and other solution cavities in such rocks. Groundwater moving through a crack or fracture can gradually dissolve away the walls and make a larger and larger opening. When a cave breaks through to the land surface, a sinkhole is formed. Similar to the high permeability soils, when contaminants are introduced into carbonate bedrock terrain, the potential for rapid dispersal exists. The green and blue areas on the Bedrock Map (Figure 4) represent carbonate terrain in the Town of Hurley. Some provision should be made address the vulnerability of these areas.

To avoid drilling problems in limestone terrain, it may be appropriate for the Planning Board or Building Inspector to recommend consultation with a hydrogeologist prior to drilling. The potential developer or homeowner could then meet with a professional hydrogeologist who is familiar with drilling and development problems and also treatment methods in limestone and dolostone formations. That recommendation applies to all well site locations from Hurley Mountain Road southeast to the Thruway.

Wells on Steep Slopes of Ohayo Mountain and Mount Tonshi. Complaints from homeowners on the mountainside have been common for at least the past 10 years. Most hills and mountains have a mound of groundwater in their core. Put another way, the water table tends to mimic the surface topography. However, the sloping water table can be some distance down or out behind the hillside. In Highland we drilled a horizontal well on a mountainside and the first sign of water was encountered at 400 feet. Drilling a vertical well on the side of the mountain may require significant depth to reach water. For that reason, it is recommended, that when drilling a well on a mountainside, the well should be as far back from the steep slopes as possible. Larger lot size, 5 to 10 acres may be appropriate on the steep slopes.

Potential Areas for New Water Supplies. As a result of examining the individual well

logs, bedrock aquifer areas, the wetland distribution, the soil properties, and topography, three areas have been identified with the potential to provide significant water supplies for future residential and commercial development. All three areas have unique surface features, but each water supply is in the groundwater within bedrock. These areas include the West Hurley area close to the eastern town boundary in the vicinity of an unconsolidated aquifer on the USGS map, the Stony Creek wetland (AS-16 and AS-6) complex, and an area in the Onondaga limestone outcrop area bounded by the Town border on the south, the old railroad grade on the west, Lucas Avenue to the east and wetlands KW-8 and KW-9 to the north. These areas all show positive signs of good water yield. If municipal water systems are needed in the future, these are the potential sources. Provisions should be made to identify specific parcels and develop a well drilling and testing program to quantify the potential yield of these bedrock aquifers. To set aside these precious areas, long range planning is needed to establish a preserving and protective mechanism such as conservation easements or critical environmental areas.

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TABLE 2
 Classification of Soils by Permeability
 Measured in Inches Per Hour
 from Ulster County Soils Survey (1979)

Very Slow	Slow	Mod Slow	Moderate	Rapid	Very Rapid
<.06	.06 - .2	.2-.6	.6 - 2	6 - 20	>20
OdA Odessa OdB Odessa	BgC LEE SmB, SmC Stock- bridge	Cc	AcB NBF Nassau	CgA	Hev
	BgD LY Lyons STD	Cd	ARD, ARF NMC, NNF	CgB	PmD Rivr- head
	BnC Bath Ma SwB, SwC	Ce	At OgB Oquaga	CnA, CnB, CnC	PmF Rivr- head
	BOD Bath MdB TuB, TuC, TuD	Lm	Be OlC	HfA, Hga, HgB, HgC, HgD	RvA, RvB, RvC
	BRC Bath MgB VoA,VoB, Mardin VoC		BnC Nassau ORC, ORD	HSF	
	BRC Mardin MTB Mn, MO VSB		BOD Nassau Pa	PlB, PlC	
	CaB, CaC NBF Bath Wb, Wc		FAE Pb	PmD Plainfield	
	CvA, CvB Ra WeB, WeC		Ha, He Re	PmF Plainfield	
	HuB, HuC RhA, RhB WLB		LnB RXC, RXE, RXF	PrC Plainfield	
	HvC3, HwD SaB, SaC WOB		LOC Sc	Pt	
	HXE SdB WSA, WsB		LY Atherton SmB, SmC- Farmingtn	Su	
	LaB, LaC SEB		MgB Nassau Te, Un, VAB,VAD	Tg	
	LCD, LCF SGB		Mr	TKA, TKB, TKC Wa	

Table 3
Characteristics of Residential Wells in Specific Areas
Based on Drillers' Well Logs on File with Ulster County Health Department
Aquifer Protection Study
Town of Hurley, Ulster County, New York

Area (numbers refer to areas on map)	Number of Wells	Average Total Depth (feet)	Average Static Water Depth (feet)	Average Casing Depth (feet)	Average Yield (gpm)
1. Southeast Ohayo Mtn	18	442	121	23	10
2. Hurley Ridge- West Hurley	24	169	37	26	15
3. Southeast of Ashokan Reservoir	37	204	47	22	17
4. Northwest Wall of Esopus Valley	10	375	71	25	10
5. Onondage Limestone Outcrop Area	19	239	26	25	13
6. Folded Limestone Belt (Pink Hill)	1	400	na	150?	1

Statistics Pertaining to Total Depth of Wells in Each Area

Area (numbers refer to areas on map)	Minimum Total Depth (feet)	Maximum Total Depth (feet)	Average Total Depth (feet)	Median Total Depth (Feet)	Standard Deviation Total Depth
1. Southeast Ohayo Mtn	193	998	442	330	242.7
2. Hurley Ridge- West Hurley	70	498	169	140	100.17
3. Southeast of Ashokan Reservoir	62	550	204	150	138.2
4. Northwest Wall of Esopus Valley	98	750	375	363	191.7
5. Onondage Limestone Outcrop Area	60	520	239	248	110.9
6. Folded Limestone Belt (Pink Hill)	na	na	na	na	na

Statistics Pertaining to Well Yield in Each Area

Area (numbers refer to areas on map)	Minimum Yield (gpm)	Maximum Yield (gpm)	Average Yield (gpm)	Median Yield (gpm)	Standard Deviation Yield
1. Southeast Ohayo Mtn	1	15	7	7	4.83
2. Hurley Ridge- West Hurley	1	45	15	10	12.51
3. Southeast of Ashokan Reservoir	1	100+	18	8	19.07
4. Northwest Wall of Esopus Valley	1	50	10	5	14.13
5. Onondage Limestone Outcrop Area	3	60	13	6	14.3
6. Folded Limestone Belt (Pink Hill)	na	na	na	na	na

na = inappropriate for an area with only one well

? = well log reports 150 feet of casing, however, bedrock is at surface

Table 4

Definitions of "Aquifer" from Technical References:

1. US Department of Interior, 1985, "Ground Water Manual, A Water Resource Technical Publication," Bureau of Reclamation, US Government Printing Office, Denver, CO, 480p.

An aquifer is "a water-bearing bed or stratum of earth, gravel, or porous stone. Some strata are good aquifers, whereas others are poor. The important requirement is that the stratum must have interconnected openings or pores through which water can move. The nature of each aquifer depends on the material of which it is composed, its origin, the relationship of the constituent grains or particles and associated pores, its relative position on the Earth's surface, its exposure to a recharge source and other factors." (pages 5-6)

2. Fetter, C.W., 1988, "Applied Hydrogeology," Second Edition, Merrill Publishing Company, Columbus, OH, 592p.

"An aquifer is a geologic unit that can store and transmit water at rates fast enough to supply reasonable amounts to wells. The intrinsic permeability of aquifers would range from about $10E-2$ darcy upward. Unconsolidated sands and gravels, sandstones, limestones and dolomites, basalt flows, and fractured plutonic and metamorphic rocks are examples of rock units known to be aquifers." (page 101)

3. Freeze, R.A. and J.A. Cherry, 1979, "Groundwater," Prentice-Hall, Inc., Englewood Cliffs, NJ, 604p.

"An aquifer is best defined as a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients." An alternate definition states "that an aquifer is permeable enough to yield economic quantities of water to wells". (page 47)

4. Driscoll, F.G., 1986, "Groundwater and Wells," Second Edition, Johnson Division, St. Paul, MN, 1089p.

Two definitions are provided: "An aquifer is a water-bearing reservoir capable of yielding enough water to satisfy a particular demand." (page 19) "Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economic quantities of water to wells and springs." (page 885, Glossary)

Table 5

ESTIMATED GENERIC WATER BUDGET FOR ULSTER COUNTY

Equation: $\text{RECHARGE} = \text{PPT} - \text{ET} - \text{RUNOFF} + \text{SW} + \text{SM}$

RECHARGE = change in groundwater storage
 PPT = precipitation
 ET = evapotranspiration using Thornthwaite calculation
 RUNOFF = surface water runoff from PPT
 SW = change in surface water storage (assume zero)
 SM = change in soil moisture storage (assume zero)

Other Assumptions:

Average precipitation and temperature for
 Ulster County from 1979 Soil Survey.
 Lateral groundwater inflow = outflow.
 Loss to deeper bedrock aquifer = zero.
 Pumping production = zero.

Monthly Data

	PPT inches	TEMP F	ET inches	RUNOFF inches
Jan	3.11	24.4	0.0	1.30
Feb	3.40	26.2	0.0	1.30
Mar	3.79	34.1	0.2	1.05
Apr	4.39	46.9	1.4	0.80
May	3.95	57.5	2.9	0.55
Jun	3.76	66.1	4.5	0.30
Jul	4.18	70.7	7.4	0.30
Aug	4.12	69.1	6.0	0.30
Sep	4.00	62.1	2.9	0.30
Oct	3.85	52.5	1.4	0.55
Nov	4.19	40.4	0.5	0.80
Dec	4.24	28.5	0.0	1.05
Avg		48.2		
Tot	46.98		27.2	8.60

$\text{RECHARGE} = \text{PPT} - \text{ET} - \text{RUNOFF} + \text{SW} + \text{SM}$

$\text{RECHARGE} = 46.98 - 27.2 - 8.6$

$= 11.2 \text{ inches/year}$



SCALE
0 400 800 1400 1800 meters
0 2000 4000 6000 feet
1 mile



FIGURE 1

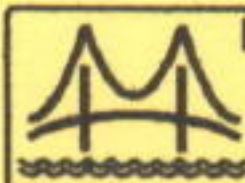
FRESHWATER WETLANDS MAP
FEDERAL AND STATE PROTECTED



State-Protected Wetlands



Federal-Protected Wetlands



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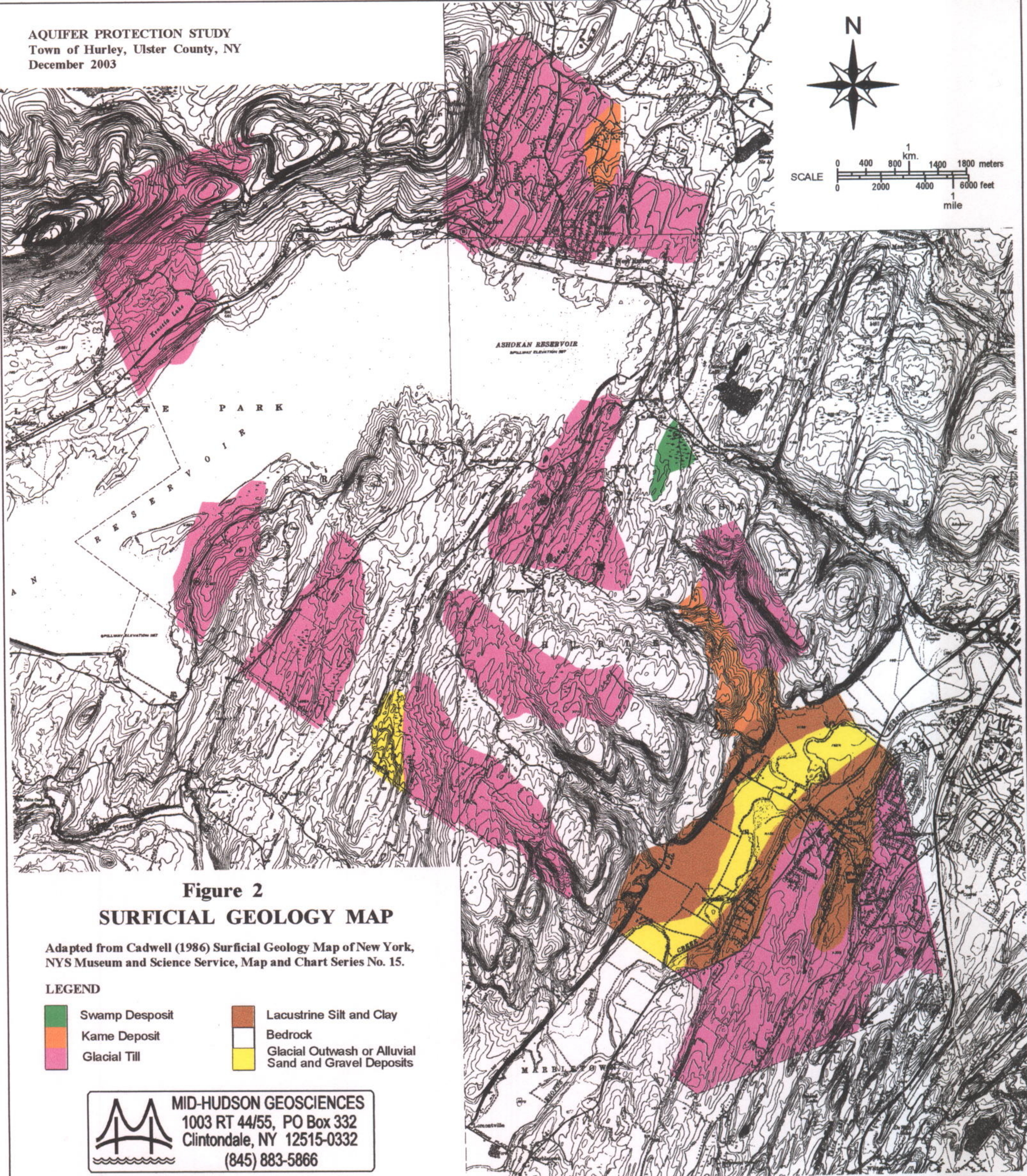
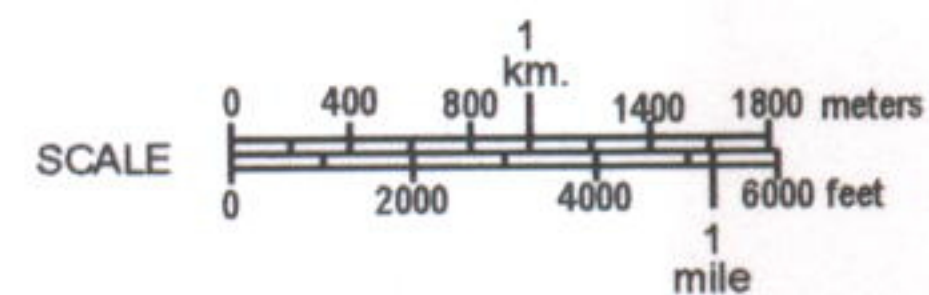








Figure 2

SURFICIAL GEOLOGY MAP

Adapted from Cadwell (1986) Surficial Geology Map of New York,
 NYS Museum and Science Service, Map and Chart Series No. 15.

LEGEND

	Swamp Deposit		Lacustrine Silt and Clay
	Kame Deposit		Bedrock
	Glacial Till		Glacial Outwash or Alluvial Sand and Gravel Deposits

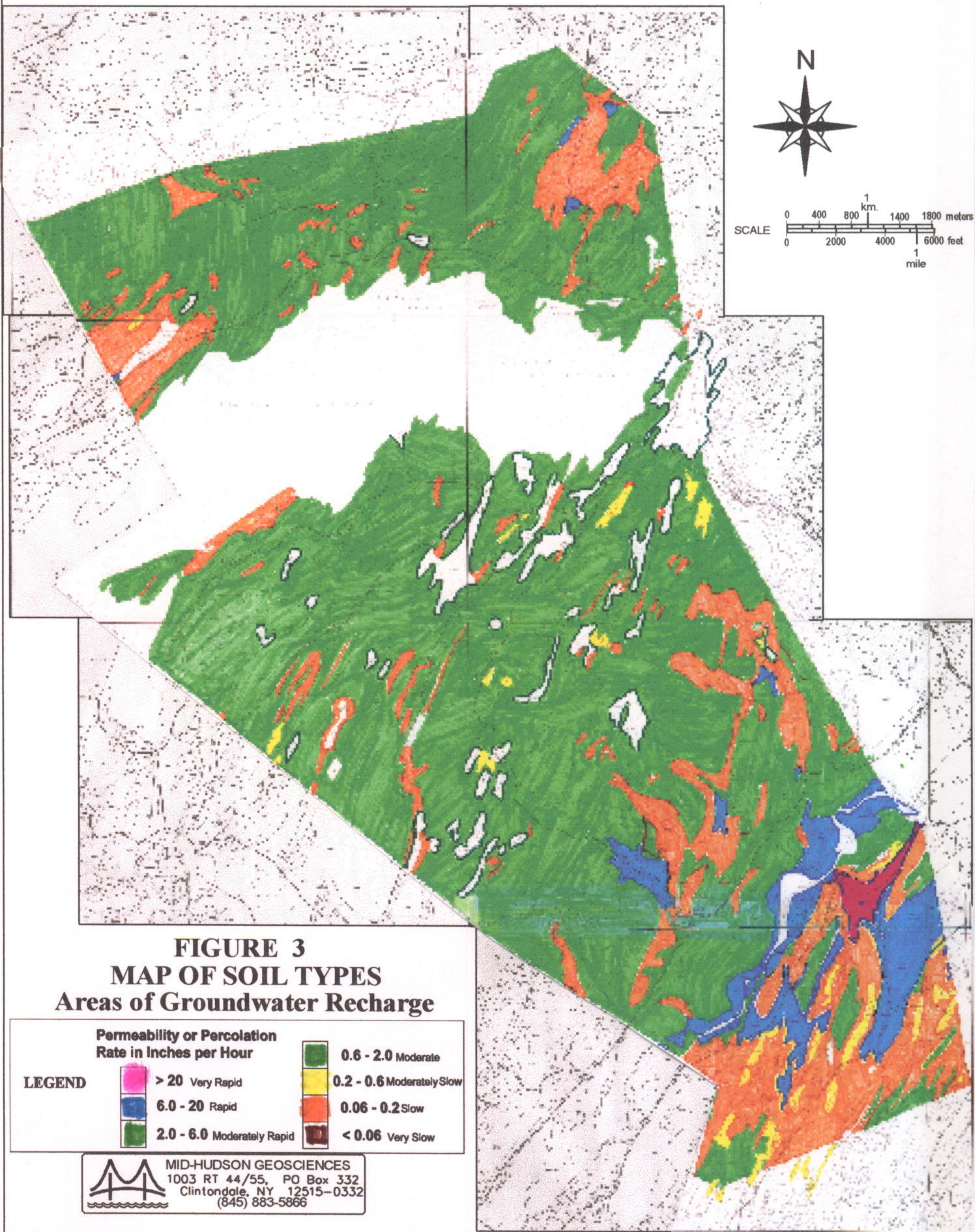


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AQUIFER PROTECTION STUDY

Town of Hurley, Ulster County, New York

October 2003



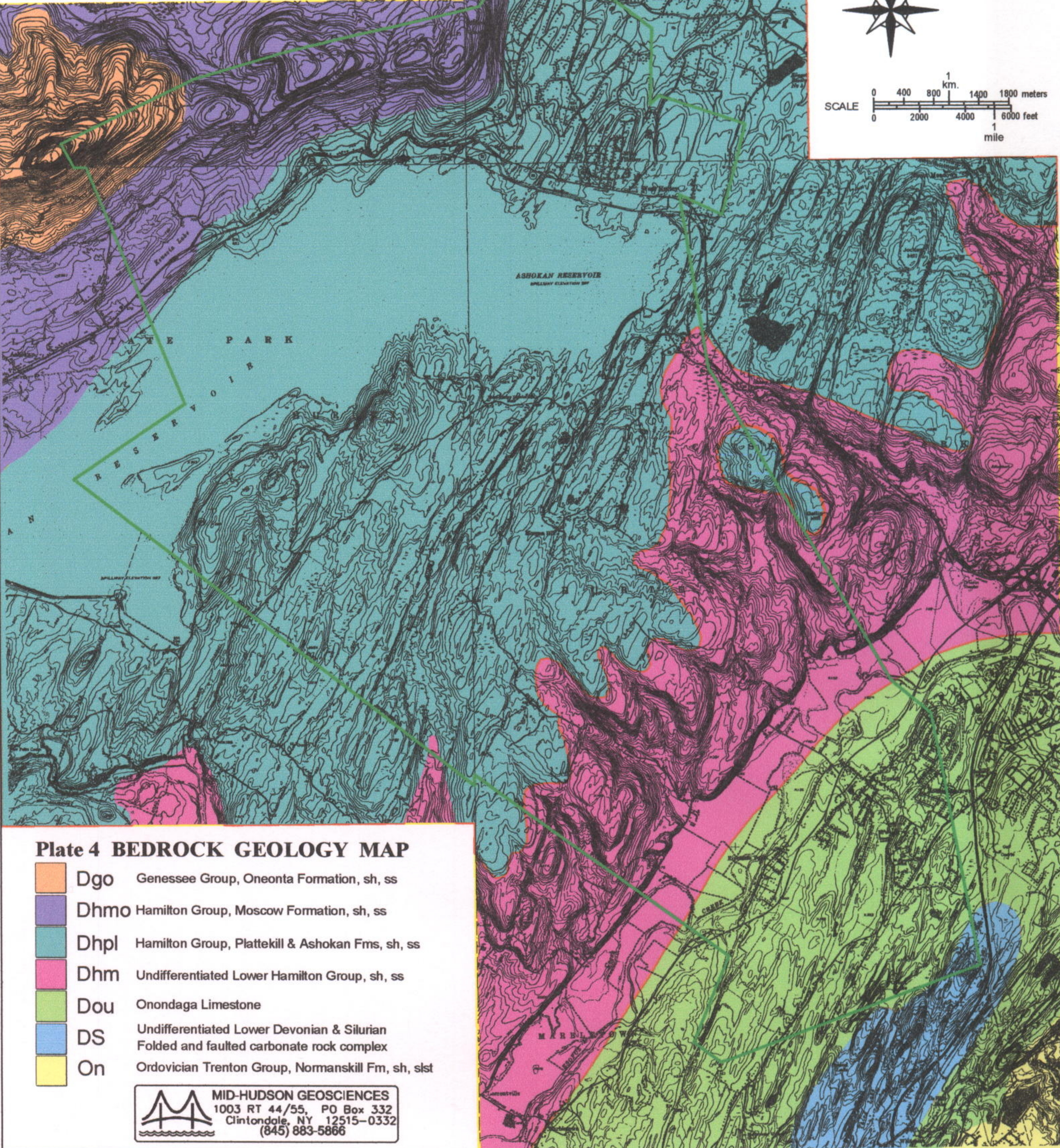
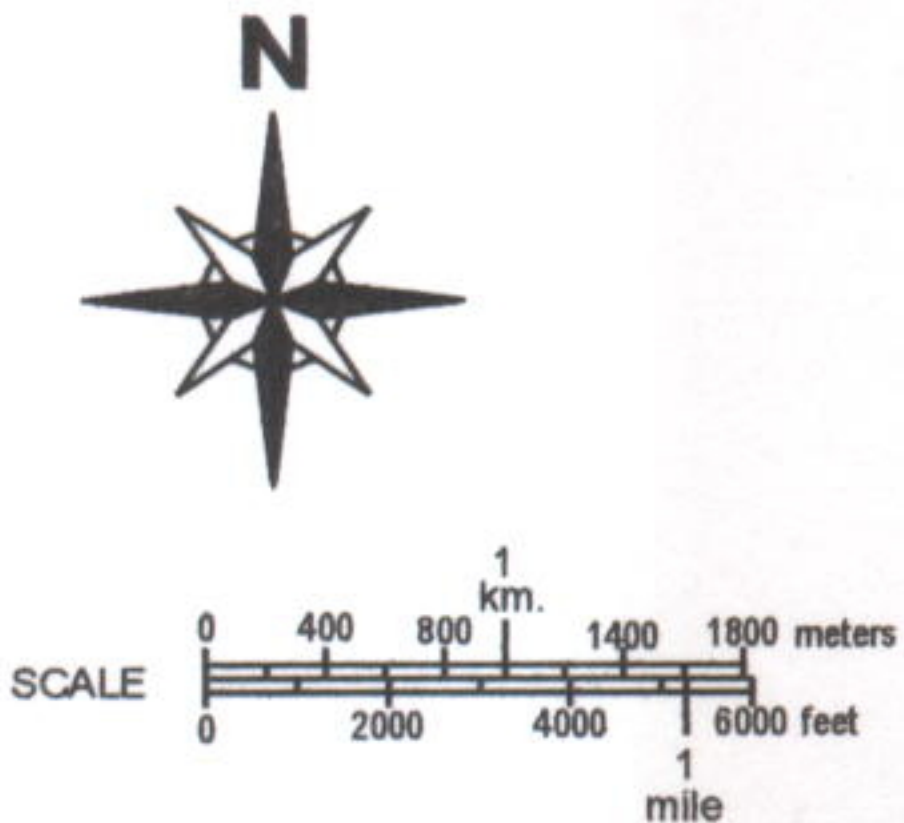



Plate 4 BEDROCK GEOLOGY MAP

- Dgo** Genesee Group, Oneonta Formation, sh, ss
- Dhmo** Hamilton Group, Moscow Formation, sh, ss
- Dhpl** Hamilton Group, Plattekill & Ashokan Fms, sh, ss
- Dhm** Undifferentiated Lower Hamilton Group, sh, ss
- Dou** Onondaga Limestone
- DS** Undifferentiated Lower Devonian & Silurian
Folded and faulted carbonate rock complex
- On** Ordovician Trenton Group, Normanskill Fm, sh, slst

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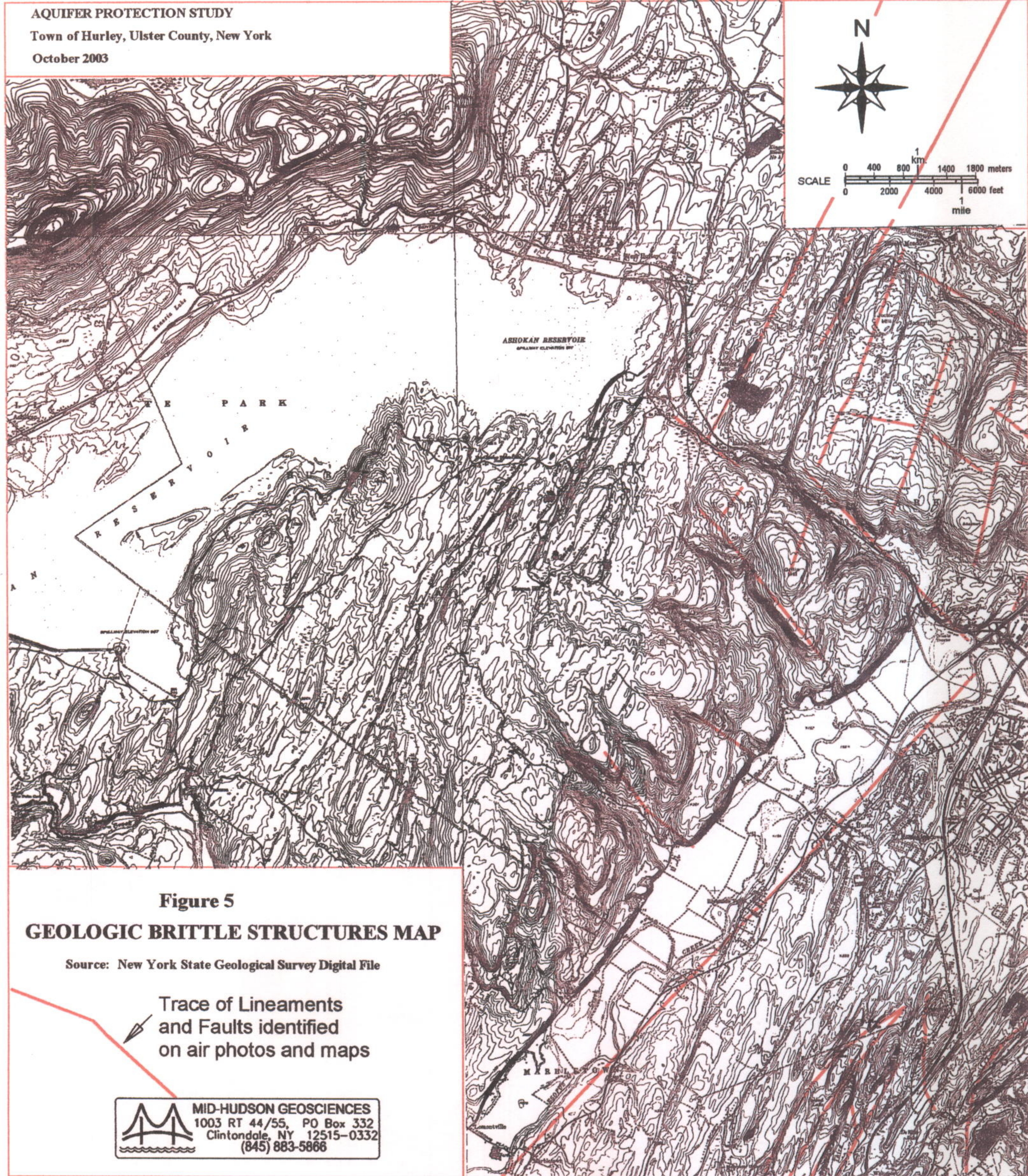
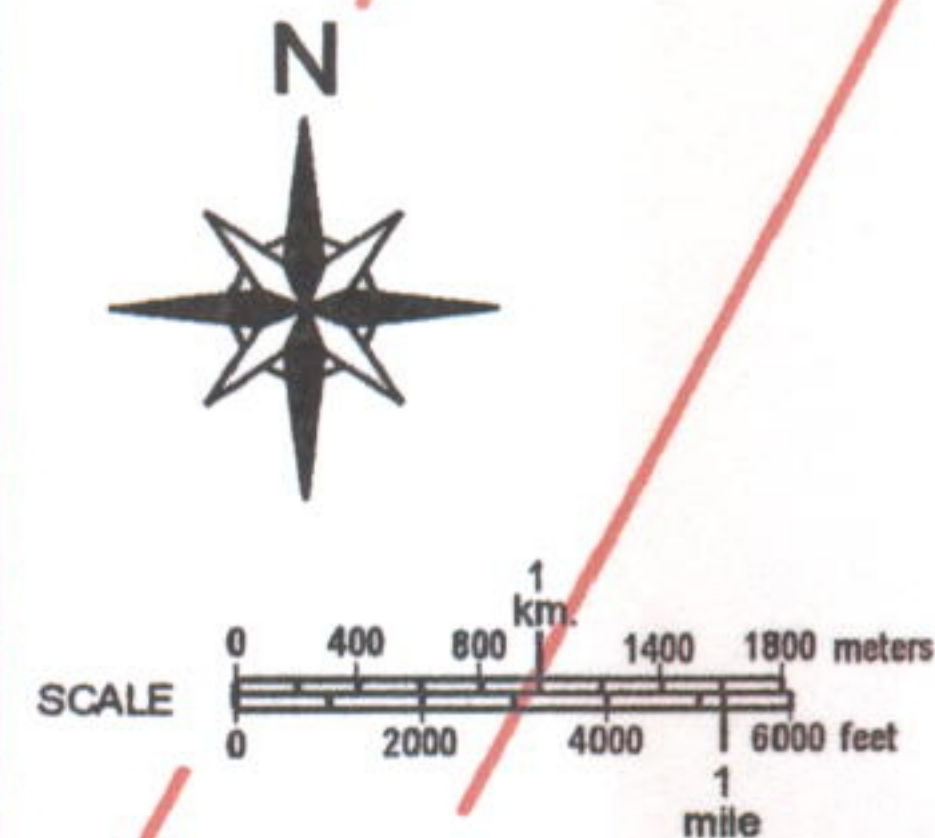


Figure 5

GEOLOGIC BRITTLE STRUCTURES MAP

Source: New York State Geological Survey Digital File

Trace of Lineaments
and Faults identified
on air photos and maps

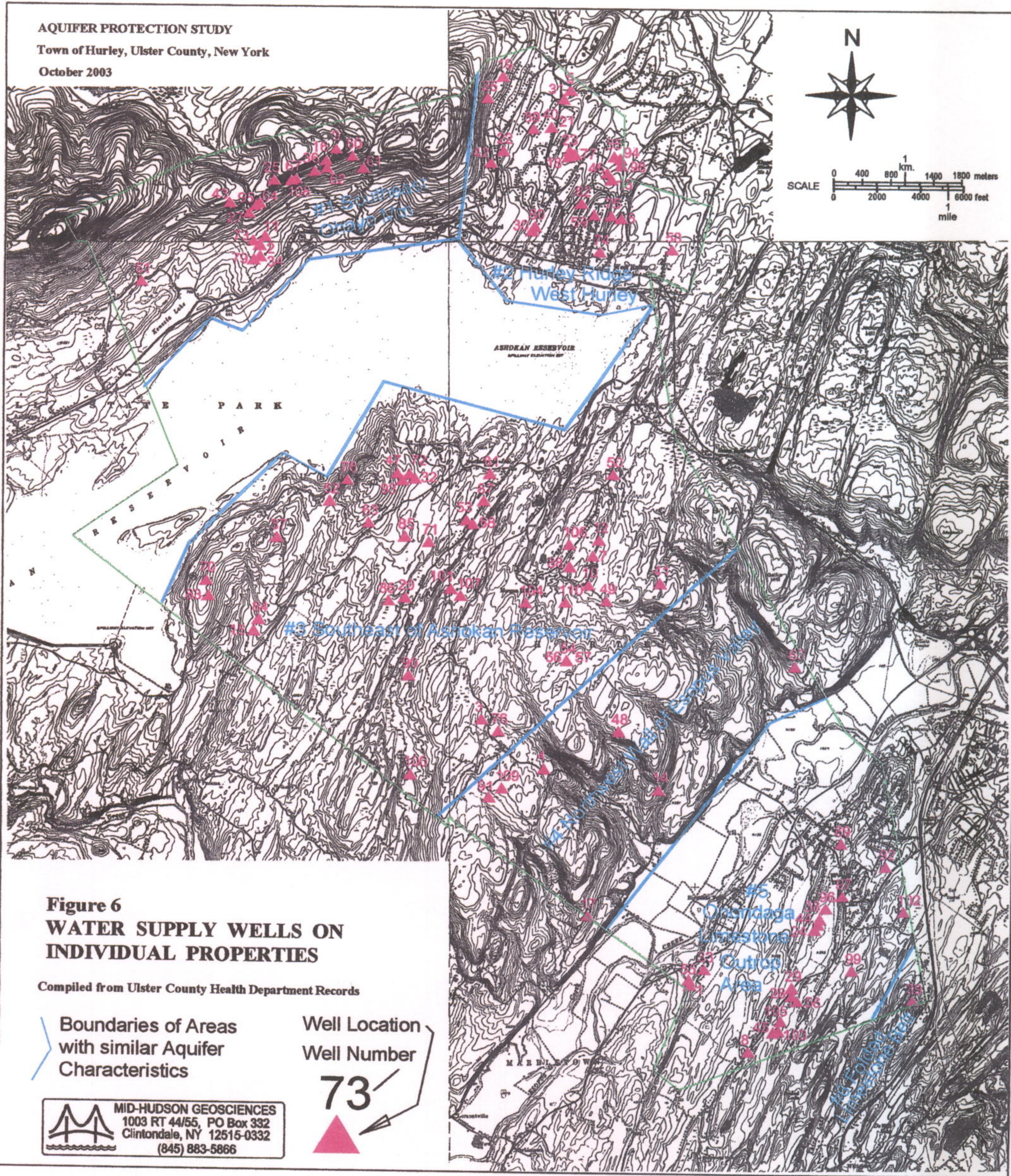
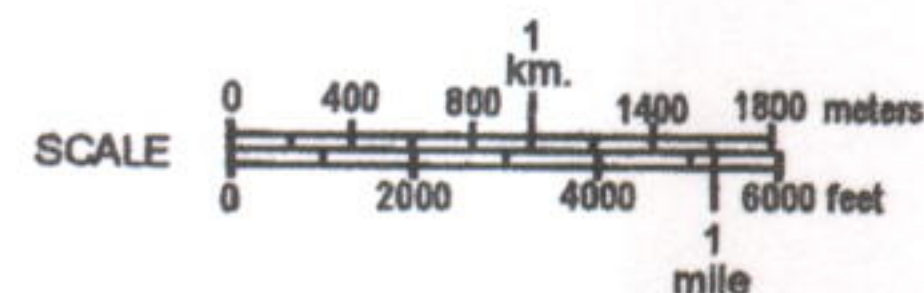


Figure 6
WATER SUPPLY WELLS ON
INDIVIDUAL PROPERTIES

Compiled from Ulster County Health Department Records

Boundaries of Areas
 with similar Aquifer
 Characteristics

Well Location
 Well Number

73



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AQUIFER PROTECTION STUDY

Town of Hurley, Ulster County, New York

December 2003

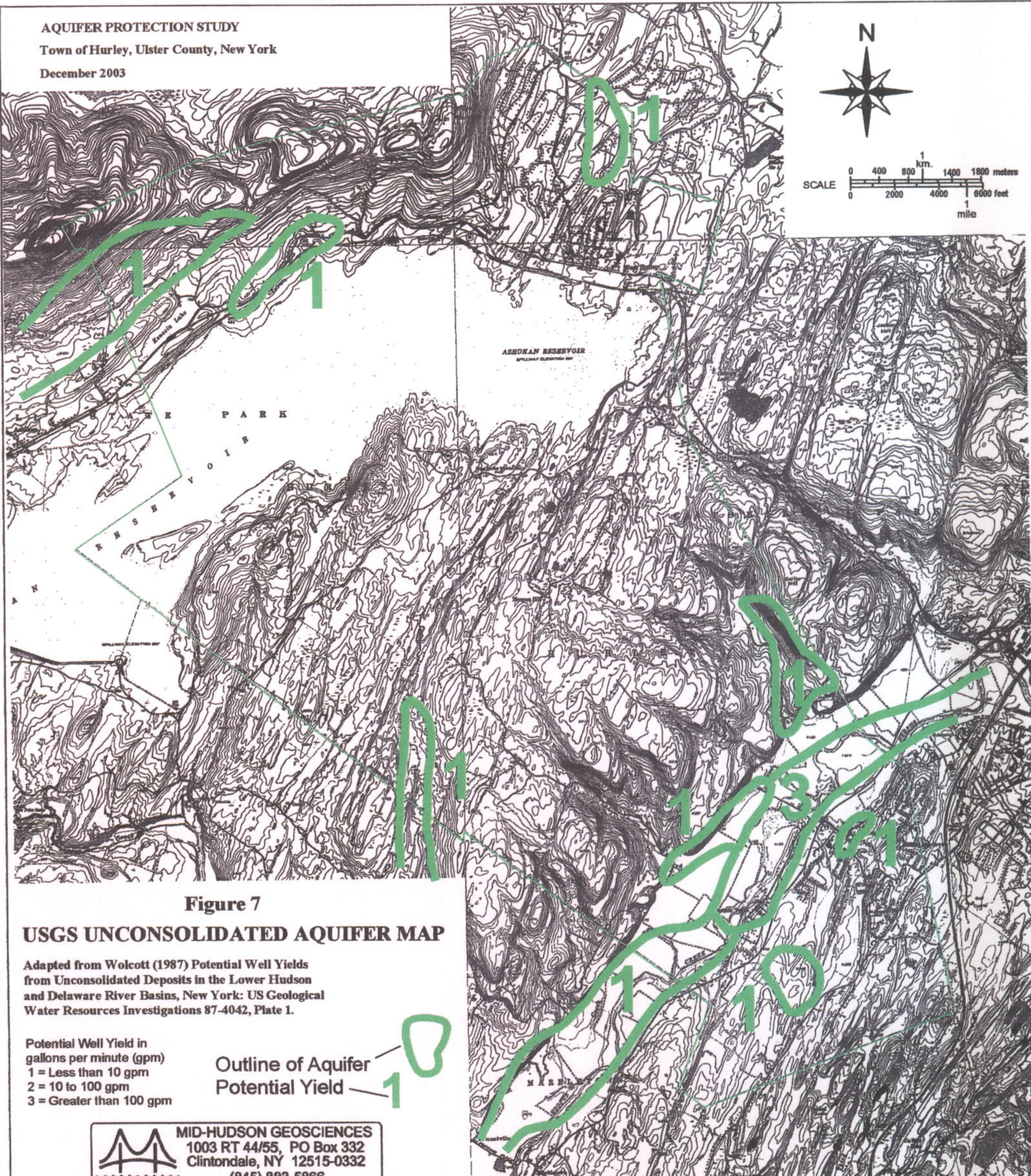
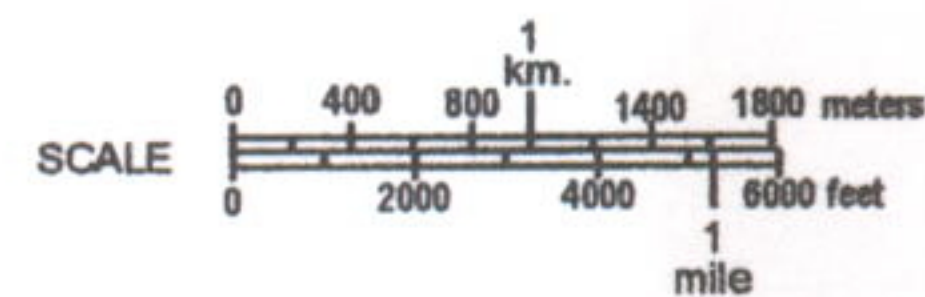


Figure 7

USGS UNCONSOLIDATED AQUIFER MAP

Adapted from Wolcott (1987) Potential Well Yields from Unconsolidated Deposits in the Lower Hudson and Delaware River Basins, New York: US Geological Water Resources Investigations 87-4042, Plate 1.

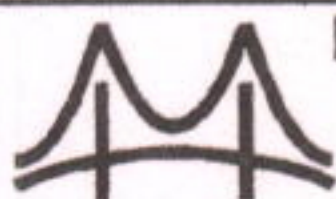
Potential Well Yield in gallons per minute (gpm)

1 = Less than 10 gpm

2 = 10 to 100 gpm

3 = Greater than 100 gpm

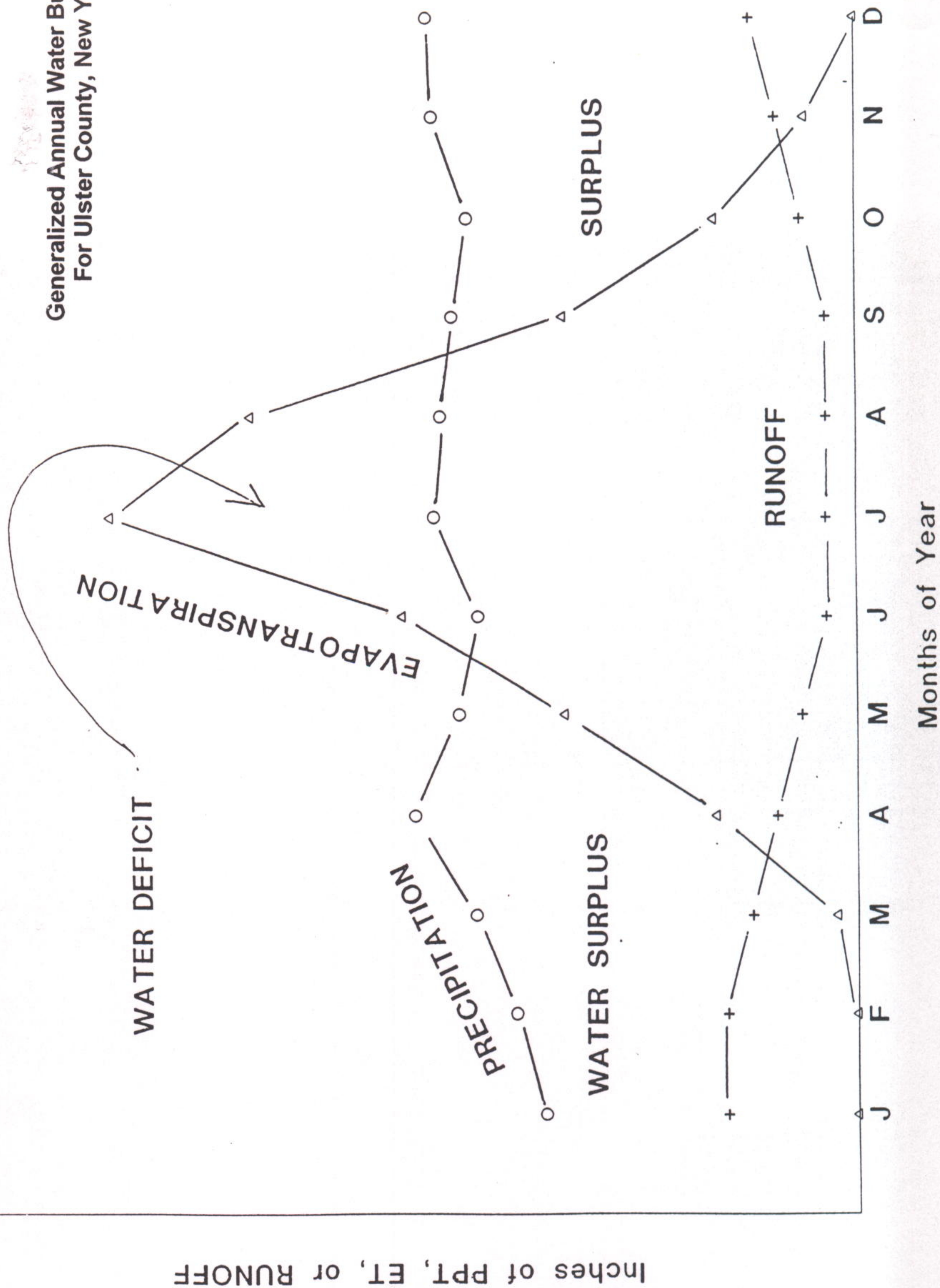
Outline of Aquifer
Potential Yield



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Figure 9

Generalized Annual Water Budget For Ulster County, New York



Toxics Targeting Selected Toxic Sites for the TOWN OF HURLEY

www.toxictargeting.com
(800) 2TOXICS
March 04, 2002

Figure 10



Ulster County

NPL/CERCLIS/NYSDEC Inactive
Hazardous Waste Disposal Site

Hazardous Substance Site

Solid Waste
Site

Hazardous Waste Treatment,
Storage or Disposal Site

MTBE Spill
that does not meet cleanup standards

Tank Failure
that does not meet cleanup standards

Tank Test Failure
that does not meet cleanup standards

Spill greater than or equal to 100 units
that does not meet cleanup standards

Waterbody

Minor
Roads

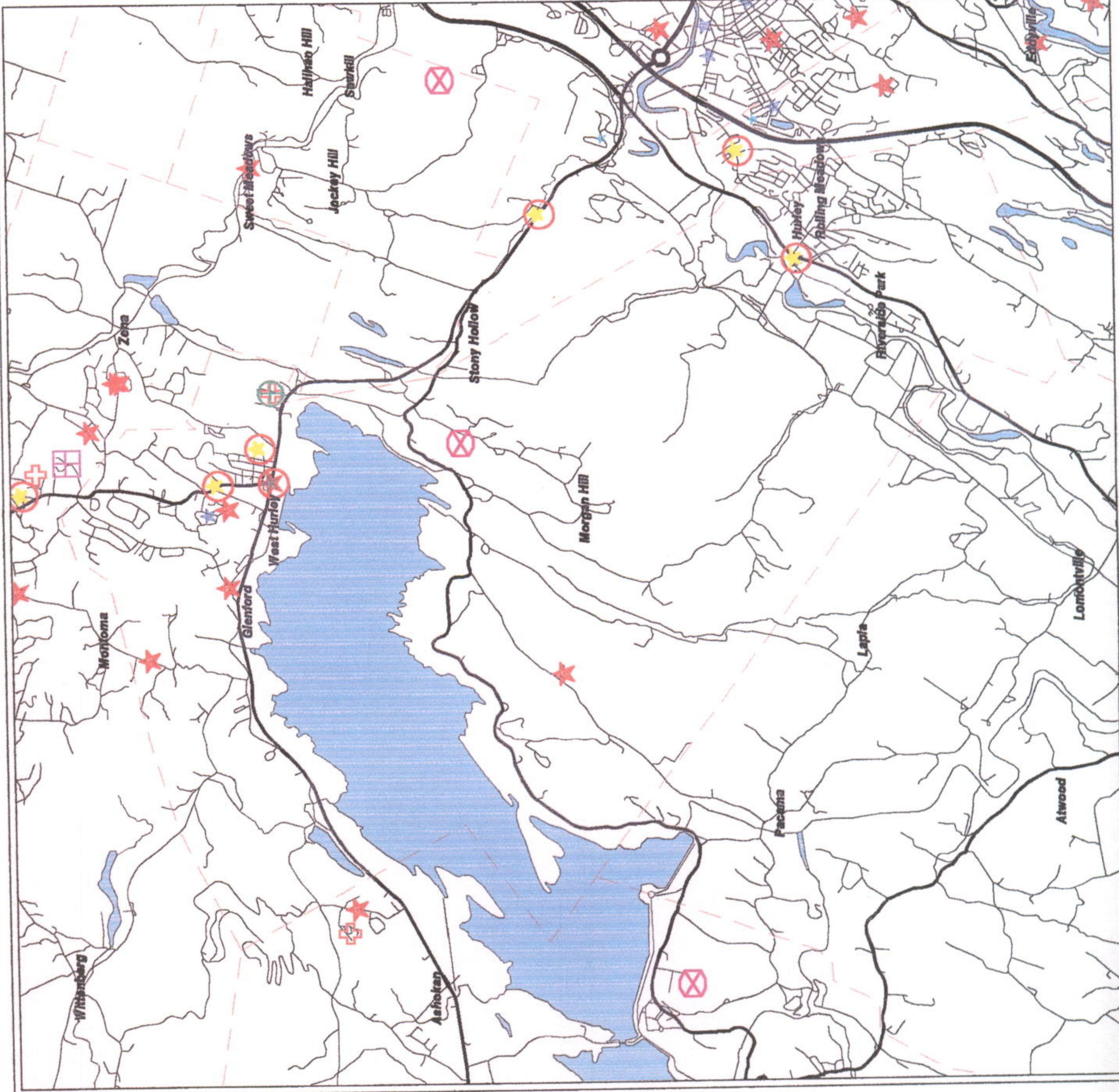
Major
Roads

Expressways

Municipal
Boundary

County
Border

Railroad
Tracks



Scale: 1 inch = 6105 feet (1.16 miles)