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In Cooperation with Cortland County Soil and Water Conservation District

# Hydrogeology and Simulation of Ground-Water Flow in a Glacial-Aquifer System at Cortland County, New York

The City of Cortland and surrounding communities obtain water from a highly productive glacial-aquifer system that underlies the western part of Cortland County (figs. 1 and 2). The study area encompasses about 12 square miles and includes the Otter Creek-Dry Creek valley and parts of the West Branch, East Branch, and Tioughnioga River valley and surrounds the bedrock hill (figs. 1 and 2) in Cortland upon which the State College campus stands.

This aquifer system has been designated as a "Primary Aquifer" by the New York State Department of Environmental Conservation and as a "Sole Source Aquifer" by the U.S. Environmental Protection Agency (EPA). The upper (unconfined) aquifer is highly permeable and close to land surface, which makes it highly susceptible to contamination. Potential sources of contamination include leaking petroleum-product storage tanks, leachate from landfills and septic systems, road-deicing salts, agricultural pesticides and fertilizers, and chemical spills (such as solvents and degreasers) at commercial and industrial facilities. Protection of this aquifer system from contamination is critical to ensure a safe drinking-water supply for the area.

In 1989, the U.S. Geological Survey (USGS), in cooperation with Cortland County Departments of Health and Planning, began a 3 1/2-year study to define the hydrogeology of the glacial aquifer. The results of the study were published in Miller and others (1998). This Fact Sheet summarizes the results of that study and depicts the stratigraphy and model-generated areas that contribute ground water to wells.

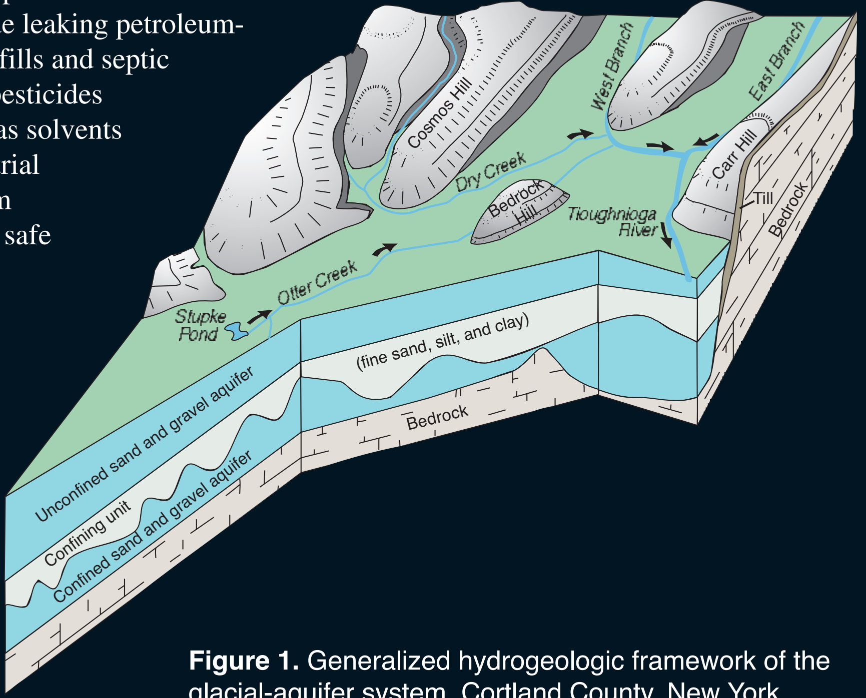

**Figure 1.** Generalized hydrogeologic framework of the glacial-aquifer system, Cortland County, New York.

**U.S. Department of the Interior**
**U.S. Geological Survey**

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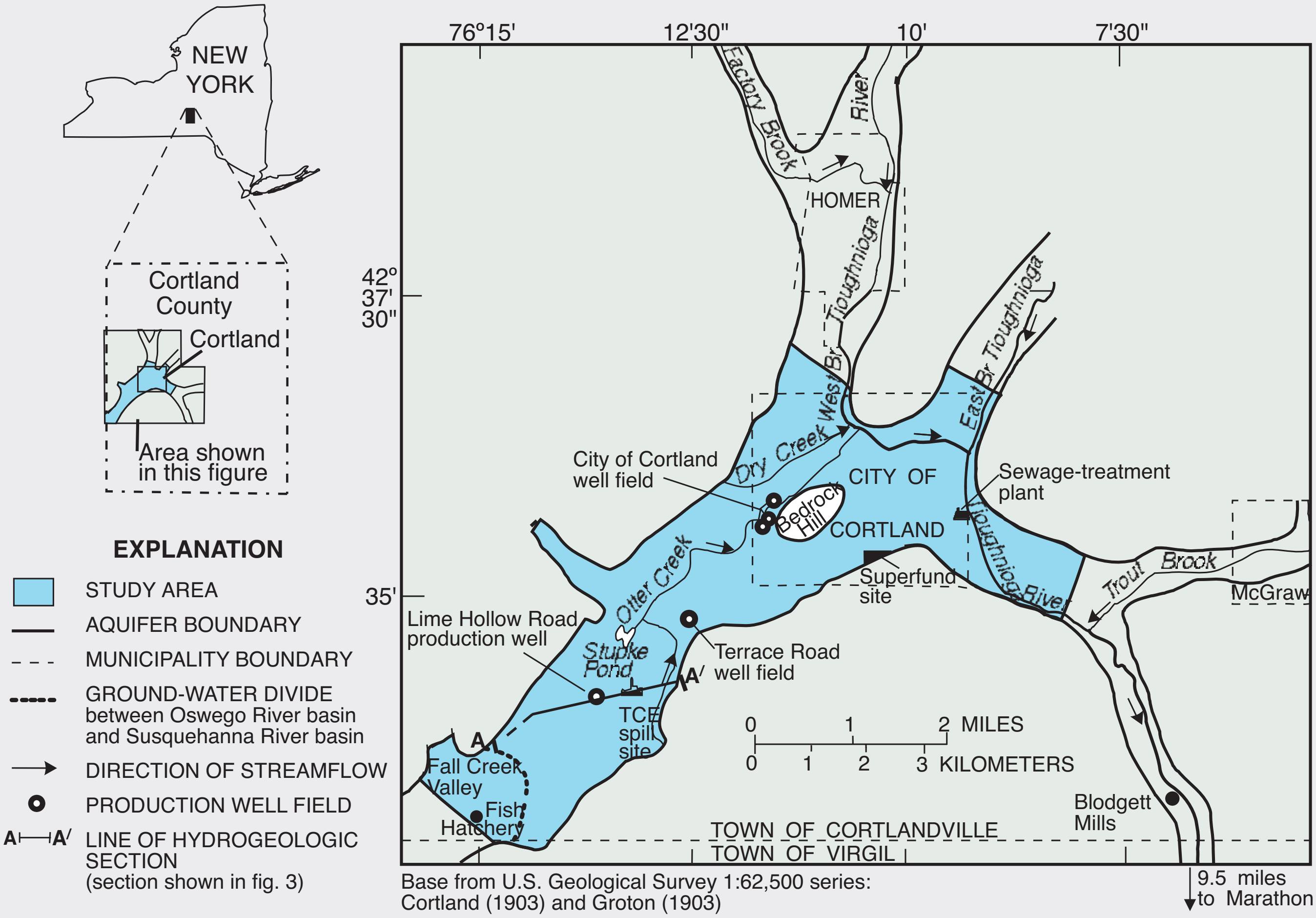
## HYDROGEOLOGY OF THE GLACIAL-AQUIFER SYSTEM

The **glacial-aquifer**[1] system in the Cortland area is bounded laterally by **till**-covered bedrock hills and beneath by the bedrock valley floor (figs. 1 and 3). It consists of an **unconfined** sand and gravel **aquifer** 40 to 80 feet thick that overlies a **lacustrine confining layer** 1 to 155 feet thick that, in turn, overlies a **confined** sand and gravel **aquifer** that ranges from 1 to 170 feet thick (figs. 1 and 3). The **confining unit** impedes vertical movement of ground water between the upper and lower aquifers in the middle of the valley, but the two aquifers are connected in many places along the valley walls where the confining layer is absent (fig. 3).

A supply well in Cortland aquifer



Base from U.S. Geological Survey 1:62,500 series: Cortland (1903) and Groton (1903)

**Figure 2.** Location and principal features of study area, Cortland County, New York.

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[1] Boldface terms are explained in glossary

## GLACIAL HISTORY

Glaciers covered central New York several times during the Ice Age, or Pleistocene Epoch, which began around 1.6 million years ago and ended when the ice left the New York area about 10,000 years ago. A major readvance (Valley Heads readvance) and standstill of the ice in central New York between 14,000 and 14,900 years ago resulted in the deposition of large amounts of sediment at the ice front. This material formed several types of deposits, one of which was a series of hummocky ridges that blocked several north-south-trending valleys. These ridges form a complex that extends across central New York and is known as the Valley Heads **Moraine**. Segments of the Valley Heads Moraine are found in the western part of the study area and in valleys to the north (fig. 4). The upper part of these segments consists of unsorted sediments, mainly coarse sand and gravel; the lower part consists of mostly fine-grained material such as till and lacustrine sand, silt, and clay (fig. 3).

The Valley Heads Moraine formed plugs in the major valleys; these plugs blocked the natural drainage and resulted in the formation of lakes. One such lake formed in the valleys of the Tioughnioga River basin. Upland streams and meltwaters from the glacier transported large amounts of sediment into the lake; the coarse-grained sediments (sand and gravel) settled near the water's edge, whereas the fine-grained sediments (very fine sand, silt, and clay particles) were carried farther out into the lake, where they settled to form lacustrine (lake-bottom) deposits. These lacustrine deposits typically range from 90 to 155 feet thick in the central parts of the valleys and pinch out along the valley edges (fig. 3). The lacustrine unit forms the bottom of the surficial (unconfined aquifer) and the top boundary of the confined basal aquifer in the study area (figs. 1 and 3).

The outlet of the lake (at Messengerville, fig. 4) was gradually lowered by erosion, and this lowering eventually allowed the lake to drain. Subsequent meltwater from the retreating ice developed a braided-stream system within the valleys, and large amounts of outwash sand and gravel (fig. 4) were deposited on top of the former lakebed (fig. 3). This outwash forms a wedge-shaped deposit that is more than 100 ft thick in the western part of the study area and thins eastward to the Tioughnioga River, where it is 35 to 45 feet thick. The outwash and morainal sediments form the highly permeable unconfined surficial aquifer in the Cortland area.

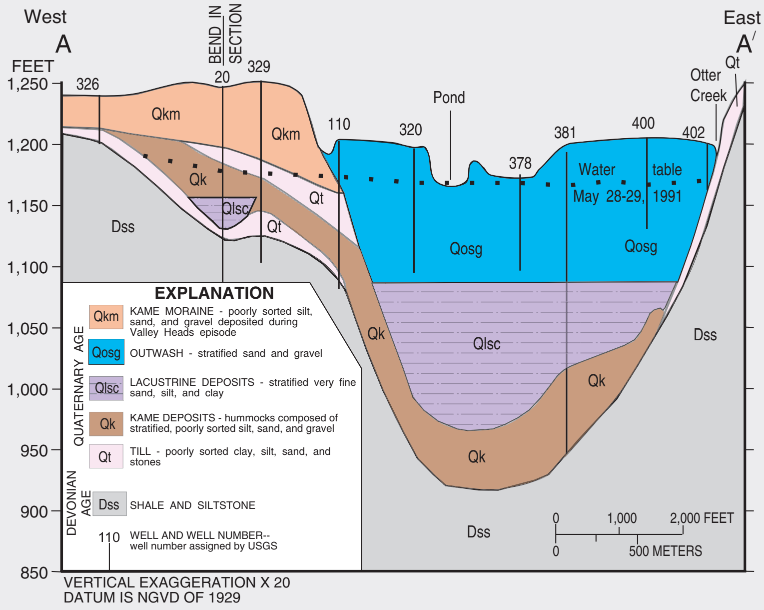

**Figure 3.** Hydrogeologic section A-A′ (Line of section shown in fig. 2).

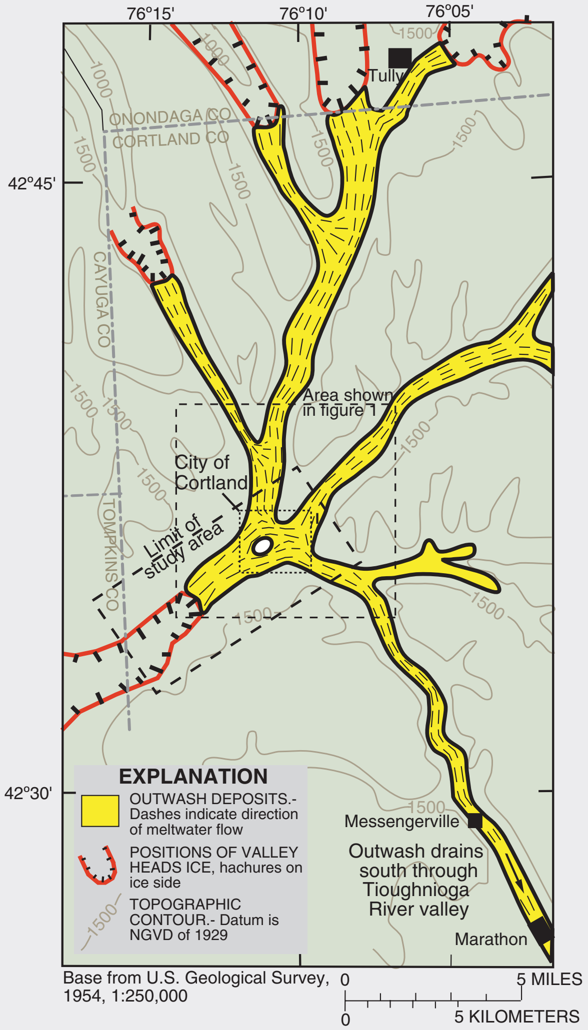

**Figure 4.** Positions of Valley Heads ice and of outwash deposits in the Tioughnioga River basin, Cortland County, New York.

## AQUIFER RECHARGE AND DISCHARGE

The unconfined aquifer receives **recharge** from three sources under natural (nonpumping) conditions—(1) infiltration of precipitation that falls directly on the aquifer, (2) upland sources, such as **runoff** from unchanneled hillsides and seepage from bedrock slopes that border the aquifer, and (3) seepage from tributaries that flow onto the aquifer (fig. 5). The aquifer receives additional recharge from (1) infiltration beneath recharge basins at an industrial site in the western part of the aquifer (fig. 6), and (2) induced infiltration from streams and ponds near the major pumping wells. The confined aquifer is recharged along the edges of the valley (fig. 5).

Water in the unconfined aquifer **discharges** (1) into the West Branch and main stem of the Tioughnioga River and, during seasonally high water-level conditions, to the lower reaches of Otter Creek, (2) to pumping wells, and (3) to springs that are the headwaters of Fall Creek valley in the western part of the study area (fig. 2). The study area contains four major pumping centers— the City of Cortland well field, the well field for the Town of Cortlandville on Terrace Road, a well for the Town of Cortlandville on Lime Hollow Road, and a purge well at the former typewriter plant in the western part of the study area (fig. 6). Most of the water pumped from the production wells is eventually routed to the sewage-treatment plant as wastewater (fig. 2), where it is treated and discharged into the Tioughnioga River.

## SIMULATION OF GROUND- WATER FLOW

A numerical ground-water flow model was constructed through the computer program MODFLOW to calculate hydraulic heads (water-table elevations) in the aquifer system and to derive water budgets. The directions of ground-water flow can be inferred from the hydraulic heads calculated by the model. Ground water moves from areas of high head to areas of low head, and the direction of flow is controlled by local factors such as aquifer geometry, distribution of recharge, and location of discharge areas (streams, ponds, and pumping wells), all of which are represented in the model. Model simulations indicate that water in the unconfined aquifer moves laterally from the edges of the valley toward the center, then flows northeastward along the axis of the Otter Creek-Dry Creek valley, where it discharges to pumping wells, the West Branch Tioughnioga River, and the main stem of the Tioughnioga River.

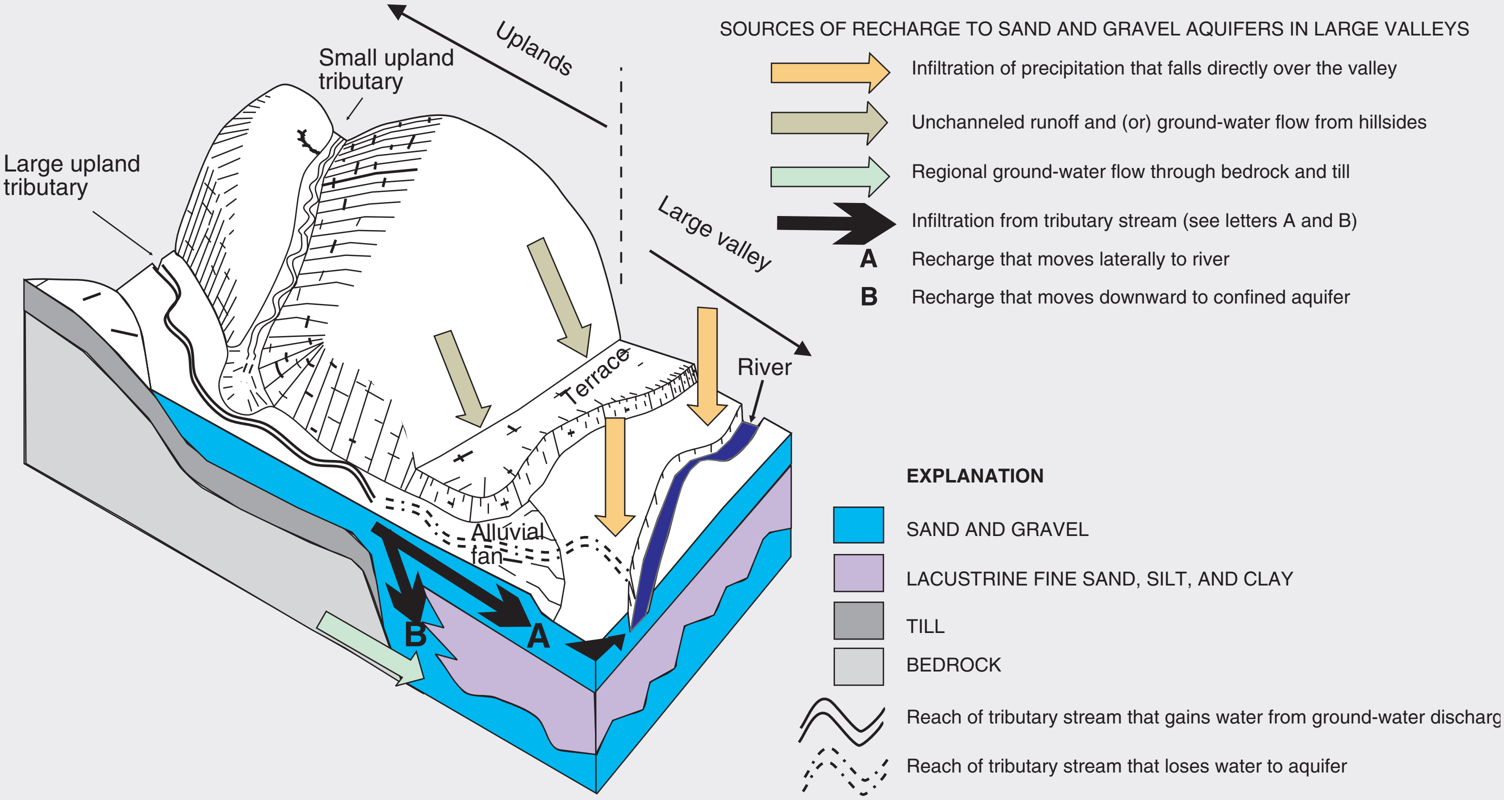

**Figure 5.** Sources of recharge to the glacial-aquifer system at Cortland County, NewYork.

## RECHARGE AND DISCHARGE

Water from the uplands is the largest source of aquifer recharge under average-recharge conditions and provides 55 percent of total recharge; this includes seepage from upland streams that flow onto the aquifer (32 percent of total recharge) plus unchanneled runoff and ground-water inflow from uplands (23 percent, table 1). The second-largest source is precipitation that falls directly onto the aquifer (38 percent of total recharge). The greatest discharge from the aquifer occurs as leakage to streams  (69 percent of total discharge, table 1); the second largest is to pumping wells (28 percent of total discharge).

## AREAS CONTRIBUTING RECHARGE TO LARGE PUMPING WELLS

**Contributing areas** to major pumping wells were calculated through the computer program MODPATH, which computes hypothetical paths of imaginary “particles” of water moving through a simulated ground-water-flow system and their traveltimes (fig. 6). Pumping large quantities of water from an aquifer system causes a drawdown of water levels within the aquifer, and the **drawdown** decreases with increasing distance from the pumping well. The lowering of the water level by pumping causes ground water to flow to the well. The **flowpaths**, and the size and extent of the well’s contributing area depend on the hydraulic characteristics of the flow system, such as aquifer geometry, recharge rate, discharge rate, **permeability** of aquifer material, and type of well construction, including location, pumping rate, and position and length of the screen.

Contributing-area analyses were done for low-, average-, and high-recharge conditions. The analysis for low-recharge conditions (fig. 6) resulted in the largest contributing areas. The model-generated contributing areas are U-shaped, with the open end facing upgradient from the well, and extend over most of the unconfined-aquifer area upgradient from the wells (fig. 6). The City of Cortland municipal well had the largest contributing area of all wells simulated. Recharge from tributaries such as Otter Creek and the unnamed tributary north of Otter Creek were indicated to be sources of water to the city well; thus, evaluations of the quality of water pumped by the city well need to consider the water quality of these two streams.

The largest contributing areas resulted from the low-recharge condition; therefore, the low-recharge condition defines the “worst case” (largest area) that water managers will need to consider when evaluating potential sources of contaminants that may threaten the water supply.

## GLOSSARY

**Aquifer** - A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to springs and wells.

**Confined aquifer (artesian aquifer)** - An aquifer that is completely filled with water under pressure and that is overlain by material that restricts the movement of water.

**Confining layer (confining unit)** - A body of impermeable or distinctly less permeable (see permeability) material stratigraphically adjacent to one or more aquifers that restricts the movement of water into and out of the aquifers.

**Contributing area** - The area in a drainage basin that contributes water to streamflow or recharge to an aquifer.

**Discharge** - The volume of fluid passing a point per unit of time, commonly expressed in cubic feet per second, million gallons per day, gallons per minute, or seconds per minute per day.

**Discharge area (ground water)** - Area where subsurface water is discharged to the land surface, to surface water, or to the atmosphere.

**Drawdown** - The difference between the water level in a well before pumping and the water level in the well during pumping. Also, for flowing wells, the reduction of the pressure head as a result of the discharge of water.

**Flowpath** - An underground route for ground-water movement, extending from a recharge (intake) zone to a discharge (output) zone such as a pumping well or shallow stream.

**Glacial** - Of or relating to the presence and activities of ice or glaciers.

**Lacustrine** - Pertaining to, produced by, or formed in a lake.

**Moraine** - A mound, ridge, or other distinct accumulation of glacial drift, deposited chiefly by direct action of glacier ice.

**Permeability** - The capacity for transmitting a fluid; a measure of the relative ease with which a porous medium such as unconsolidated sediment can transmit a liquid.

**Recharge (ground water)** - The process involved in the absorption and addition of water to the zone of saturation.

**Recharge area (ground water)** - An area within which water infiltrates the ground and reaches the zone of saturation.

**Runoff** - That part of precipitation or snowmelt that appears in streams or surface-water bodies.

**Till** - Predominantly unsorted and unstratified drift, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders.

**Unconfined aquifer** - An aquifer whose upper surface is a water table free to fluctuate under atmospheric pressure.

**Upgradient** - Of or pertaining to the place(s) from which ground water originated or traveled through before reaching a given point in an aquifer.

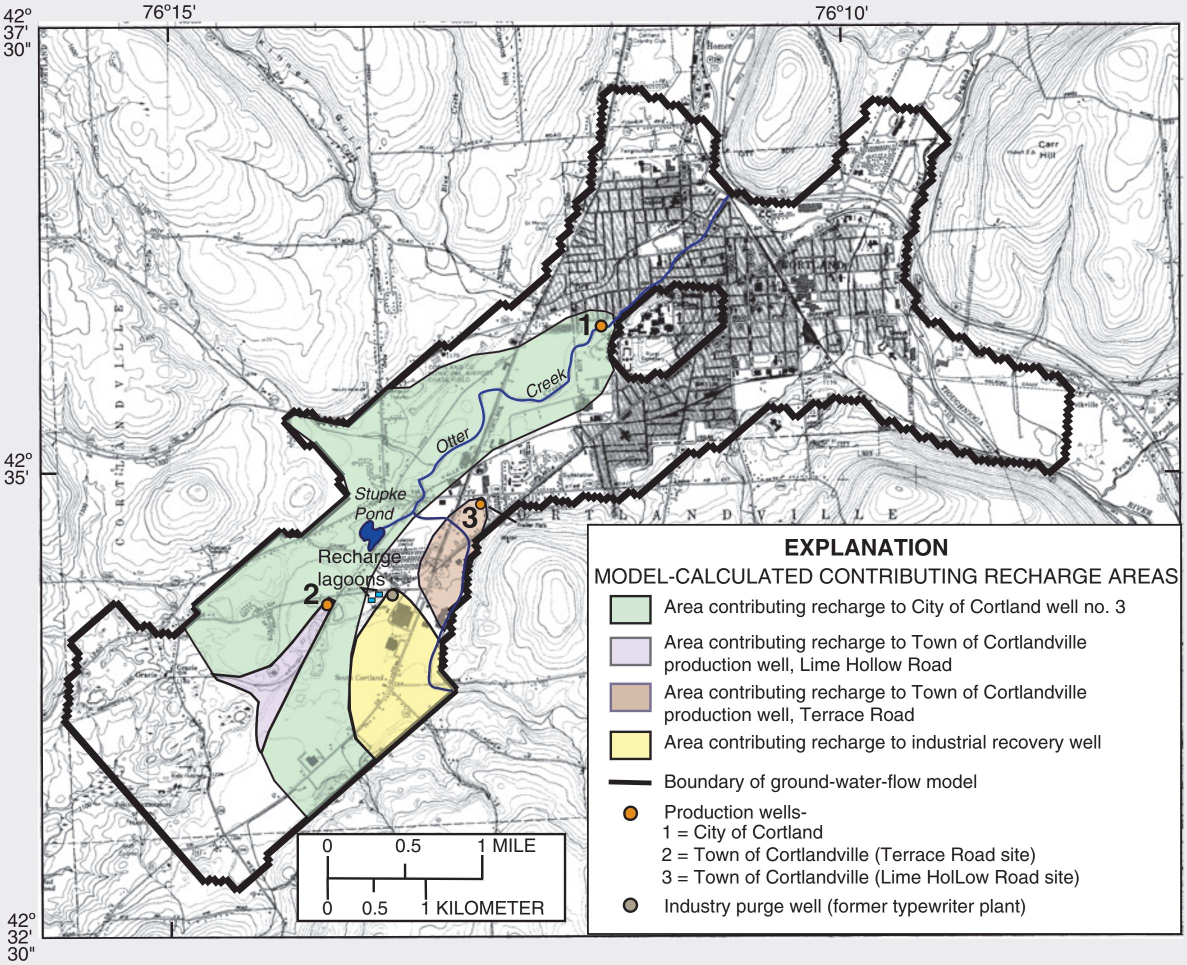

**Figure 6.** Model-calculated contributing recharge areas for major production wells during low-recharge conditions, in the unconfined aquifer, Cortland County, New York.

**Table 1.** Steady-state water budget for glacial aquifer at Cortland, N.Y., for average-recharge conditions, May 28 through June 4, 1991.

[ft $^3$/s, cubic feet per second]

| Budget component | Amount (ft$^3$/s) | Percent of total |
|---|---|---|
| **A. Recharge to the aquifer system** | | |
| Precipitation on the aquifer | 14.4 | 38 |
| Upland sources | | |
| Seepage losses from tributary streams | 12.2 | 32 |
| Unchanneled runoff and ground-water inflow from uplands | 8.8 | 23 |
| Ground-water inflow from valleys to model area | .9 | 3 |
| Infiltration at recharge basins | 1.7 | 4 |
| TOTAL | 38.0 | 100 |
| **B. Discharge from aquifer system** | | |
| Pumping wells | 10.7 | 28 |
| Discharge from aquifer to streams | 26.1 | 69 |
| Ground-water outflow from model area | 1.2 | 3 |
| TOTAL | 38.0 | 100 |

## REFERENCE CITED

Miller, T.S., Sherwood, D.A., Jeffers, P.M., and Mueller, Nancy, 1998, Hydrogeology, water quality, and simulation of ground-water flow in a glacial-aquifer system, Cortland County, New York: U.S. Geological Survey Water-Resources Investigations Report 96-4255, 84 p.

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This fact sheet and related information can be found on the world wide web at http://ny.usgs.gov