Preliminary Hydrogeological Report
& Large-Diameter Well Development and Testing Plan
Well #3
Town of Sterling, New York

submitted to
New York State Department of Health (NYSDOH)
New York State Department of Environmental Conservation (NYSDEC)

June 22, 2022

INTRODUCTION

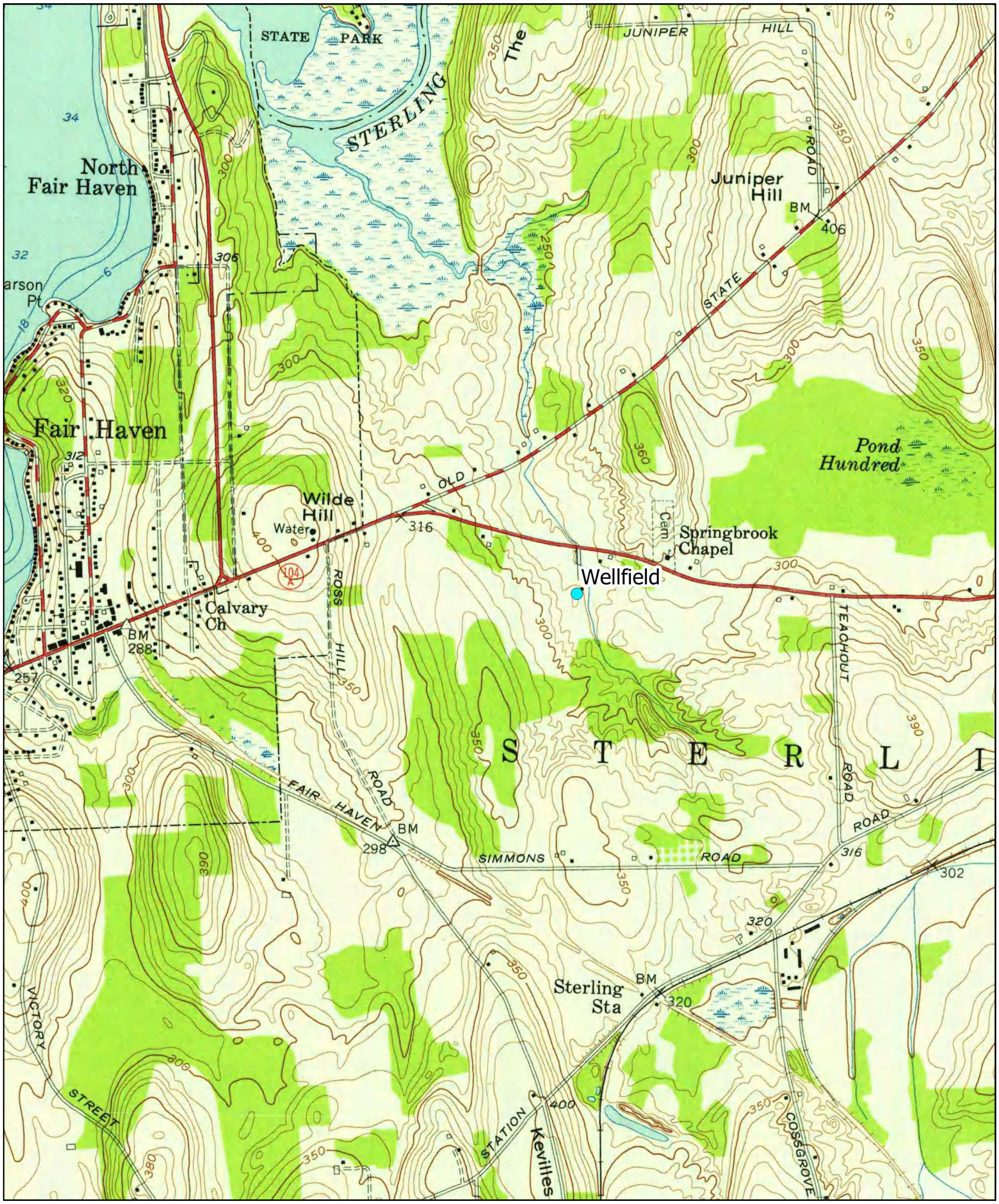
The Town of Sterling, New York, is proposing to develop an additional supply well at a wellfield on the south side of Route 104A, one mile east of Fair Haven (Figure 1). Two supply wells already exist at this property (Well #1 and Well #2), and they jointly serve distribution systems owned by the Town of Sterling and the Village of Fair Haven. The new well will be named Well #3. The primary purpose of the new well will be to serve as the water supply to a new Town water district, although it may also be used to provide increased source redundancy for the Town and Village systems. The wellfield taps a glacial sand and gravel aquifer.

Efforts to identify a suitable site for the new well have been conducted by HydroSource Associates, which also wrote this report. HydroSource has been working on the project in cooperation with the Town's engineering consultant, C2AE.

HYDROGEOLOGIC SETTING

Bedrock Geology

Published mapping shows that the area including the Sterling wellfield is underlain by sedimentary rock of the Grimsby Formation (Isachsen & Fisher, 1970). The following description is based on information from an online U. S. Geological Survey stratigraphic database (USGS, 2020). The Grimsby Formation consists of interbedded red and green sandstone, siltstone, and shale, and is a member of the Medina Group of Early Silurian age. A phosphate-rich bed occurs near the base of the Grimsby, and the basal five to ten feet of the formation typically consists of greenish-gray and maroon shale. The lower part of the formation tends to be fossiliferous. Higher parts of the unit consist of red and white mottled fine-grained to medium-grained sandstone and conglomerate interbedded with shale. The formation's thickness ranges from 56 to 72 feet.



0 2,000 ft

N

Figure 1 - Wellfield Location

The sedimentary sequence that includes the Grimsby is flat-lying and undeformed in this area. Taking that into account, it appears likely that the bedrock surface on which the younger glacial sediments of the area were deposited has a generally flat, table-like form, similar to the orientation of bedding planes in the sedimentary rock itself. However, that flat bedrock surface may be interrupted at least occasionally by glacially deepened troughs.

Surficial Geology

Information on the surficial geology of the area including the wellfield comes from recent quadrangle-scale mapping (Bird & Kozlowski, 2015). Figure 2 is a surficial geologic map. Bedrock in the area is covered by a relatively thin layer of glacially derived sediments.

Glacial till is exposed at the higher elevations. The sediment is described in the map legend as "diamicton." The material making up the till was derived from the bedrock surface as the glacial ice flowed into this area from the northwest. The rock was ground up in and beneath the moving ice, producing a mixture of boulders, sand, and rock flour, and the disorganized sediment was left in place when the ice melted.

The movement of the ice contoured the ground surface, leaving behind a longitudinal grain in the topography. The many low elongate hills near the wellfield are drumlins, composed of mounded-up till. The drumlins near the Town's wellfield show a northerly or north-northwesterly direction of elongation, which indicates that the ice moved across the region from NNW to SSE. The till thickness can be as much as 100 feet in some of the drumlins.

Melting of the ice during the glacier's retreat produced large volumes of meltwater, and the resulting high-volume meltwater streams left behind substantial volumes of permeable sand and gravel. At some point during the glacial retreat, the ice margin stalled for a time at a location about a half-mile southeast of the wellfield (Figure 2, line of red dots). At this time, a fast-moving southeast-flowing meltwater stream must have developed in an ice tunnel in the region between the wellfield and the ice margin. This stream left behind an esker, which is largely within an area marked Psg on Figure 2. Presumably, at least one of the Town's existing wells taps sediments associated with this esker. Although Figure 2 shows the esker as terminating just south of the wellfield, it is possible and perhaps likely that esker sediments persist at depth for some distance to the north.

An outwash fan developed in the area just south of the ice margin. The water of the meltwater river that left behind the stringlike esker deposit, where its course was confined in the ice tunnel, was able to spread out over a broad area after it emerged from the tunnel and flowed out beyond the edge of the ice. It dumped a large load of sediment in a fan-shaped deposit along the ice margin.

The sediment of the esker and the outwash fan was deposited during a brief interruption in the glacier's retreat, when the ice margin was stationary. After the retreat resumed, and the edge of the ice moved further north, the area was partly submerged beneath a glacial lake. This lake, called Lake Algonquin, covered much of the low-lying area around the Great Lakes in the whole region northwest of the Adirondacks.

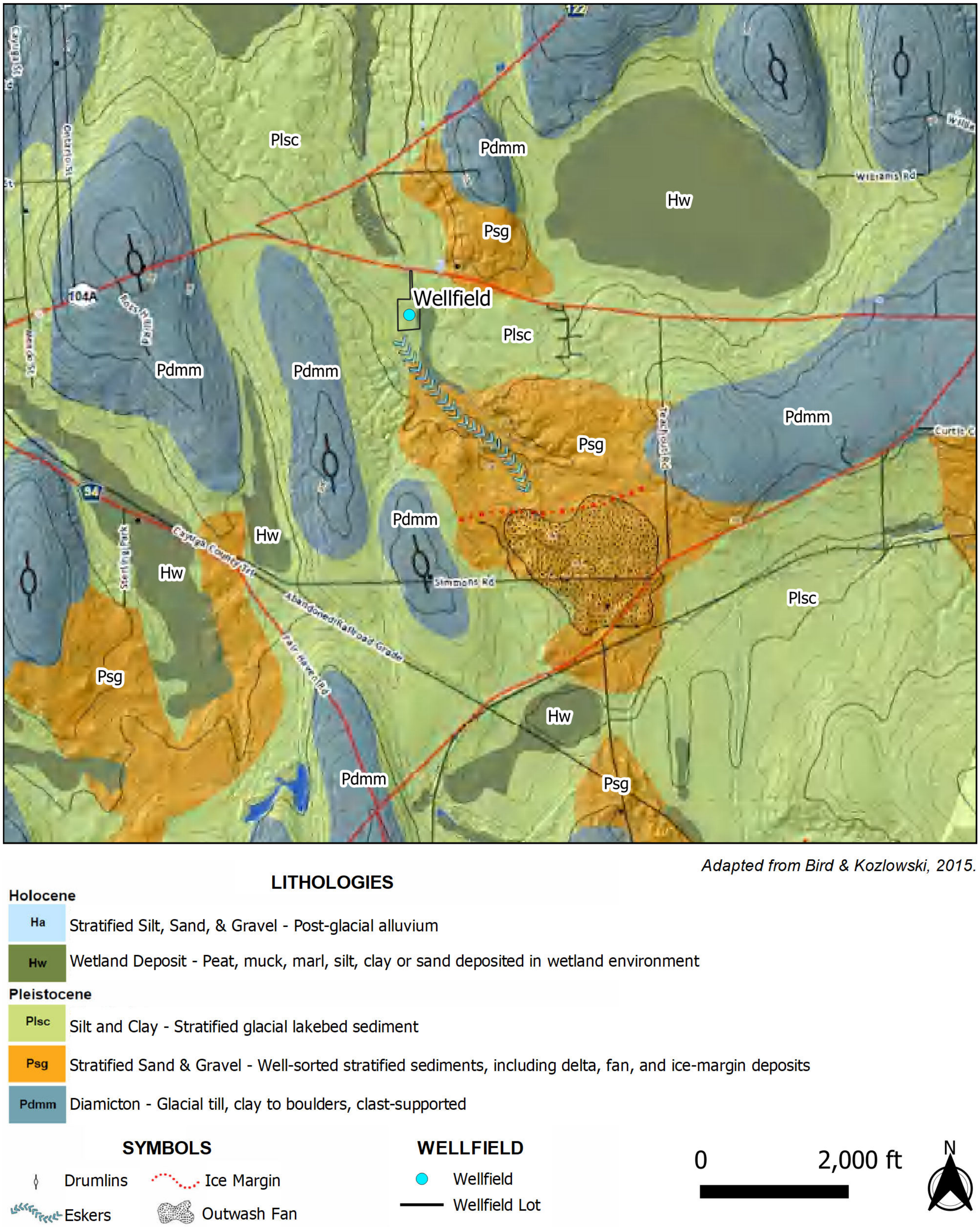


Figure 2 - Surficial Geology

The meltwater carried a heavy load of fine-grained sediments that slowly rained out of the quiet water of the lake. This resulted in a layer of lakebed sand, silt, and clay (Plsc on the map) being deposited at the lower elevations that were flooded by the lake. During the period when the lake occupied this area, the drumlins of till stood up as islands, as did some of the areas of coarse-grained sand and gravel. The 1967 driller's log of the Town's Well #1 shows that the productive gravel at this site was covered by about 20 feet of this fine-grained lakebed sediment (clay in this case). It is likely that substantial thicknesses of productive sand and gravel are hidden beneath lakebed sediments at many other nearby locations.

The sediments described above are of Pleistocene age, meaning that they were deposited during the last glaciation. Holocene sediments are those deposited after the end of the glaciation. These include sand and gravel deposits laid down along the course of post-glacial streams, though no such deposits appear in the map view of Figure 2. The other category of Holocene sediments is wetland deposits, represented most prominently by the large peat bog northeast of the wellfield.

WELLFIELD

Figure 3 shows the Town of Sterling / Village of Fair Haven wellfield, including the approximate proposed location of Well #3. The wellfield property takes in about three acres. The property is bordered by fields to the west. An unnamed stream passes the property on the east. The stream originates in the area of sand and gravel deposits southeast of the wellfield, and empties into Lake Ontario about two miles to the northwest.

Pre-Existing Wells

The wellfield presently hosts two gravel pack supply wells. Well #1 is near the north end of the property. The well was drilled between June 1 and June 8, 1967, by the drilling contractor that was then known as Layne-New York, but which is now named Layne Christensen. The well is described in Layne's drill log (Figure 4) and their construction diagram (Figure 5) as a 22x18x12 well, with a total depth of 46 feet. It hit "boulders, sand & gravel, medium to coarse" from 21 to 24 feet, and "gravel & sand" from 24 to 46 feet. The driller's report states that the well has 10 feet of screen, but the slot size is not provided. During an eight-hour pumping test at 350 gallons per minute (gpm) conducted in 1967, the well showed about one foot of drawdown.

Well #1 was briefly tested again in 2019 following redevelopment. It was pumped at 339 gpm, and showed drawdown of about 1.5 feet, for a specific capacity of 225 gpm/ft.

Less information exists for Well #2, which is roughly 275 feet south of Well #1. The available information comes from a 2016 Layne Christensen installer's report, which was written after well redevelopment. The well is reported to be 54 feet deep. The top of the screen assembly is at 35.5 feet, but the screen length and slot size are not known. A brief pumping test was run after well redevelopment. The well was pumped at 183 gpm for 30 minutes, resulting in drawdown of 9.2 feet and a specific capacity of about 20 gpm/ft.

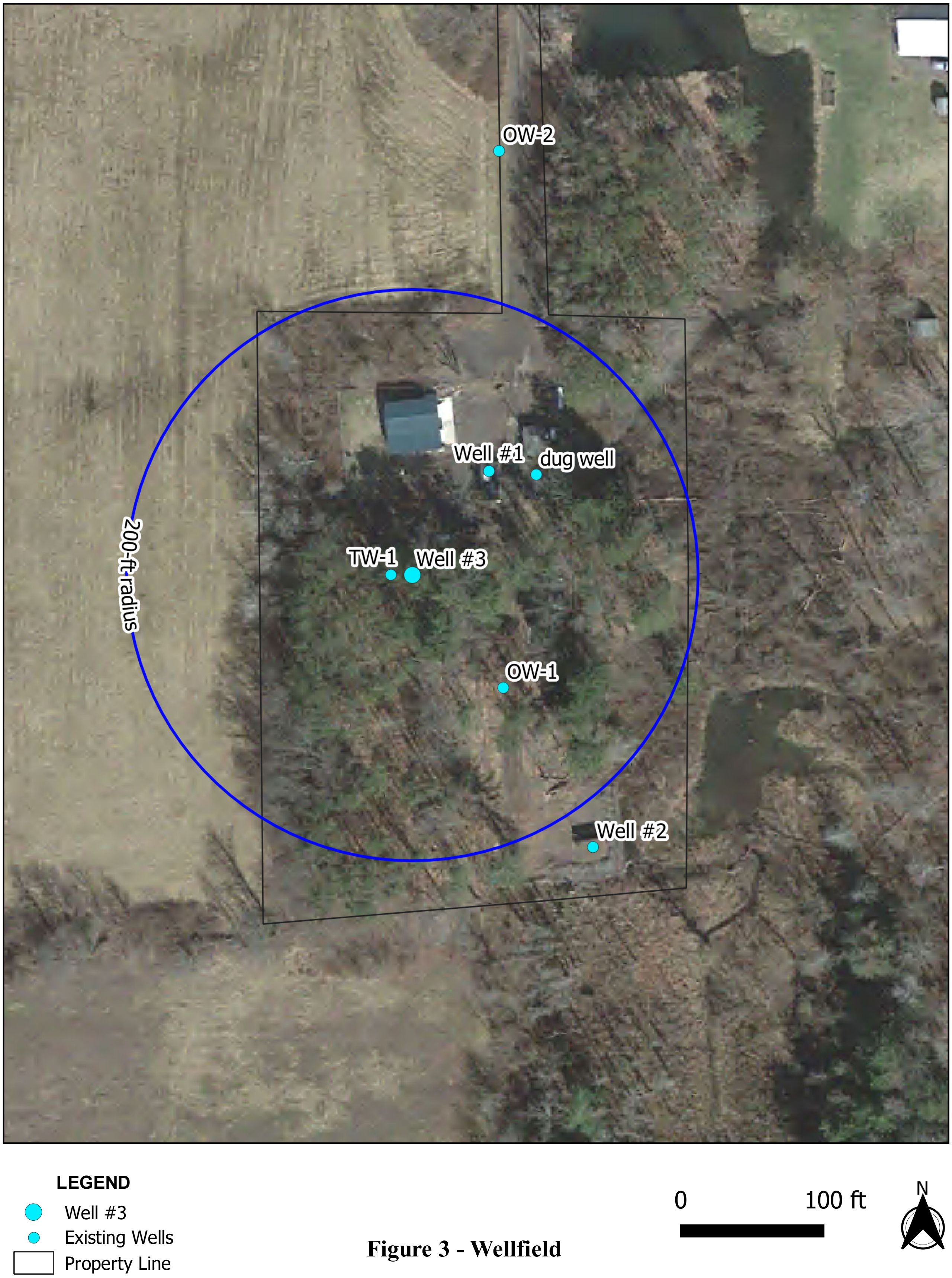


Figure 3 - Wellfield

Figure 4 - Driller's Log

LAYNE-NEW YORK CO., INC.

92 LIBERTY STREET, NEW YORK CITY

LOG OF WELL

Log of Well for *Fair Haven, N.Y.* Test No.

Address

Well located at *Water Plant* in County, State of *N.Y.*

Date Drilling started *June 1-67* Date Test Hole Completed *June 8-67*

Total depth to bottom of Well *46'* ~~Diameter Test~~ Hole *22" x 18" x 12"*

Water stands when not pumping *3* feet *11* inches from the surface of the ground

EACH STRATUM	DEPTH OF STRATA	FORMATION FOUND EACH STRATUM	EACH STRATUM	DEPTH OF STRATA	FORMATION FOUND EACH STRATUM
1'	1'	Clay			
1'6"	2'6"	top soil			
8'6"	21'	Clay			
3'	24'	Boulders, sand + gravel			
		Med. to coarse			
22'	46'	gravel + sand			
		sand clay +			
2'	48'	some gravel			

…marks and opinion of Test

…illed in 46' to 48'

W R Blair

Driller

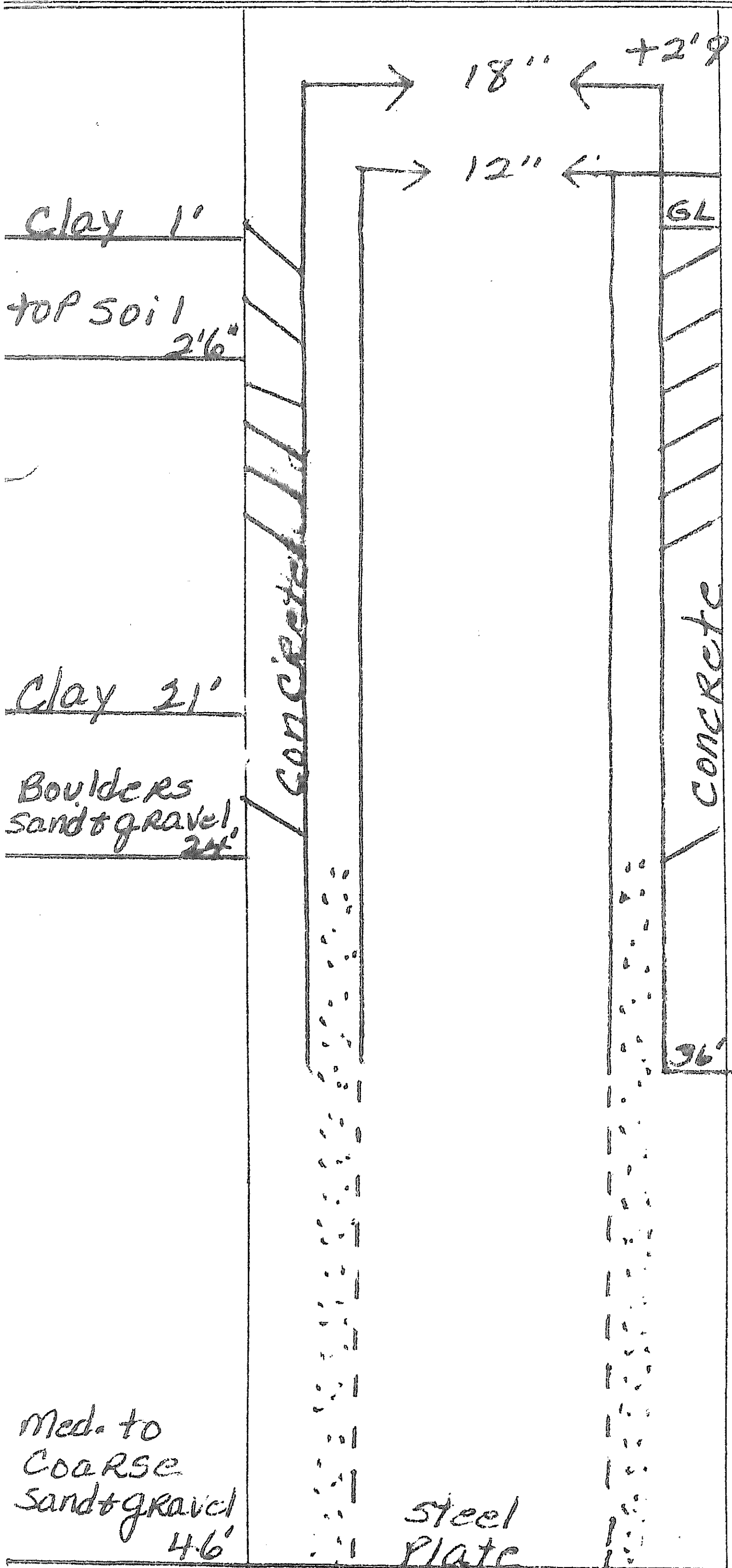
Figure 5 - Well #1 Construction Diagram

[L]AYNE-NEW YORK CO., INC.
[illegible] WEST ELIZABETH AVE., LINDEN, N. J.

DRILLERS REPORT

JOB No. R163 DRILLER W. R. Blair CUSTOMER WELL No. 1
CUSTOMER Village of Fair Haven, N.Y. LAYNE WELL No. 1
WELL LOCATION Water Plant STATE PERMIT No.

FORMATION SKETCH OF SETTING REMARKS



PIPE SET:

DIA.	WALL	LGTH.	MATL.	~~T & C (OR)~~ WELDED
18"	375	52'9"		
12"	375	37'		

PIPE LEFT IN PLACE:

DIA.	WALL	LGTH.	MATL.	~~T & C (OR)~~ WELDED
18"	375	48'9"		
12"	375	37'		

SCREEN:
NOM. SIZE 12" I.D. 10 LGTH. OPNG.
MFG. Layne TYPE Layne METAL SS GA. No.
SET IN 22' Med. to Coarse Sand & Gravel FORMATION
WELL UNDEREAMED TO DIAMETER

MISCELLANEOUS:
R & L BACK OFF CUT OFF PACKER TYPE

CONE:
DIA. TOP DIA. BOTT. LGTH. MTL.

PLUG:
DIA. LGTH. MTL.

GRAVEL: AMT. 3 BBL SIZE
CLAY: BAGS PWDR. REG. BAGS LAYNEITE B-3

CEMENT: BAGS USED YDS. CONCRETE 1½
SEAL: CLAY CEMENT LGTH. 19'5" of 22"

METHOD OF DRILLING:
☐ STD. ROT. ☐ REV. ROT. ☒ CABLE TOOL ☐ AIR ROT.
☐ OTHER

MEASUREMENTS:
GROUND ELEV. ABOVE SEA LEVEL
DEPTH OF WELL AFTER PLUG 46'
DEPTH TO GRAVEL WALL 23' to 46"
FROM ☐ GRD. LEV. ☐ TOP OF ____ CASING ☐ ORIG. GRD. LEV.

MISCELLANEOUS:
DATE WORK STARTED 6/1/67 DATE FIRST PUMPED 6/8/67
DID WELL CLEAR UP Yes HOW SOON 15 min.
WAS SAND PUMPED Yes HOW LONG 3 hrs.
HOW LONG AGITATED 3 hrs. HOW LONG PUMPED 9 hrs.
CHEM. USED TO DEVELOP SAMPLE TAKEN Yes

PRELIMINARY TEST DATA:
STATIC LEVEL 3'11" DATE 6/8/67 WATER TEMP.
CAPACITY 350 GPM WITH 10'6" PUMPING LEVEL

SKETCH OF LOCATION

W R Blair
SIGNATURE OF DRILLER

1M-4-66WP

A dug well is approximately 33 feet east of Well #1. The well was constructed using concrete well tile that is 16 feet in diameter. The well's depth was measured to be about 13 feet.

The Village of Fair Haven recently constructed two observation wells on the property, labeled OW-1 and OW-2 on Figure 3. OW-1 is about 100 feet southeast of the Well #3 site, and this well is reported to have intersected the gravel aquifer. OW-2 did not encounter the aquifer.

One additional older test well is reported to exist some distance south of Well #2. HydroSource has not observed this well, but it would potentially be available for monitoring during the Well #3 test.

Well TW-1

HydroSource conducted a hydrogeologic evaluation for the Town, and then ran geophysical surveys to identify promising sites for an additional well. The work resulted in identification of several potential sites on the property, one of which became the site of Test Well TW-1. TW-1 is about 90 feet southwest of Well #1 and 235 feet northwest of Well #2 (Figure 3).

Test Well TW-1 was installed by Frey Well Drilling of Alden, New York, using a Foremost DR-12 dual-rotary rig. The well was completed with seven-inch-diameter casing and a six-inch-diameter screen as shown in Figure 6. A seven-inch-diameter casing was used in order to accommodate a six-inch-diameter submersible test pump, which was expected to allow testing of the well at a pumping rate of as much as 350 gpm.

The geophysical surveys used to site the test well indicated that sand and gravel might underlie a layer of finer-grained sand, silt, and clay lacustrine deposits. The objective of the test well installation was to test whether sand and gravel did indeed exist beneath this location, and whether it constituted a productive aquifer that could support development of an additional groundwater source for the Town.

The upper portion of the test well passed through approximately 14 feet of reddish-brown very fine sand, silt, and clay. Well-rounded, coarse sand and gravel with silt and fine sand was observed starting at a depth of approximately 14 feet and continuing to 49 feet. Airlifted water production gradually increased with depth as drilling proceeded past 14 feet. Site conditions did not permit accurate measurement of the well’s airlift yield, but a rough visual estimate of 100+ gpm airlift yield was consistently observed while drilling through the interval from approximately 30 to 49 feet in depth.

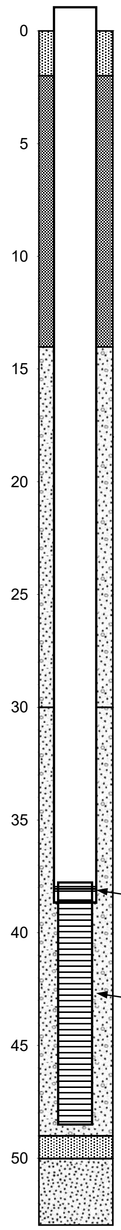
Sediment encountered at 49 feet consisted primarily of very fine sand, silt, and gravel. Airlift water production ceased at this depth. Red-tinted fine-grained sand, silt, and angular gravel consisting mainly of red sandstone clasts, was observed from 50 to 53 feet. Further drilling was discontinued at this depth because the geophysical surveys suggested a depth to bedrock of approximately 50 feet, and also because a layer of “red clay and gravel” was reported as immediately overlying “red sandstone” bedrock in a few nearby wells.

Figure 6 - Well TW-1 Log

Project: Sterling, NY
Well: TW-1
Completion date: 10/26/21
Well depth: 48.5 ft

Driller: Frey Well Drilling
Water level: 3.0 ft below ground

Graphic Log



Lithology

0-2: Reddish brown loam, silt, and FG sand.

2-14: Red-brown VFG sand, silt, clay. Loose.

14-30: CG gravel and sand, well rounded.

30-49: CG sand and gravel with some silt and FG sand. Gray-black with some reddish clasts. Well rounded. 100+ gpm airlift yield throughout.

K-packer.

38.5-48.5: 100-slot screen.

49-50: VFG sand, silt with gravel. More angular (till-like). Sample cements at bottom of bucket. No airlift water production.

50-53: Red-tinted VFG sandstone, silt, and angular gravel, clasts are >70% red sandstone.

NOTES: Drilled by advancement of 7-inch-diameter, using a dual-rotary rig. Set 10 feet (two 5-foot lengths welded together) of 100-slot stainless steel screen (5.675-inch diameter) in interval from 38.5 to 48.5 ft.

The seven-inch-diameter well casing was retracted to a depth of 49 feet, whereupon the borehole naturally backfilled to a depth of about 48.5 feet. An assembly consisting of two five-foot lengths of stainless steel, continuous-slot screen was telescoped to the bottom of the well. Drill rods were used to push the screen to the bottom, confirm the correct screen depth interval setting, and to hold the screen in place as the casing was retracted to expose the screen to the water-bearing gravel layer. The screen is 100-slot, and the screen assembly includes a K-packer at the top that forms a seal between the top of the screen and the inside of the casing, with a welded end plate on the bottom.

The well was airlift-developed for roughly 3.5 hours. The airlifted water was initially an opaque gray, but it gradually cleared.

Step Test - A step test was performed on Well TW-1 on October 27, 2021. The test consisted of four steps, each of them sixty minutes long, ranging from 100 to 350 gpm.

In addition to measuring water levels in TW-1 during the step test, water levels were also monitored in the dug well and Well #1. A transducer was used to monitor the dug well. The transducer was programmed to take readings at 15-minute intervals. The only opening into Well 1 was a monitoring tube with a diameter of three-fourths of an inch, too small to allow use of a transducer. However, the tube was large enough to allow use of a Solinst-style water level probe, and manual measurements were made once or twice during each step. It was not possible to measure water levels in Well #2.

Well #2 was operated on an as-needed basis to supply water to the system while Test Well TW-1 was drilled, developed, and step tested, and for several days thereafter. Given the closer proximity of Well #1 to the test well, that well was shut down throughout the drilling, test well development, and step-testing process to eliminate the risk that Well #1 would capture turbid water.

Water levels were measured manually in TW-1, using a Solinst probe inside a one-inch-diameter PVC measuring tube. The measurements were reported in terms of depth below the top of the tube, which was 4.2 feet above ground surface. During each of the rate steps, water levels were measured using a variable schedule, with measurements made once a minute at the start of each hour, and once every five minutes by the hour's end.

The step test on Well TW-1 began at 11:15 A.M. (Figure 7). The first step was run at 100 gpm, the second at 150 gpm. At the end of the second step it was concluded that the well was productive enough to justify increasing the rate increments from 50 gpm to 100 gpm, and the last two steps were thus run at 250 gpm and 350 gpm.

The water level in Well TW-1 was 7.2 feet below the measuring point just before the test started, or three feet below ground surface after accounting for the 4.2-foot stickup. Most of the drawdown associated with each step occurred during the first minute of the step, with the water level remaining generally stable for the remainder of each hour. By the end of the final step at 350 gpm, the TW-1 water level had declined to 18.31 feet, which amounts to drawdown of 11.11 feet.

Figure 7 - Well TW-1 Step Test

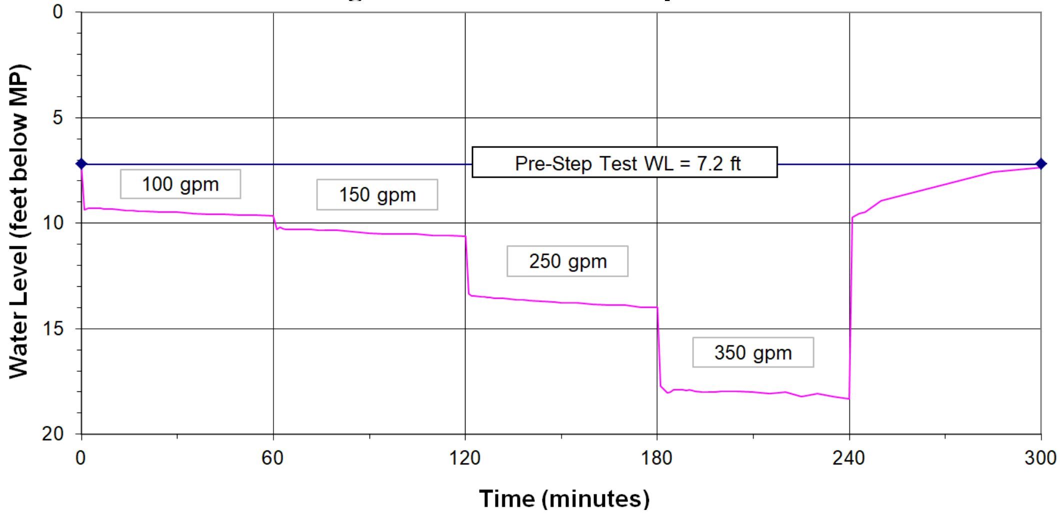
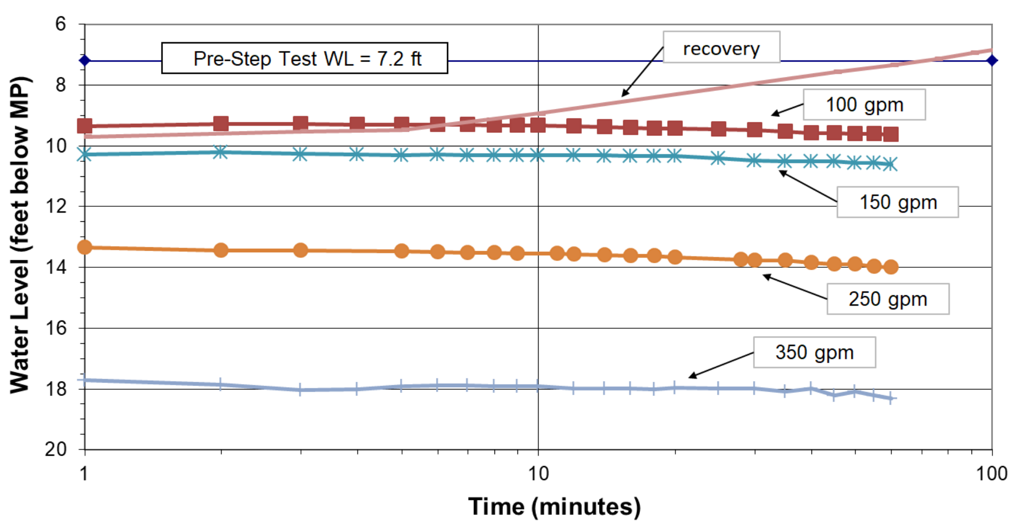


Figure 8 shows the same data as Figure 7, but using a logarithmic time axis, with time as measured from the start of each rate step for the pumping period, and from the start of recovery for recovery data. In logarithmic time, all of the rate steps show relatively minor rates of decline. Small high-frequency fluctuations in the pumping water level were observed to occur during the 350-gpm step. These are suspected to have been caused by surging action of the test pump, presumably because of the limited annular space between the pump motor and well casing, which may have acted to limit flow from the well's screened interval to the pump intake above the motor. As such, it is possible that a small proportion of the drawdown observed may be a result of head loss that wouldn't occur in a larger-diameter well that provided sufficient room for an appropriately sized production pump.

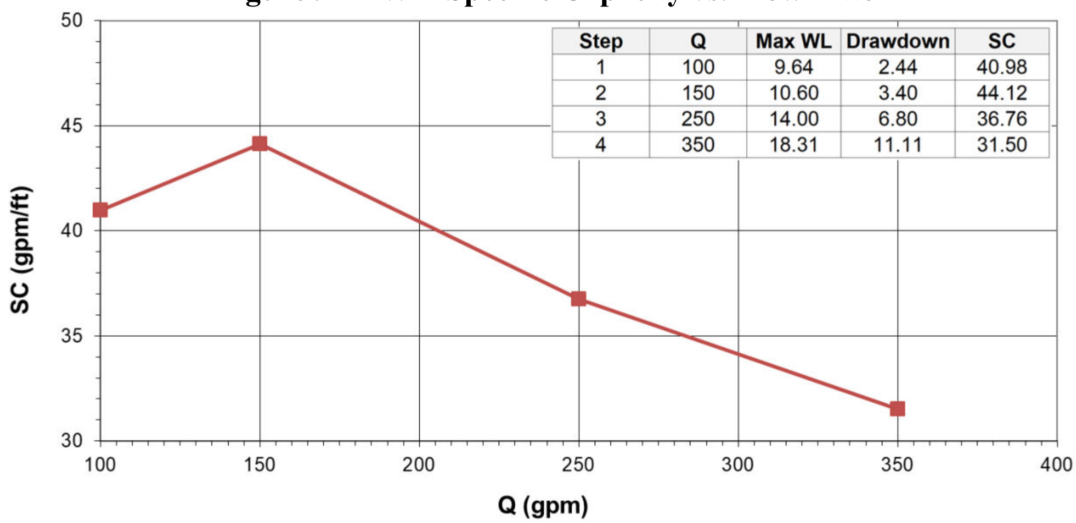
Figure 8 - TW-1 Step Test Semilog Graph



It will be noted that the curve showing recovery begins on a near-horizontal trend, but then steepens after about five minutes. The steeper slope of the recovery curve persists with time, until the recovery water level rises to a level higher than the pre-test water level after about 80 minutes of recovery time. The point where the steeper recovery curve begins probably marks the end of a Well #2 pumping cycle (and this is consistent with the Well #2 pumping cycle pattern seen in the days after the test; see Figure 12). After Well #2 stopped pumping, the water table was then recovering from the combined effects of cessation of pumping in both TW-1 and Well #2. The TW-1 water level recovered to a level higher than the level measured at the beginning of the step test presumably because at the start of the step test the aquifer had not completely recovered from prior Well #2 pumping, or from airlift development of the test well.

Figure 9 shows the variation of specific capacity with changing flow rate. The first point to make is that the range of specific capacities shown here (31.50 gpm/ft to 44.12 gpm/ft) suggests that the well and aquifer are quite productive. Aside from that, for the final three steps specific capacity varies inversely with flow rate, showing the predictable decreasing efficiency of the well with increasing pumping rate.

Figure 9 - TW-1 Specific Capacity vs. Flow Rate



Step	Q	Max WL	Drawdown	SC
1	100	9.64	2.44	40.98
2	150	10.60	3.40	44.12
3	250	14.00	6.80	36.76
4	350	18.31	11.11	31.50

Figure 10 shows water levels in Well #1. The water level was rising during the two hours preceding the start of the step test (rising by about 0.3 feet), recovering from airlifting of the test well that took place during the TW-1 well development process that concluded about two hours before the step test began. The water level in Well #1 was 5.31 feet below the measuring point, or about 3.3 feet below ground, a few minutes before the step test started. Although it was not feasible to measure water levels in Well #1 frequently enough to precisely define how the well responded to each TW-1 rate step, Well #1 showed drawdown that was proportionate to the TW-1 rate steps. By the end of the test, the water level had fallen to 8.31 feet, for drawdown of three feet.

Figure 10 - Well #1 Water Levels

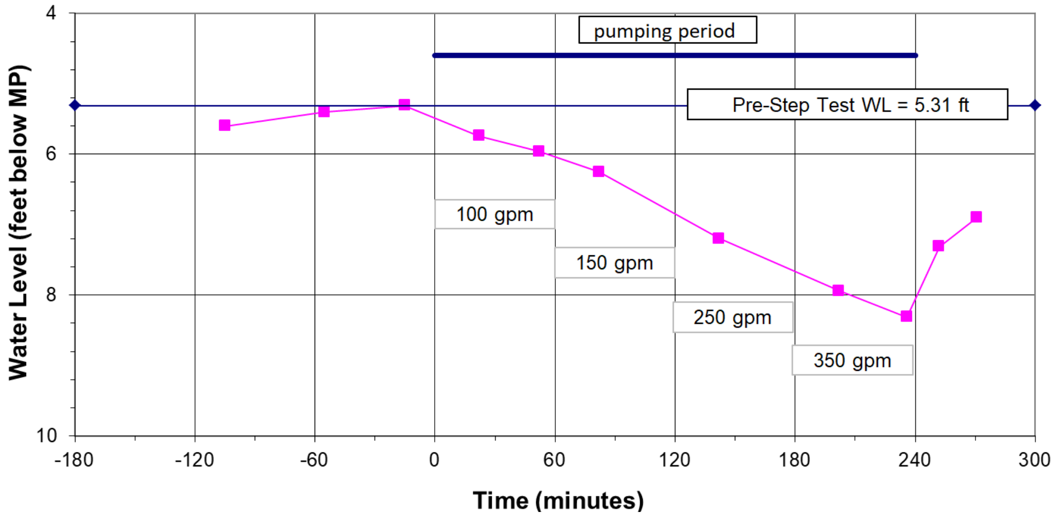
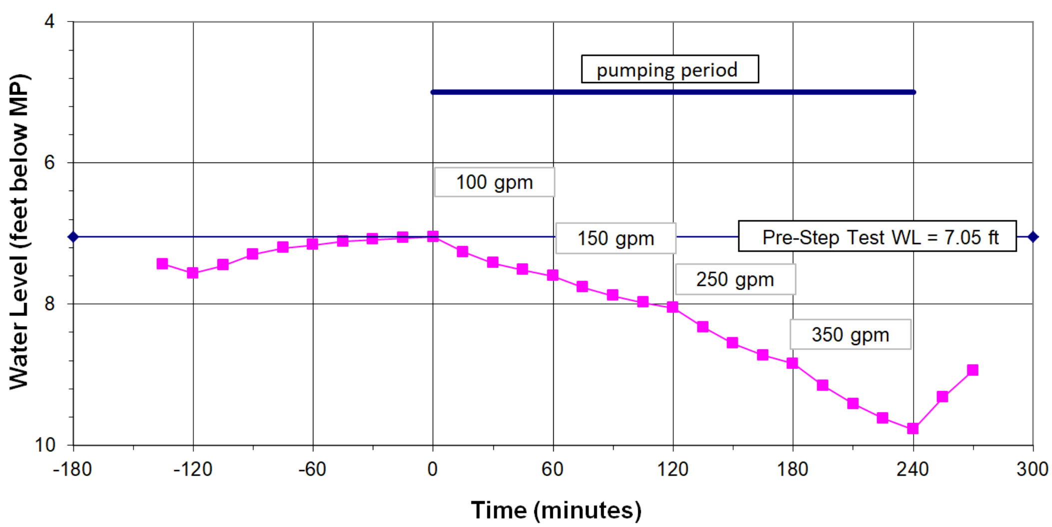


Figure 11 shows water levels in the dug well. As was seen in Well #1, the dug well water level was rising during the two hours preceding the start of the step test. The level rose by about 0.4 feet. The water level was 7.05 feet below the dug well measuring point (a point on the edge of a four-inch diameter PVC vent that extends through the concrete well tile cap; the PVC vent extends approximately 4.2 feet above ground), or about 2.85 feet below ground, just prior to the start of the TW-1 step test. By the end of the test, the water level in the dug well had drawn down 2.72 feet.

Figure 11 - Dug Well Water Levels



A pressure transducer was used to continue measuring water levels in TW-1 for several days after the step test ended. Figure 12 shows TW-1 water levels for the period beginning at 11:15 on October 27 (the start of the step test) through 11:15 on November 1.

The transducer water levels indicate that five complete cycles of pumping and recovery occurred in Well #2 during the period shown in Figure 12. The associated data is reported in Table 1. The average length of the five pumping periods was 12.7 hours, and the average time between pumping periods was about 10 hours. Pumping of Well #2 produced average drawdown of slightly more than one foot in TW-1, and the recovery amount between each pumping cycle was about the same.

Figure 12 - Well TW-1 Water Levels for Days Following Step Test

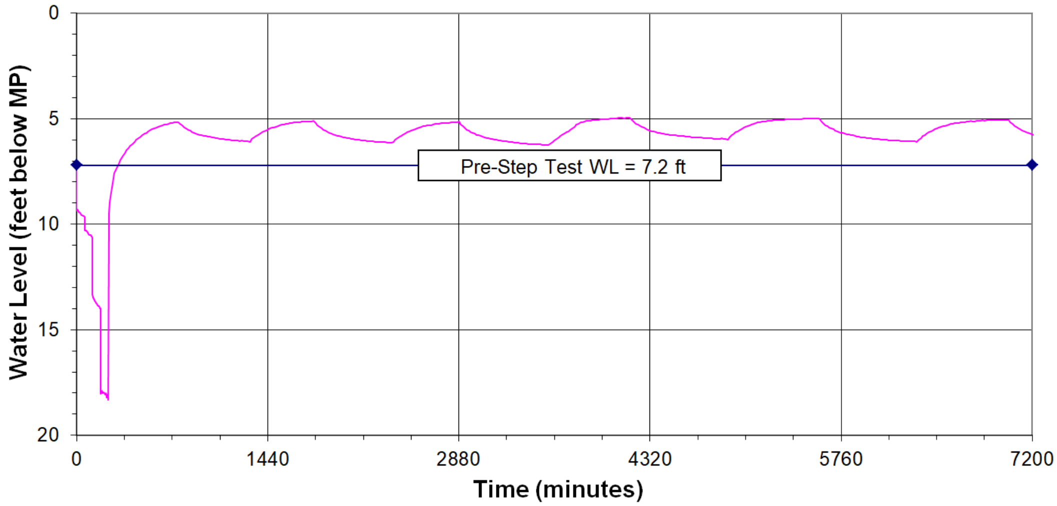


Table 1 - Well #2 Pumping Events, TW-1 Recovery Period

Pump On		WL	Pump Off		WL	Pumping Duration	Drawdown	Recovery Duration	Recovery Amount
		ft			ft	hrs	ft	hrs	ft
10/27/21	15:00	5.16	10/28/21	9:00	6.09	18.00	0.93	8.00	0.98
10/28/21	17:00	5.11	10/29/21	2:45	6.13	9.75	1.02	8.50	0.98
10/29/21	11:15	5.15	10/29/21	22:30	6.24	11.25	1.09	10.25	1.29
10/30/21	8:45	4.95	10/30/21	21:00	5.98	12.25	1.03	11.50	0.98
10/31/21	8:30	5.00	10/31/21	20:45	6.09	12.25	1.09	11.50	1.04

Following the step test, the water level in Well TW-1 rose to a depth of about five feet, or about 2.2 feet higher than the water level that was measured at the start of the test. As noted earlier, this presumably occurred because the water level at the start of the step test had not completely recovered from the effects of extractions from the aquifer during airlift development of the test well, or from the most recent Well #2 pumping event.

Wetlands and Floodplain

Figure 13 is a wetlands map, obtained from the National Wetlands Inventory "Wetlands Mapper" web site. The wellfield is bordered on its east side by a band of seasonally flooded wetlands along the course of the unnamed stream mentioned above.

The nearest 100-year floodplain is 3,300 feet to the north, along Sterling Creek just before the point where the creek reaches Lake Ontario. The Flood Insurance Rate Map for the area shows the elevation of the 100-year flood to be 249 feet at that point. The ground surface elevation at the wellfield is about 270 feet.

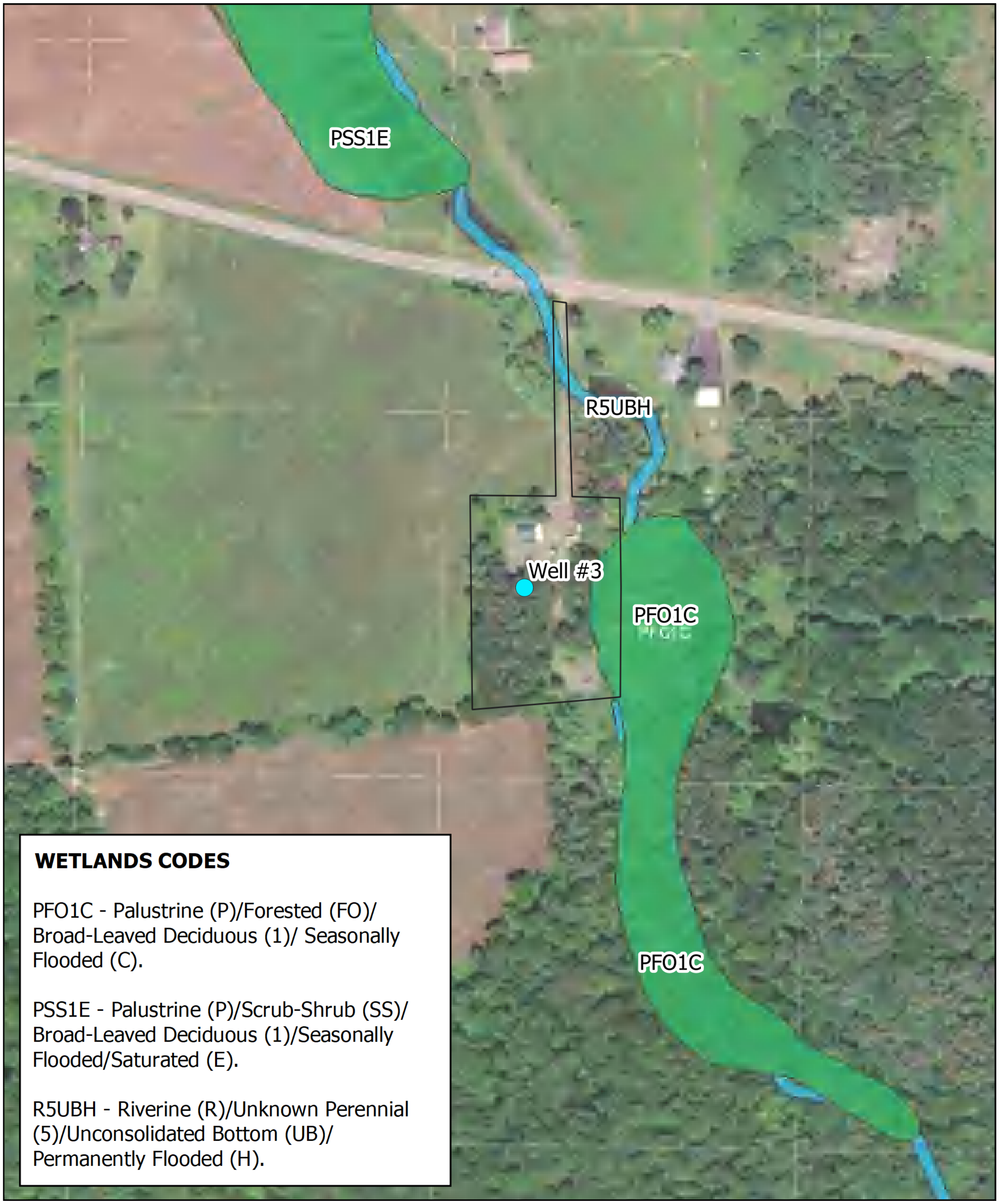
Recharge

A standard approach to assessing the sustainability of a proposed groundwater extraction is to compare the planned pumping rate to the amount of recharge from precipitation arriving in the upgradient watershed area. Figure 14 shows the outline of the topographically defined watershed upgradient from the wellfield. The outline was defined by making the initial assumption that the proposed withdrawal would have a cone of depression with a radius of 1,000 feet. The watershed outline was then drawn to take in all of the area topographically upgradient from that radius, extending to the enclosing ridge lines. The resulting outline encloses a total area of about 400 acres.

Precipitation in the Sterling area averages 40 inches per year, but only a fraction of the precipitation arriving in a watershed is available for aquifer recharge. The amount of precipitation that infiltrates the soil and enters underlying aquifers varies depending on the surficial sediment type. Based on research on infiltration rates in the northeastern U. S., the rate of infiltration into permeable glacial sediments (like the stratified sand and gravel of Figure 2) is around 23 inches per year. Sediments with lower permeability have lower infiltration rates. For the areas underlain by till and glacial lakebed silt and clay, we assume average annual recharge of 9 inches per year.

About 43% of the watershed area outlined in Figure 14 is underlain by sand and gravel deposits, and the rest is underlain by till, or by glacial lakebed silt and clay. Applying the recharge rates discussed above to these areas produces estimated recharge of 207 gpm for the area underlain by sand and gravel, and 106 gpm for areas underlain by other materials. The total estimated recharge rate for the topographically defined watershed is 313 gpm.

It should be kept in mind that the generalized recharge rates estimated for the different surficial material types cannot be considered precisely definitive of conditions in a specific watershed. Nonetheless, use of these values is considered to produce an approximation of watershed-scale recharge amounts that is sufficiently accurate to be useful as a factor in judging the feasibility of a proposed aquifer extraction.



Source: National Wetlands Inventory online Wetlands Mapper.

LEGEND

Well #3

Property Line

0 300 ft

N

Figure 13 - Wetlands

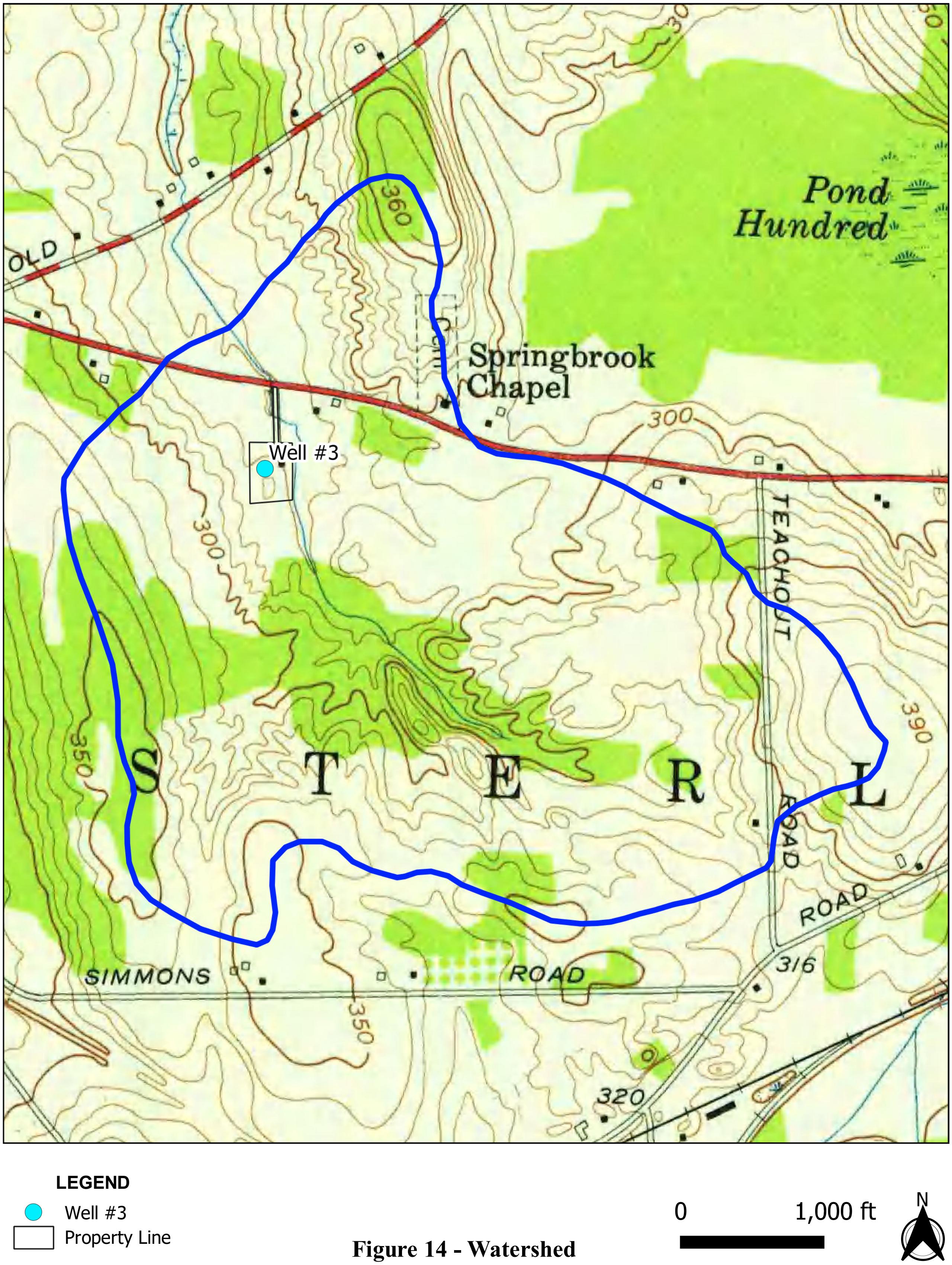


Figure 14 - Watershed

Note that the recharge calculations described above were applied to a watershed area upgradient from the wellfield that was defined based on surface topography. In fact, based on what we know of the local geology, the aquifer tapped by the Town/Village wellfield may receive additional groundwater from regions beyond the edge of the topographically defined watershed.

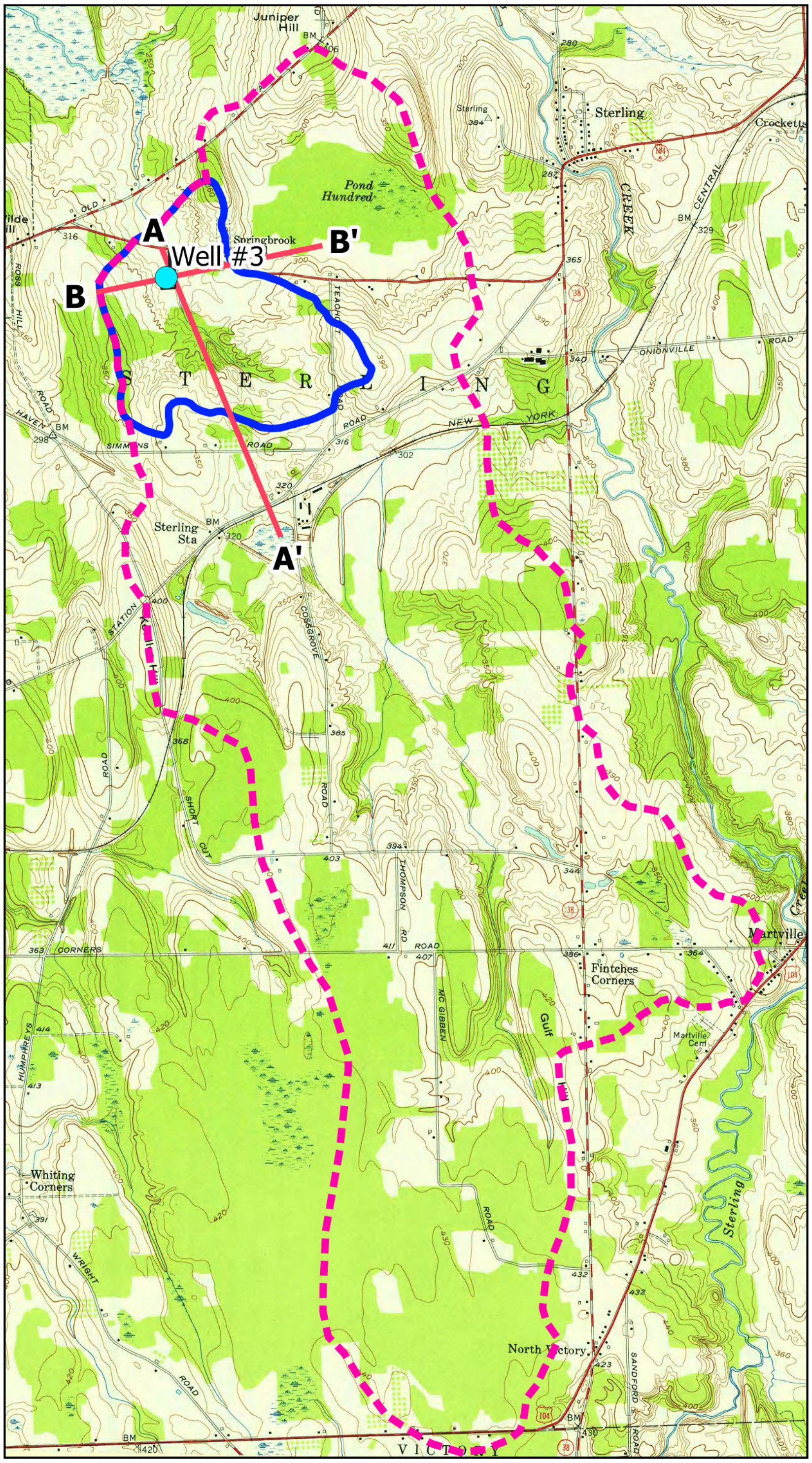
The area that is capable of contributing water to the wellfield may be more a function of the shape of the bedrock surface than of the ground surface. This is likely to be especially true in this area where bedrock consists of flatlying Paleozoic sedimentary rocks. Although glacial erosion is likely to have produced local overdeepening of the bedrock surface, over much of the area the shape of the bedrock surface may be dominantly planar (parallel to the near-horizontal bedding planes), and table-like. It thus may bear only a limited relationship to surface topography.

Figure 15 is a map of a larger watershed area. The map shows the larger area outlined with a magenta dotted line, along with the smaller topographically defined watershed outlined in solid blue. The larger area is the area from which the wellfield might receive recharge assuming that the shape of the bedrock surface is permissive and that relatively permeable sand and gravel deposits extend continuously from the wellfield beyond the southern and eastern boundaries of the smaller topographically defined watershed.

Figures 16 is a cross section that passes through Well #3 and extends beyond the south edge of the topographically defined watershed into the adjacent watershed. Figure 17 is a cross section doing the same thing to the east. The lines of both sections are shown on Figure 15. Both sections have vertical exaggeration of 10:1.

Surface topography for both sections is derived from a digital elevation model with a resolution of one meter, obtained from the New York state government GIS site (GIS.NY.GOV). The sections show areas underlain by lakebed silt and clay, sand and gravel, and till. The surface distribution of the sediment types is as shown in Figure 2. The contacts shown between different lithologies should be considered schematic, because the only stratigraphic data derived from drilling comes from the wellfield, where the base of the lakebed sediments was observed at a depth of 14 feet in TW-1, and the bedrock surface was encountered at about 50 feet.

The sections have been drawn using the assumption that the maximum thickness of lakebed sediments is probably not much greater than the thickness seen at TW-1. Similarly, the depth to bedrock is known with certainty only at the wellfield, but the assumption is made that the bedrock surface is relatively flat in this area of undeformed Paleozoic sedimentary rocks.



LEGEND

- Well #3
- Expanded Watershed
- Topographic Watershed
- Cross Sections

0 4,000 ft

N

Figure 15 - Expanded Watershed

Figure 16 - Section A-A'

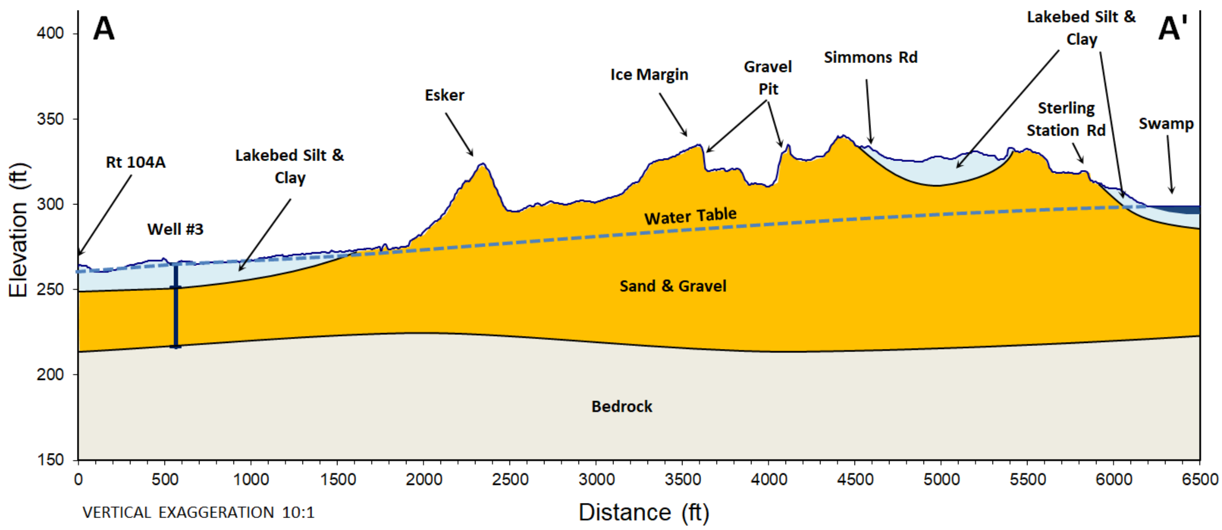
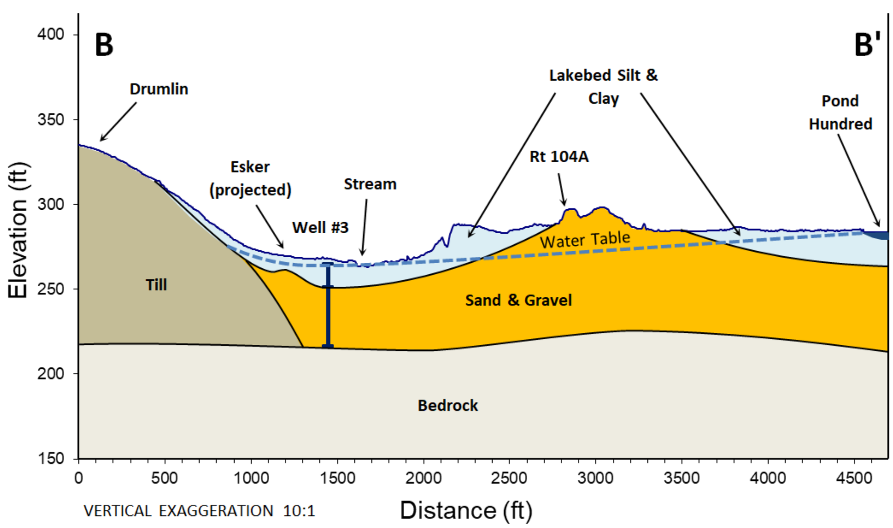


Figure 17 - Section B-B'



The inferred shape of the water table is shown in both sections. In Section A-A', it can be seen that the water level in the swamp at the south end of the section is nearly 40 feet higher than the level at the wellfield. The water table is shown as sloping smoothly between the swamp and the wellfield, which seems reasonable in the absence of evidence to the contrary. If there are no hydraulic obstructions between these points, it would appear that the wellfield would be capable of capturing water from south of the topographically defined watershed. This would be true even though surface water drainage from the southern area is through a small stream flowing east. This stream is a tributary to Sterling Creek. It flows into the creek just south of the point where the creek is crossed by the railroad tracks (Figure 15).

Similarly, in Section B-B', the elevation of Pond Hundred at the east side of the section is about 20 feet higher than the wellfield water level. If there are no hydraulic impediments to flow between the two points, it is reasonable to expect that pumping of wells in the Town/Village wellfield could result in capture of groundwater from beyond the east edge of the topographically defined watershed.

The larger watershed area of Figure 15 takes in a total of 4,439 acres. About nine percent is mapped as sand and gravel, with the balance being lakebed sediments, till, or swamp deposits. If we assume that recharge averages 23 inches per year in the areas of sand and gravel, and 9 inches per year in the other sediment categories, estimated total recharge for the larger watershed would be 2,338 gpm.

Not all of the precipitation recharge arriving in the larger watershed area is susceptible to being captured by the wellfield. Clearly, water will escape from the system toward Sterling Creek to the east, both via the established surface water drainage, and by flow through the sediments in the direction of the creek. However, based on what is known of the surficial geology, it is reasonable to expect that the wellfield may capture groundwater from an area larger than the confines of the topographically defined watershed.

Contaminant Threats

A comprehensive contaminant source inventory was not conducted as part of this project. Such a task was not considered necessary in view of the fact that the wellfield has functioned as a public water supply for many years without experiencing water contamination problems.

A virtual survey was done of the area surrounding the wellfield using Google Earth and Google Maps. Few land uses were observed that would be expected to be associated with a significant risk of groundwater contamination. Land within a few thousand feet of the wellfield largely consists of fields under cultivation or wood lots. A few residences are distributed along Route 104A, and a trailer park is about a half-mile to the east.

Most of the land in the upgradient watershed is field or forest. One apparently active gravel pit can be seen about a half-mile to the southeast, and at least two other areas that look like they were mined for gravel in the past can be seen nearby.

LARGE-DIAMETER WELL SPECIFICATIONS

Figure 18 is a provisional well construction diagram. The sieve analysis done on the Test Well TW-1 samples indicates that a naturally developed well should be an appropriate design at this location, and that a large-diameter well may be outfitted with perhaps a 10-foot to 15-foot length of screen. Based on observations made at TW-1, it is expected that it should be possible to use a screen with a slot size of at least 130, spanning the depth interval from roughly 35 to 50 feet below ground.

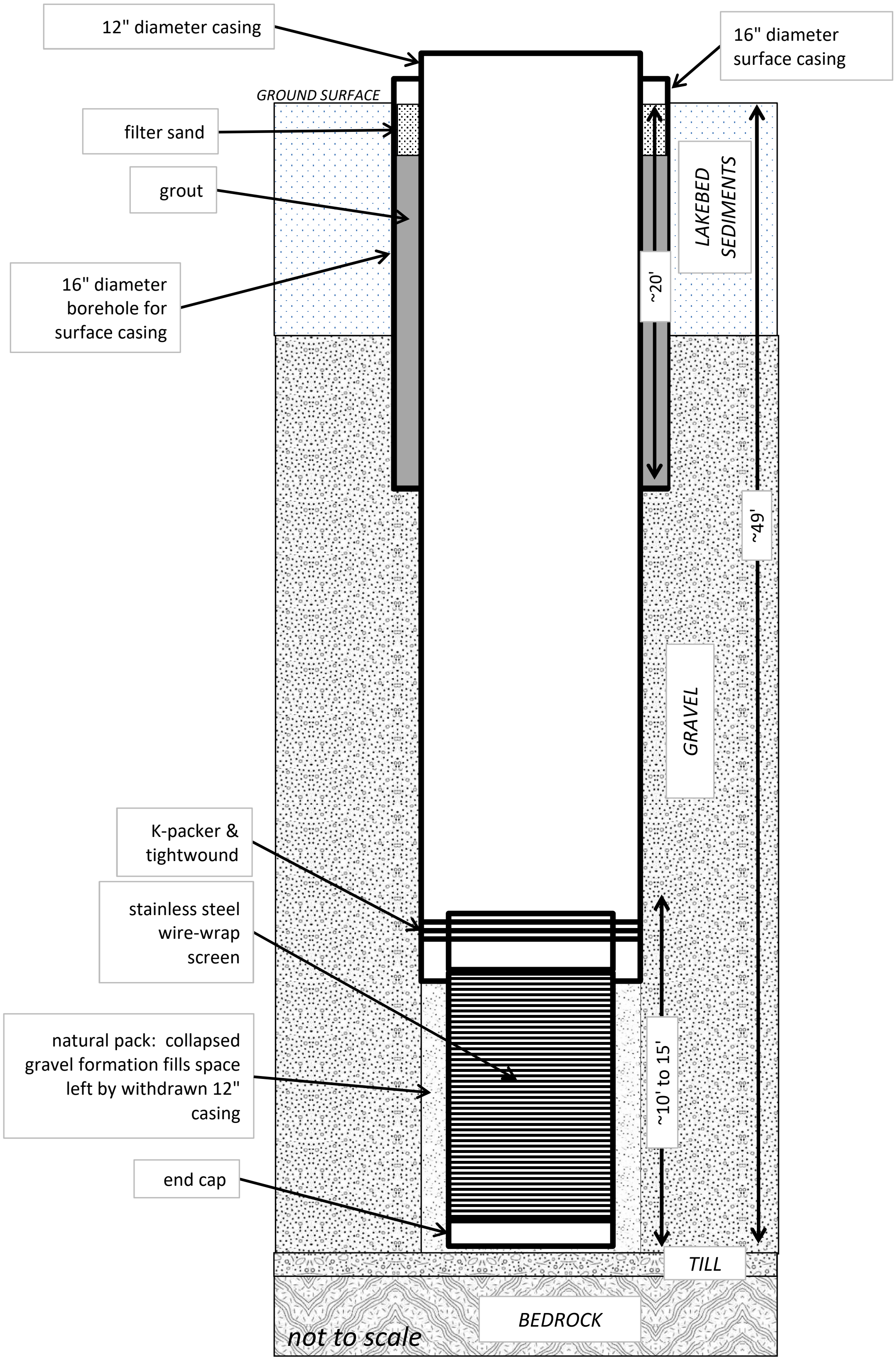


Figure 18 - Proposed Preliminary Well Design and Schematic Construction Diagram

Well construction plans involve using a 12-inch-(telescoping) diameter screen assembly, telescoped inside 12-inch-(pipe size) diameter casing, within a length of 16-inch-diameter surface casing.

Following installation of the well screen, the well will be developed to remove sediment that is fine enough to pass through the screen, and to optimize the well's efficiency. Development will be done using the pump-and-surge method. The development process can be expected to take a week or more. The well's specific capacity will be tracked over the course of the development process, and observations will be made of the amount of sediment carried in the discharge water. Care will be taken to ensure that silt-laden water discharged during the process does not reach the adjacent wetlands. Development will be considered substantially complete when the well's specific capacity is no longer improving, and when the rate of sediment production reaches acceptable levels.

PUMPING TEST

Well #3 will be subjected to a 72-hour constant rate pumping test. The test will include a minimum 14-day pre-pumping ambient conditions water level monitoring period, and post-pumping recovery monitoring as described below.

The target rate for the 72-hour test could be chosen based on the results of a step test carried out before the constant rate test. However, a step test may not be necessary. The testing of Well TW-1 that has already been done suggests that a large-diameter well nearby should be capable of delivering 200 gpm without difficulty, and if this is confirmed by observations made during development of Well #3, a decision may be made to go forward with a 72-hour test of the new well at 200 gpm without first conducting a step test.

Wellhead Setup

A temporary submersible pump will be set at a depth slightly above the top of the screen assembly. A plastic monitoring tube will be installed in the well, terminating just above the pump. The wellhead setup will include a gate valve, a sample spigot, and discharge line adequate to reach the discharge point. The discharge line will terminate with an orifice weir whose measurement range includes the expected target rate for the pumping test. The ground surface at the point where the discharge reaches the ground will be lined with plastic or plywood to prevent erosion.

Pumping Test Specifications

The constant rate test will be scheduled to start on a Monday morning. This will allow collection of water samples for lab analysis on a Thursday, so that they can reach the lab before the weekend.

Table 2 is a list of points that are expected to be monitored during the Well #3 constant rate pumping test, along with their distances from the pumping well, and a letter code indicating the monitoring schedule. Distances in the tables are approximate. Table 3 explains the meaning of the letter codes in Table 2. Figure 19 shows the locations of the points to be monitored. The unnamed test well reported to be south of Well #2 is not shown on Figure 19 because it has not been precisely located. It was not possible to monitor water levels in Well #2 during the Well TW-1 step test, but it is expected that with minor modifications the well can be set up to permit monitoring with a transducer during the Well #3 test. Water levels collected using pressure transducers will be corrected for changes in atmospheric pressure using barometric pressure data gathered using a barometric transducer set up at the site.

Table 2 - Monitoring Points

Point	Distance (ft)	Monitoring Schedule
Wells		
Well #3	-	A
TW-1	15	B
Well #1	90	B
OW-1	101	B
Dug Well	112*	B
Well #2	228	B
Staff Gage		
SG-1	230	C
Discharge		
Discharge point	235	-

*Dug well distance is to nearest edge of concrete tile

Table 3 - Monitoring Schedule

Schedule	Methods/Monitoring Frequency
A	Ambient conditions period: transducer, 15 minute intervals.
	Pumping period: manual; once a minute through 10 minutes; once every two minutes through 20 minutes; once every five minutes through 50 minutes; once every 10 minutes through 120 minutes; hourly thereafter.
	Recovery period: manual first two hours, and same schedule as pumping period; thereafter, transducer, 15-minute intervals.
B	Ambient conditions period: transducer, 15 minute intervals.
	Pumping period: transducer; once every minute through 10 minutes; once every two minutes through 20 minutes; once every 5 minutes through 50 minutes; 15-minute intervals thereafter.
	Recovery period: same as pumping period.
C	Ambient conditions period: manual; first day, last day.
	Pumping period: manual; twice a day.
	Recovery period: manual; first day and last day.

Figure 19 - Monitoring Points

Water levels are to be measured in all of the known wells on the wellfield property. This includes Well #3, Well #1, Well #2, the dug well, and TW-1. The test well reported to be south of Well #2 might be monitored if investigation shows that monitoring is feasible and worthwhile. Surface water levels will be monitored at a staff gage (SG-1) installed on the shore of the pond east of Well #2.

Water pumped during the test will be discharged to the ground surface a short distance from the stream, about 230 feet northeast of Well #1. Our assumption is that the lacustrine sediments overlying the site minimize the potential that the discharged water will be rapidly recycled back to the aquifer. The distance between the discharge point and SG-1 is also expected to prevent the ability of the discharge to influence water levels at the staff gage location.

A rain gage will be set up at the wellfield. Precipitation data collected at the gage will be supplemented by data from a local weather station.

Potential Offsite Well Monitoring

All of the aquifer monitoring points listed in Table 2 are on the wellfield property, and are less than 300 feet from Well #3. The possibility of monitoring a selection of offsite wells at greater distance has been discussed, since this would allow a more complete characterization of the aquifer's response to pumping of Well #3.

A virtual survey was done using Google Earth to identify nearby properties that are likely to have wells that might be available for monitoring. Generally, these are properties occupied by single-family residences. Figure 20 shows the locations where wells were inferred to exist. Note that the existence of wells on these properties has not been confirmed, and the actual locations of the wells have not been determined. Ownership information was obtained from the Cayuga County tax map web site, and is shown in Table 4. The table includes the property identification number (corresponding to the labels on Figure 20), owner name, address, and the distance between the inferred well and Well #3. Note that it has been assumed that a single well serves the roughly dozen residences at the Sterling Pines Community, but this is only an assumption.

Table 4 - Inferred Offsite Wells

Tax ID	Owner	Address	Distance
9.00-1-32.111	Sterling Spring Water LLC	900 State Rt 104A	500
9.00-1-32.121	Sterling Spring Water LLC	883 State Rt 104 A	1200
9.00-1-42	Sterling Pines Community	974 State Rt 104A	2100
9.00-1-43.2	Guess, Delwin & Cassandra	963 State Rt 104A	1650
9.00-1-44.1	Sweeting, Donald	832 State Rt 104A	1425
9.00-1-44.2	Smith, Gary & Linda	856 State Rt 104A	1120
12.00-1-13.3	Skinner, Joshua	1010 Simmons Rd	4000
12.00-1-5.121	Deferio, Jason	986 Simmons Rd	3800
12.00-1-5.2	Stone, Steven & Cynthia	937 Simmons Rd	3600
12.00-1-6.3	Green, Gregory, & Barbara Malinowski	989 Simmons Rd	3700
12.00-1-7.123	Leaveck Family Trust; Katherine Leaveck	14401 Teachout Rd	4700

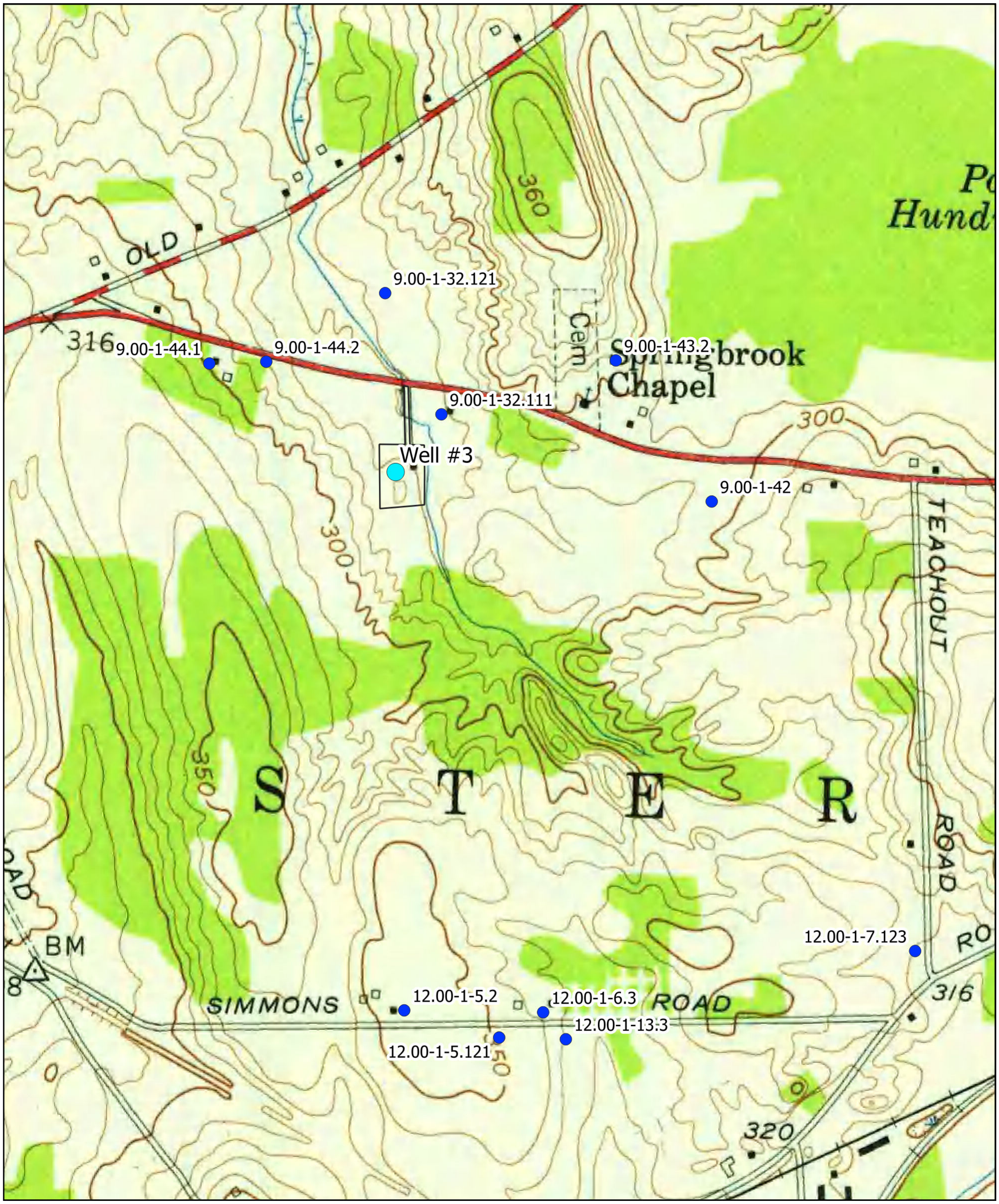


Figure 20 - Inferred Offsite Wells

The Town might consider monitoring a subset of these wells. However, it should be kept in mind that only one of them is less than 1,000 feet from Well #3, and it is not clear that pumping Well #3 at 200 gpm would produce detectable impacts at the others. Also, it should be noted that the region where additional aquifer monitoring points might be most helpful would be upgradient from the wellfield, to the south and southeast, in the direction of Simmons Road and Teachout Road. The closest wells in this area are all several thousand feet away, and unlikely to register impacts from Well #3 pumping. Steve Winkley of New York Rural Water is reported to have information on some local wells, and we would expect to consult with him in the process of assessing likely candidates for monitoring.

Step Test

If a step test is warranted, the test will consist of four to five one-hour rate steps. The range of flow rates, and the rate increments, will be determined after well development has been completed and it is possible to roughly estimate the well's potential maximum yield. The step test results will be used to choose the flow rate adopted for the 72-hour constant rate test. The step test will also be used to shake down the wellhead setup prior to the start of the 72-hour test.

Monitoring Period Schedule

The monitoring period will consist of a 14-day ambient conditions period preceding the constant rate test, the 72-hour constant rate pumping period, and a recovery monitoring period lasting three days or until substantially complete recovery has been achieved in the pumping well.

Ongoing Use of Town/Village Wellfield

A complication associated with testing Well #3 is that it will not be possible to stop using the existing Town/Village supply wells during the monitoring period. However, observations made during the testing of TW-1 suggest that it should be possible to adequately account for the effects of ongoing pumping of the existing wells. This will be done by making adjustments to the monitoring to be carried out during the ambient-conditions monitoring period. The ambient-conditions monitoring period will be expanded to two weeks, a week longer than the period's customary duration.

During the first week, Well #1 will be used to supply both the Town and Village distribution systems, and Well #2 will be idle. During the second week, Well #2 will be operated, and Well #1 will be idle. In each case, the start and stop time of each pumping event will be recorded, along with the total volume pumped during the event. This will require manual operation of the pumps, so that the operator can record flow meter totalizer values both at the beginning and end of each pumping event, in addition to pump start/stop times.

Water levels will be monitored in all wells in the wellfield throughout the period. This will allow determination of the current specific capacity of both existing wells, along with determination of how much drawdown pumping of each well independently produces at Well #3 under normal operational conditions. After this information has been generated, it will be used to support an assessment of interference among the wells using standard analytical methods applicable to porous-medium aquifers.

After the ambient-conditions period, during the 72-hour test of Well #3, water for the Town and Village distribution systems will be produced exclusively by Well #2, because it is further from Well #3 than Well #1. Well #1 will not be operated during the testing period. Well #2 will continue to be operated manually. Pumping of Well #2 will be timed to ensure that the well can be left idle for a period beginning at least a few hours before the start of the Well #3 constant rate test (long enough for substantial recovery after the most recent Well #2 pumping event), and continuing for as long as possible after the start of the test. The same thing will be done near the end of the 72-hour test. Well #2 will be pumped in a manner that allows it to be shut down long enough before the end of the test so that the aquifer could substantially recover from the most recent Well #2 pumping event before the Well #3 recovery period begins. As was done in the ambient-conditions period, the start time, stop time, and volume pumped will be recorded for each Well #2 pumping event. The regimen described here should allow generation of the information needed to factor out the effects of Well #2 pumping from aquifer impacts caused by Well #3.

Water Quality

Water quality samples for lab analysis of the NYSDOH Part 5 parameter list will be taken in the final hours of the pumping period. The parameter list will include PFAS parameters and 1,4-dioxane. Waivers are requested for analysis of parameters that commonly are waived by NYSDOH (e.g., endothall, glyphosate, diquat, dioxin).

The well site is a little more than 200 feet from the stream to the east. The low-permeability layer of lakebed silt and clay that caps the gravel aquifer makes it seem unlikely that the well would be susceptible to surface water influence, and the absence of GWUDI problems in the existing supply wells leads to the same conclusion. Nonetheless, GWUDI testing will be carried out. An MPA test will be run during the final 24 hours of the pumping period. Also, samples will be collected from the stream near SG-1, and from the Well #3 discharge stream, three times a day. The samples will be analyzed for pH, total dissolved solids, and temperature. These results will be used to assess correlation between surface water and groundwater characteristics.

FINAL HYDROGEOLOGICAL REPORT

A final hydrogeological report on the new well will be submitted to NYSDOH and NYSDEC following completion of the 72-hour pumping test. The report will include the following:

- documentation of the construction of Well #3, including a schematic as-built construction diagram;
- description of well development;
- documentation of the 72-hour pumping test;
- analysis of test results;
- qualitative assessment of well interference;
- opinion of safe yield;

- water quality summary, with lab reports;
- opinions, as appropriate, on pumping schedules, routine specific capacity monitoring, periodic redevelopment, and abandonment of test wells.

The resultant data will be analyzed using standard hydrogeologic procedures for estimating safe, sustainable pumping yield, applicable aquifer parameters, and potential environmental impacts from pumping, if any, on other water resources, including wetlands and surface water bodies, where applicable. The report will include an estimate of the well's Zone of Influence (ZOI), Zone of Contribution (ZOC), and calculated aquifer parameters transmissivity and storativity. It will include an assessment, to the extent possible based on the available data, of recharge potential, and the likelihood that the wellfield is capturing groundwater from beyond the edge of the topographically defined watershed area.

The hydrogeological report will also include recommendations as to production pump depth setting for the new well based upon well hydraulics, and projected pumping water level under sustained pumping operation. The report will supply hydrogeologic information to support the other engineering and design items of the Water Withdrawal Permit Application to the State. We assume that the engineering items of the Water Supply Application and any and all other engineering-related items, as well as other design, or construction-related work, will be the responsibility of the Town and its consulting engineer.

REFERENCES

Bird, B. C., and A. L. Kozlowski, 2015. Surficial Geology of the Fair Haven 7.5-Minute Quadrangle, Cayuga and Wayne Counties, New York. Map & Chart Series 83, New York State Museum.

FEMA, August 2, 2007, Flood Insurance Rate Map.

Isachsen, Y.W., & D.W. Fisher, 1970. Geological Map of New York - Finger Lakes Sheet. Map & Chart Series 15, New York State Museum.

National Wetlands Inventory Wetlands Mapper; queried on 5/3/22.

U. S. Geological Survey, 2020. Mineral Resources Online Spatial Data database (mrdata.usgs.gov).