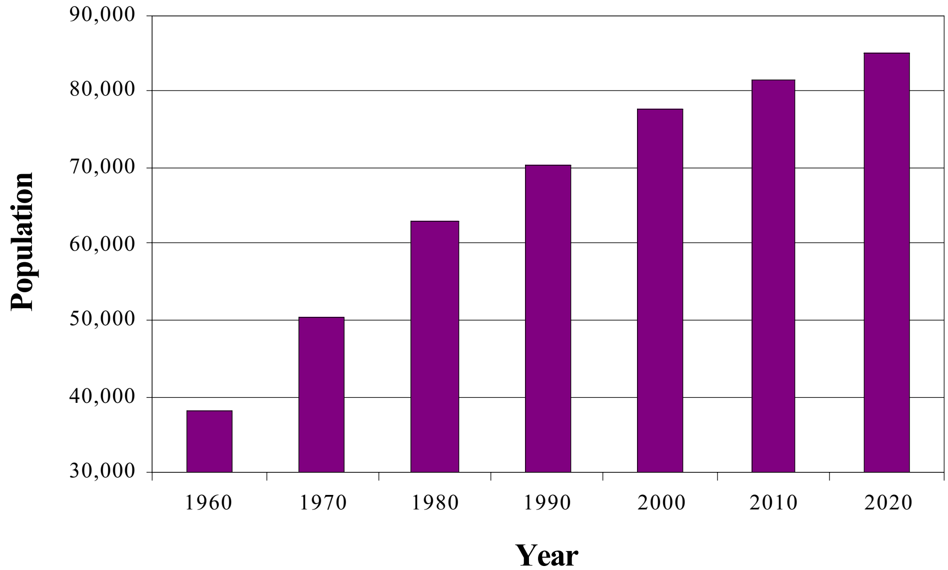
Figure 3. Population change in the eight watershed towns and Oxford between 1960 and 1995, and the projected population in these towns through the year 2020 based on data from the Office of Policy and Management, 1995.



A BRIEF GEOLOGIC HISTORY OF THE POMPERAUG RIVER WATERSHED

Five hundred million years ago (mya), what we now know as southern New England was a vastly different place. It was the southern, not eastern, shore of what would become North America, located much closer to the equator than it is presently, and was presumably far more humid and tropical. As the earth's plates shifted, this Proto-North America underwent significant change. The present geologic features of the watershed are the result of three distinct episodes in its geologic history.

The first episode, lasting from 500 to 250 mya, was the shifting and collision of the ancient continents and plates, forming a massive continent called Pangea. At the junction of the Proto-African, Eurasion, and North American plates, a Himalayan like mountain chain formed, the remnants of which now exist as the Appalachians. The metamorphic rocks known as schists and gneisses that compose the bedrock of the higher hills in the watershed are a direct result of these collisions.

The next episode, extending from 250 mya to the present, was the rifting and breakup of Pangea to form the present distribution of continents and the Atlantic Ocean. Recent measurements indicate that the continents are still separating, causing the Atlantic Ocean to grow a few centimeters each year. This rifting also created a series of down faulted blocks of bedrock called rift basins along the East Coast. One of these basins formed in central Connecticut. It extends 100 miles north from New Haven to Greenfield, Massachusetts, and averages 20 miles in width. A smaller down-faulted block called the Pomperaug Basin, formed in the watershed. Averaging two to three miles in width, it extends 6 miles north from the intersection of Route 172 and I-84 in Southbury to the vicinity of Nonnewaug Regional High School in Woodbury. This basin collected sediments that eventually formed such present day sedimentary rocks as sandstone and shale. On three separate occasions, volcanic fissure eruptions filled the Pomperaug Basin with lava flows that hardened to form an igneous rock called basalt (commonly known as traprock). Later, the sedimentary and igneous rock within the basin underwent faulting and erosion causing the harder basalt to form the traprock valley ridges extending from Rattlesnake Hill in Southbury to Orenaug Park in Woodbury (Figure 4).

The third and last geologic episode occurred one to two mya when a series of massive glaciers intermittently covered the northern half of North America. Roughly eighteen thousand years ago, the last ice age was ending and the large glaciers covering Connecticut began to retreat northward. As the ice melted, the sediments suspended in the ice and flowing in the glacial melt were deposited in the watershed.

As the higher hills of the watershed emerged, unsorted debris, of all different shapes and sizes, covered much of Connecticut's bedrock. Debris of this type is called *glacial till*. It was among the first deposits laid down on the bedrock, and was done so directly by the glacial ice. Well-sorted sediments were the last to be deposited, and were left by glacial waters in the lowest lying areas, such as valleys, stream channels, and lake bottoms. These deposits are collectively termed *stratified-drift* and generally include gravel, sand, silt, and clay. Perhaps the greatest significance of these sediments is their influence over the development of aquifers. The thick

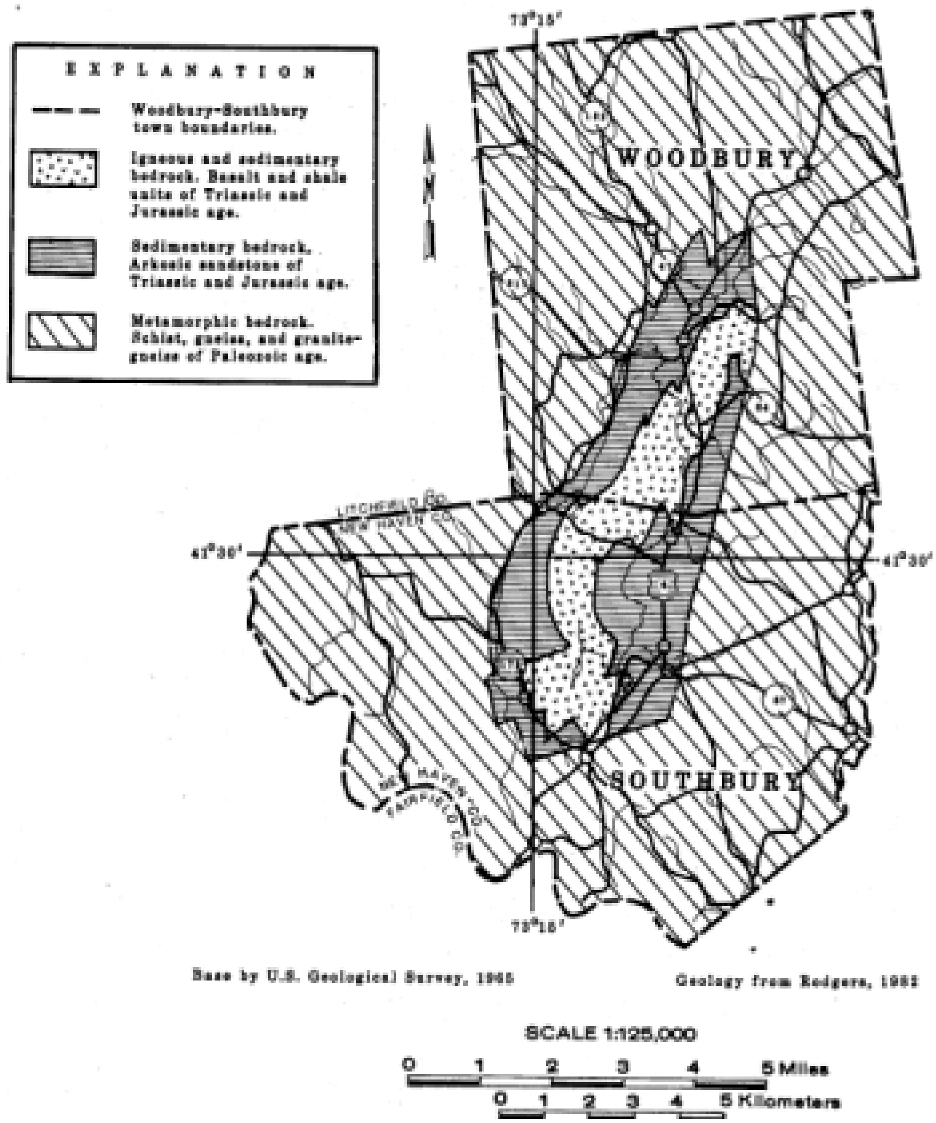


Figure 4. Bedrock geology of the Southbury-Woodbury area (Mazzaferro, 1986).

glacial deposits found in the Pomperaug Basin were extensively laid and have large pore spaces in between which water can readily flow through and be stored (Hust and Murphy, 1997). These deposits form the Pomperaug Aquifer (See Figure 2).

The topography of the Pomperaug watershed is diverse, reflecting the geological processes that help formed the New England landscape. The highest point in the Pomperaug watershed is in the town of Morris at 1,150 feet above sea level. The lowest point, where the Pomperaug River empties into the Housatonic River, is 100 feet above sea level (Meizner and

Sterns, 1929).

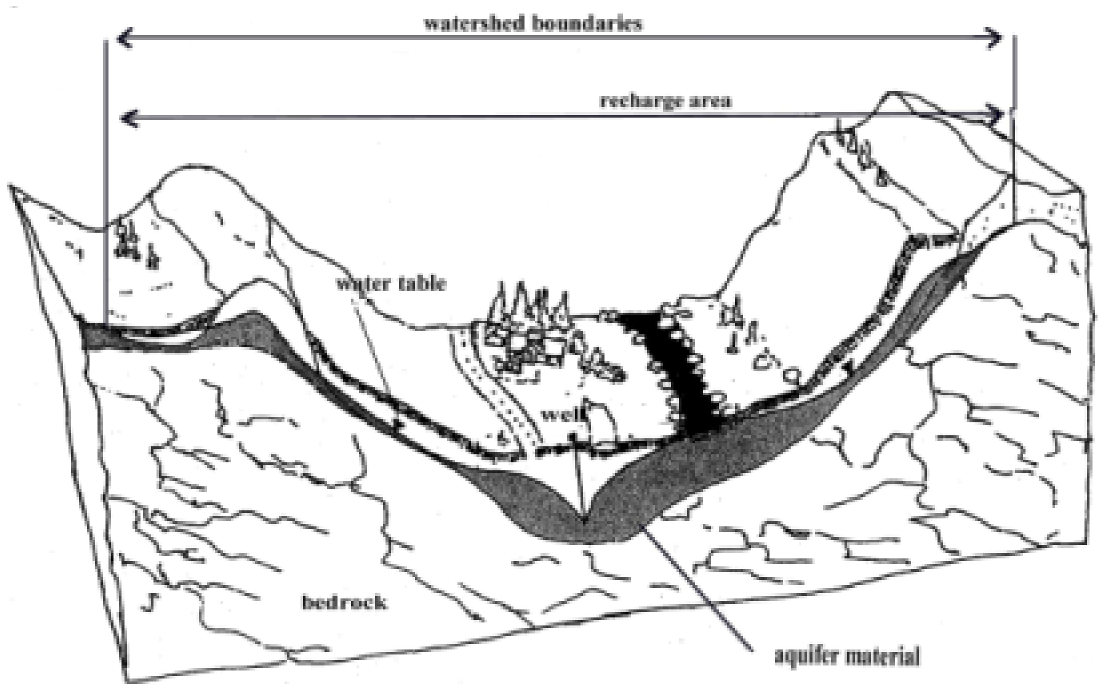
HOW THE POMPERAUG AQUIFER FUNCTIONS

The main portion of the Pomperaug Aquifer (in the down faulted Pomperaug Basin) is approximately 18 square miles, following the entire course of the Pomperaug River from central Woodbury to the Housatonic River (Mazzaferro, 1986). Less extensive aquifer materials were also deposited in the low-lying valleys of Woodbury, Southbury, and Bethlehem, including those valleys carved out by the Nonnewaug and Weekeepeemee Rivers (Marin, 1990).

The amount of water an aquifer can supply for consumption depends primarily on three factors - recharge rates, withdrawal rates, and the aquifer's storage capacity. Other factors that influence the potential of an aquifer to yield water include the number of wells, the distance between wells, the duration of pumping, and the proximity of a well to a stream, river, or impermeable boundary (Mazzaferro, 1986). Figure 5 is a representation of a typical river-aquifer system and surrounding watershed.

The recharge rate is the continual process of the aquifer replenishing itself, which also occurs after water withdrawals. Much of the recharge for the Pomperaug Aquifer comes directly from precipitation. Precipitation that lands directly on areas of stratified drift can more easily penetrate into the aquifer than precipitation falling on glacial till. In fact, precipitation falling on stratified drift may recharge the aquifer at rates up to three times higher then precipitation landing on till (Mazzaferro, 1986). Water may also re-enter the aquifer via underground flows from other aquifers, from sources of water located near the aquifer, such as wetlands, lakes and streams, and through artificial recharge by septic systems or other groundwater discharges.

Figure 5. Watershed model with a river-aquifer system, reproduced by permission from Hust and Murphy, 1997.



The withdrawal rate is the quantity of water removed from the aquifer over a period of time. Wells are a common means of removing water from an aquifer. The rate at which a well pumps out the contents of its source is one withdrawal rate. If the water from that well is used within the watershed, it may also contribute to the recharge rate. If water is diverted out of the basin, the withdrawal represents a net loss to the aquifer because this water is no longer available for recharge or to maintain river flows. In the Pomperaug watershed, examples of out-of-basin diversions are the waters supplied to portions of the towns of Middlebury, Oxford and Watertown. Besides commercial and residential private wells that withdraw water from the watershed, there are three water utilities with wells in the Pomperaug Aquifer. Heritage Water Company, United Water Connecticut, and the Watertown Fire District provide water for residents and businesses within and outside of the watershed.

The ability of an aquifer to supply water is also dependent on the aquifer's ability to store the water that enters it. Certain geologic formations, such as the stratified drift found in the Pomperaug River Basin, have a high storage capacity. Also important is the aquifers saturated thickness, the hydraulic conductivity of materials in the aquifer, and the aquifer's specific yield.

The saturated thickness of an aquifer (the depth from the water table to the bottom of the aquifer) generally determines the water yield from a well site. In the Pomperaug Aquifer, the saturated thickness ranges from 1 foot along its exterior boundaries to up to 150 feet in its interior. The coarse-grained deposits, which yield the most water, have been recorded at depths of 70 to 85 feet in Southbury and 80 to 100 feet in Woodbury (Mazzaferro, 1986).

The hydraulic conductivity is the rate at which water flows through a section of soil or aquifer over time (cubic feet of water passing through a cross-sectional area of one square foot per day). It is, in other words, a measure of how easily water is transmitted. The rate of transmission increases as the soil moisture content increases (Dunne and Leopold, 1978). Stratified drift aquifers generally have a good rate of conductivity.

The specific yield is the ratio of the quantity of water received from aquifer material per cubic foot of material. It demonstrates the availability of water in the aquifer. The specific yield for aquifers similar to the Pomperaug range from a ratio of 0.1 to 0.3 cubic feet of water per cubic foot of material, indicating that that aquifer yields water comparatively well.

The Hydrologic Cycle and How Water Recharges an Aquifer

The hydrologic cycle is the continuous movement of water from the oceans, the atmosphere, and the earth's continents. When precipitation falls within watershed boundaries, it either collects as runoff or penetrates into the soil becoming groundwater. Runoff is the term used for rainwater and melting snow that flows over the ground's surface into surface water bodies, such as oceans, lakes, rivers, and swamps. The amount of runoff generated following a rainfall or other storm event is dependent upon factors such as the rate of precipitation, topography, and the ability of the soil to absorb moisture. Steep slopes, slopes with little vegetation, and areas where soil is covered by impervious materials (such as paved parking lots, roads, driveways and roofs) affect the ability of water to infiltrate the soil and cause increased rates of runoff.

Water that penetrates into the soil is pulled downward by gravity. The unsaturated zone is the first part of sediment (mineral or organic matter) that water flows through above the water table. Here, the spaces between the particles of sediment are partially filled with water. It is not possible for wells to pump water located in this zone. Deeper down, the water flows into the saturated zone, where all the spaces between sediment particles are filled with water. Once water reaches the saturated zone, it is referred to as groundwater. Aquifers are located within this zone. The very top of the saturated zone is called the water table. The depth to the water table is generally shallowest near wetlands and permanent bodies of surface water, but the depth can change depending on precipitation rates and the rate nearby wells pump water out of the ground.

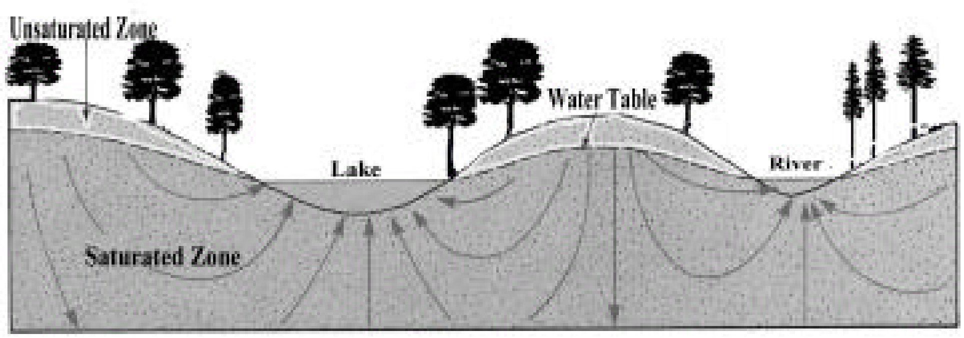
Water moves through the saturated zone from areas of recharge to areas of discharge. Recharge areas are those areas within the watershed boundaries where precipitation is able to penetrate into the soil. Areas of discharge are places where the water table and the ground's surface intersect, such as wetlands, rivers, lakes, and oceans. Groundwater is an important contributor of water to these waterbodies. If the water table drops below the level of the surface water, a portion of the surface water may flow into the ground to replenish groundwater levels.

The Pomperaug Aquifer and watershed have provided ample water for local residents and businesses, yet there are reasons for concern today. Stratified-drift aquifers are highly susceptible to contamination. For the same reasons that water is able to flow relatively quickly through these aquifers and be stored for long periods within them, so too can contaminants. Aquifers can also be depleted through overuse. As the demand for water increases, so does the potential for depleted wells and lower river flows.

The River-Aquifer Relationship

Groundwater and surface water are constantly interacting (Figure 6). Water from the Pomperaug Aquifer seeps into the Pomperaug River and its tributaries, supplementing stream flows. It is a critical source of water to the river, especially during periods of little precipitation, in which case it may be the only natural source of stream flow. Likewise, if sufficient groundwater is removed from the aquifer, surface waters can help replenish depleted aquifer levels because the two bodies of water are connected by the soils and sediments between them. The actions of humans can affect this groundwater-surface water relationship, thereby changing the quantity and quality of existing water supplies. Low stream flow rates, caused either by drought or human intervention, alter the stream environment and stress the fish and wildlife species that rely on this habitat. During periods of low flow, water temperature rises, dissolved oxygen levels decrease, the stream bank dries out, and pollutants become more highly concentrated (Oliver, 1984). During low flow conditions, it is also more difficult for the river to assimilate treated effluent discharged from wastewater treatment plants.

Figure 6. Relationship between groundwater and surface water.



Previous studies indicate that groundwater is a significant factor in maintaining surface water levels in southern New England (Mazzaferro, 1986). Precipitation that percolates into the groundwater is normally transferred over time to surface waters. This is an important source of water to the river, especially during dry summer months. The higher the percentage of stratified drift in comparison to other deposits, the higher the contribution of groundwater to surface waterbodies. Extractions of water from groundwater wells can directly impact river flows by reducing the amount of water available to supplement stream flows.

A 1990 report conducted for the towns of Southbury and Woodbury indicated that water diversions up to that point may have decreased summertime flows in the Pomperaug River by 30-40 percent (Marin, 1990). Figure 7 illustrates how high-yielding wells in stratified drift aquifers can reverse the normal flow of groundwater. In this model, the river recharges the aquifer. This process is called *induced infiltration*. In addition to drawing ground water away from the river, induced infiltration can also affect water quality in the aquifer. Wastewater, which is discharged into the Pomperaug River and its tributaries, becomes more concentrated during low river flows. This more highly concentrated effluent could be induced into the aquifer by wells pumping near the river.

WATER RESOURCES

Safe Yield and Recharge

Safe yield is the term used to express the amount of water an aquifer or well can yield for consumption without producing unacceptable negative effects. Connecticut defines the safe yield for public water as, “the maximum dependable draft, which can be made continuously from a water supply source without causing unacceptable effects during a critical dry period with a one percent chance of occurrence.” However, *unacceptable effect* is not well defined in the regulations, and therefore it is often difficult to reach a consensus on the actual safe yield of an aquifer. Potential unacceptable effects discussed previously are contamination of the aquifer water by induced infiltration, decreased river flows, and lowering of the water table.