Appendix A-12
Groundwater Monitoring Analysis of Nitrogen Capture

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THE HILLS
EAST QUOGUE GOLF RESORT
EAST QUOGUE, SOUTHAMPTON, NEW YORK

Groundwater Modeling Analysis of Nitrogen Capture

Appendix to the

Draft Environmental Impact Statement

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The Hills – Groundwater Modeling Analysis of Nitrogen Capture

A three-dimensional (3D) sub-regional numerical groundwater model was developed to analyze the placement of a new irrigation well for The Hills in East Quogue golf resort. The purpose of the modeling was to optimize the location of the well with respect to intercepting nitrogen laden groundwater originating from farm fields just to the west of the proposed golf resort. Optimization was from both horizontal and vertical standpoints with the idea being to capture as much nitrogen contaminated groundwater as possible to help reduce the amount of nitrogen reaching Weesuck Creek.

The model was developed using Groundwater Vistas Version 6.78 by Environmental Simulations, Inc. which is a finite difference method (FDM) based software program that utilizes the United States Geological Survey (USGS) MODFLOW2000 modeling code. The model was constructed using the Suffolk County groundwater model which was originally developed for the County by CDM in 2003 using a proprietary software and modeling code and then later converted to a MODFLOW version and made publicly available. The publicly available regional model was used as the basis for construction of the sub-regional model which essentially was a grid spacing refinement from 4,300 feet to 250 feet in the area of study (northern boundary roughly Sunrise Highway, eastern boundary roughly Tiana Bay, southern boundary Shinnecock Bay and the western boundary roughly the eastern end of Gabreski Airport). The grid refinement was necessary for a higher localized degree of accuracy with regards to modeling well capture zones and plotting particle trajectories. **Figure 1** below depicts the sub-regional model study area with respect to the eastern end of Long Island (study area indicated by magenta colored rectangular shaped area in the lower left).

Figure 1 – Sub-Regional Model Location

Sub-regional model boundary conditions were created using constant head conditions at Weesuck Creek, Tiana and Shinnecock Bays and general head conditions along parts of the northern and western boundaries which approximates the local groundwater divide. The model was constructed vertically in three layers to represent the Upper Glacial aquifer (top layer), the Magothy aquifer (middle layer) and the Raritan Clay layer (bottom layer). Hydrogeologic properties, boundary conditions and other model inputs (i.e., recharge values) were imported from the original regional Suffolk County model and verified using available published USGS documents. Additionally, well pumping rates for local high capacity municipal supply wells were obtained from the Suffolk County Water Authority (SCWA) and input into the model as well. The sub-regional model was calibrated using USGS groundwater elevation data from 1995, similar to the regional Suffolk County model.

The calibration process involved creating calibration targets using USGS monitoring well water level data at various locations and depths across the study area. Sensitivity analyses were carried out to assist in adjusting aquifer parameters and model inputs to achieve an acceptable level of calibration. Automated calibration procedures were also employed (Parameter Estimation or PEST) to aid and speed the process. Recharge and hydraulic conductivities were found to be the most sensitive and critical parameters with regards to model calibration. These values were optimized to achieve the highest degree of calibration for the model (i.e., minimize the difference between the documented water levels at the calibration targets and the model predicted water levels at those same locations, referred to as residuals). After optimization the aquifer parameter and model input values were compared to USGS values and ranges for the study area to ensure that reasonable values were still being used. **Figure 2** below is an image of the calibrated model showing the conditions in the Upper Glacial aquifer in the study area.

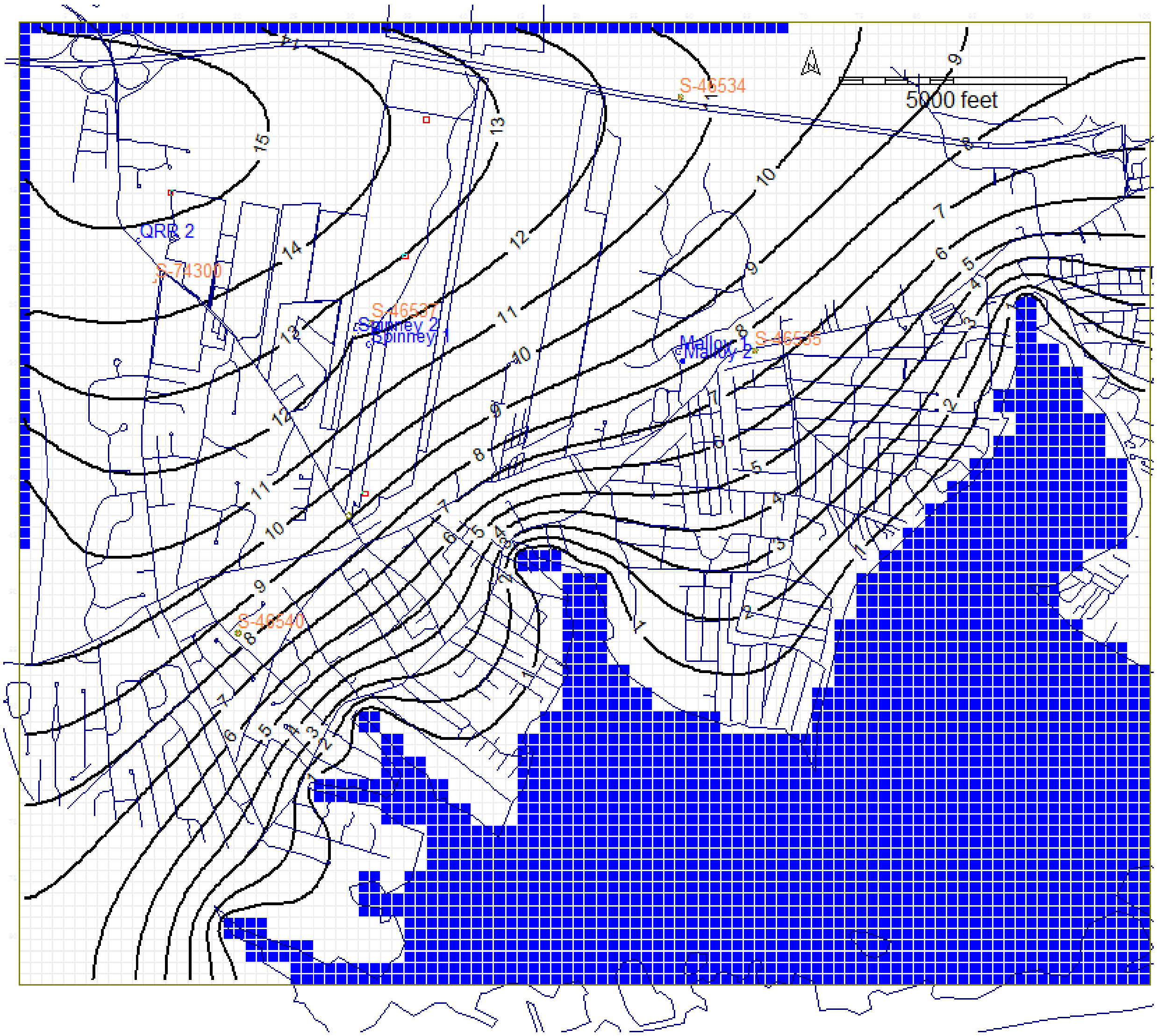

Figure 2 – Calibrated Model

The dark numbered lines in **Figure 2** represent groundwater contours with the numerical values indicating elevation of the water table in reference to mean sea level (NGVD 29), the blue colored areas represent boundary conditions and the light gray colored lines are the model grid with each square representing a model cell (250 ft x 250 ft). The reddish colored alpha-numeric identifiers are calibration targets or USGS monitoring wells. The blue text indicates SCWA supply wells.

Once the model was calibrated to acceptable levels of accuracy (all residuals were less than one foot, with the average residual being -0.44 ft), optimization of the irrigation well location was started. The well was located to maximize the interception of nitrogen laden groundwater (with concentrations of total nitrogen reported as high as 29 mg/l) that discharges to Weesuck Creek and Shinnecock Bay and originates from the farm fields immediately to the west of The Hills property.

Additionally, the existing SCWA well field on Spinney Road is also being impacted by the nitrogen from the farm fields. The two shallow Upper Glacial wells, Spinney 1 and Spinney 2, are both experiencing elevated levels of nitrogen while the deeper Magothy well, Spinney 3, is not yet observing detectable levels of nitrogen. A fourth well, Spinney 4 is a new Magothy well that is scheduled to come on line towards the end of 2015. The SCWA will abandon the two shallow wells and relocate them to the northern end of the Hills property on land that would be donated to them should the Hills development be permitted. The two remaining deep or Magothy SCWA wells at Spinney Road would ultimately over time be subjected to nitrogen contamination.

The irrigation well placement was analyzed using particle tracks to represent flow pathways for nitrogen contaminated groundwater and the extents of well capture zones. MODPATH was employed to analyze and visualize the tracks. MODPATH is a particle-tracking post-processing model that computes three-dimensional flow paths using output from groundwater-flow simulations based on MODLFOW, the U.S. Geological Survey (USGS) finite-difference groundwater flow model. The program uses a semi-analytical particle-tracking scheme that allows an analytical expression of a particle's flow path to be obtained within each finite-difference grid cell. A particle's path is computed by tracking the particle from one cell to the next until it reaches a boundary, an internal sink/source, or satisfies another termination criterion (i.e., a certain time in the future or the past).

Particles were created and released at the water table beneath the farm fields and tracked in a forward direction. The SCWA wells on Spinney Road were modified as such and remained constant as described below for all modeling scenarios performed;

Spinney 1 – turned off, pumping rate set to 0 ft^3/day (well was constructed in 1964 with a screened interval of -25’ to -63’ AMSL) – relocated to northern end of Hills property and made active with an annualized pumping rate of 64,102.5 ft^3/day (333 gpm) screened in the Upper Glacial as per SCWA.

Spinney 2 - turned off, pumping rate set to 0 ft^3/day (well was constructed in 1974 with a screened interval of -69’ to -109’ AMSL) – relocated to northern end of Hills property and made active with an annualized pumping rate of 64,102.5 ft^3/day (333 gpm) screened in the Magothy as per SCWA.

Spinney 3 – well was active with an annualized pumping rate of 56,575.75 ft^3/day (293.9 gpm) (well was constructed in 2004 with a screened interval of -417’ to -478’ AMSL).

Spinney 4 - well was active with an annualized pumping rate of 56,575.75 ft^3/day (293.9 gpm) (well assumed constructed in 2015 with a screened interval of -417’ to -478’ AMSL).

The Hills irrigation well is estimated to need to supply 20 million gallons of water per year to meet the irrigation needs of the site. Annualized this equates to a steady state or continuous pumping rate of 38 gpm [(20 x 10^6 gal/yr) x (1 yr/365 days) x (1 day/1,440 min) = 38 gpm]. A design or instantaneous pumping rate of 300 gpm for the proposed well is estimated as follows:

(20 x 10^6 gal/yr) x (1 yr/6 months) x (1 month/30 days) x (1 day/8 hrs) x (1 hr/60 min) = 231.5 gpm

This value was rounded up to 300 gpm to account for additional watering needs, shorter watering cycles, declines in well capacity/efficiency, possible future line losses and to provide a certain degree of spare capacity.

The location and depth of the irrigation well were adjusted to ensure only groundwater that is flowing from beneath the adjacent farm fields is captured and that nitrogen contaminated groundwater which is assumed to originate at the water table is also being recovered by the irrigation well. The irrigation well was input into the model pumping at a withdrawal rate of 300 gpm. The location and screened interval were positioned through an iterative trial and error process to find the optimal location with regards to nitrogen contaminated water interception. Lines of particles were used to track water flow paths and delineate the well capture zone. After several iterations a shallow irrigation well positioned near the southern end of The Hills property appeared to have the greatest influence on capturing shallow nitrogen contaminated groundwater. **Figure 3** below depicts the suggested area with the irrigation well noted in blue as the "Hills". **Figure 3** is a steady state representation of pumping the aquifer at 300 gpm continuously from the proposed irrigation well for an endless duration (this is not reality but rather an instantaneous idealized snap shot).

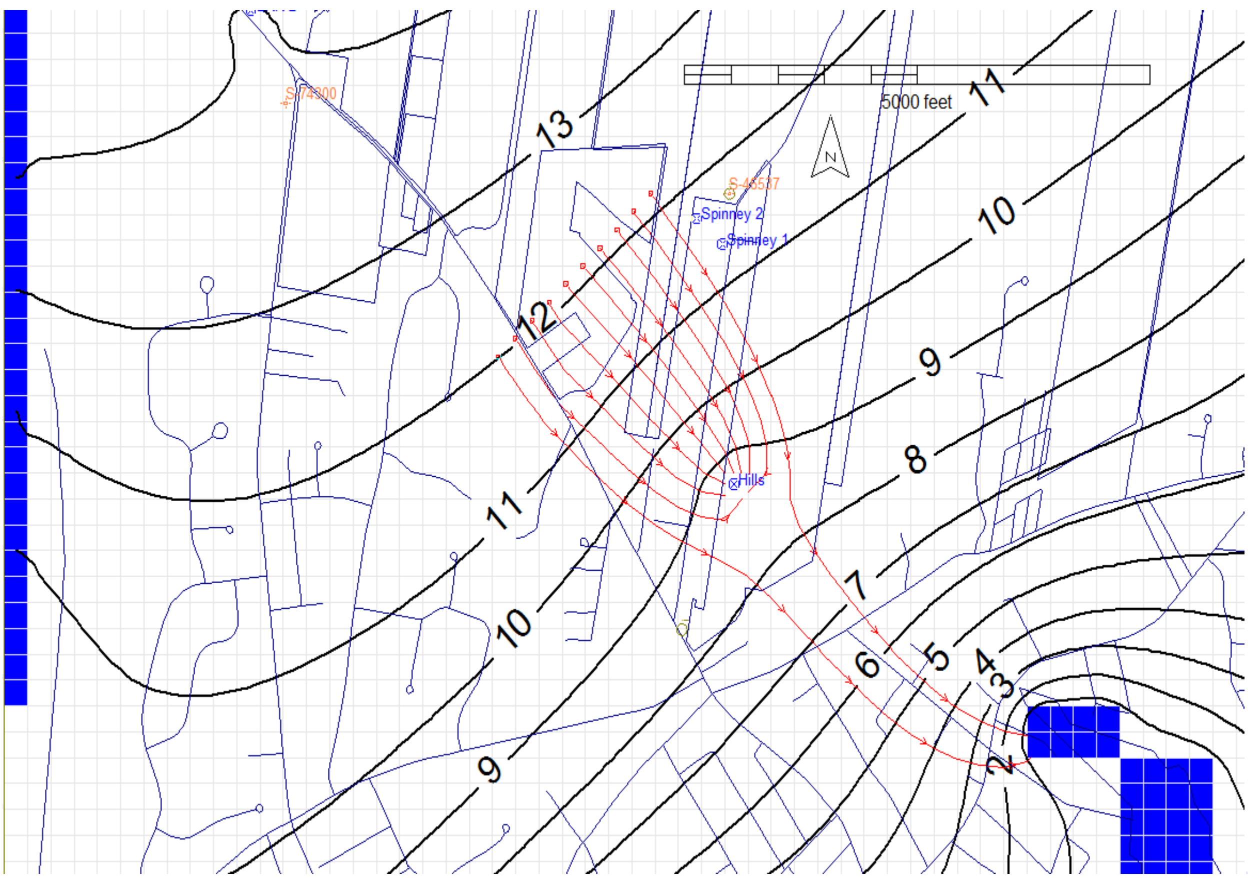

Figure 3 – Hills Irrigation Well Location and Particle Tracks: Instantaneous Pumping Rate 300 gpm

Particle tracks are represented by redlines with arrowheads along the line indicating the direction of flow. A row of particles was inserted upgradient of the proposed well location on the farmland property and were allowed to track forward. The graphic clearly shows the proposed well position to be directly upgradient from Weesuck Creek (denoted by the blue squares representing the boundary condition in the lower right of **Figure 3**). It was here that the model predicted the irrigation well would provide the most benefit to Weesuck Creek in terms of preventing nitrogen from reaching and entering the surface water body (an estimated 2,500 lbs/yr of nitrogen would be removed from the aquifer by locating a 300 gpm well at this position and operating it between May through October). Though it will obviously not prevent all the nitrogen from the farmlands from reaching Weescuk Creek a pumping well in this location operating at 300 gpm could have noticeable impact. **Figure 3A** below illustrates the predicted annualized effect of the irrigation well (constant steady state pumping rate of 38 gpm, under this scenario the 20,000,000 gallons of water to be withdrawn from the aquifer are now modeled to be pumped continuously throughout the entire year (20,000,000 gal/yr ÷ 365 day/yr ÷ 24 hr/day ÷ 60 min/hr = 38 gpm)). Though in the path of the nitrogen contaminated groundwater the capture zone of the irrigation well is not as pronounced at 38 gpm. However it still has a subtle effect by causing the particles nearest to the irrigation well to slight deflect towards it.

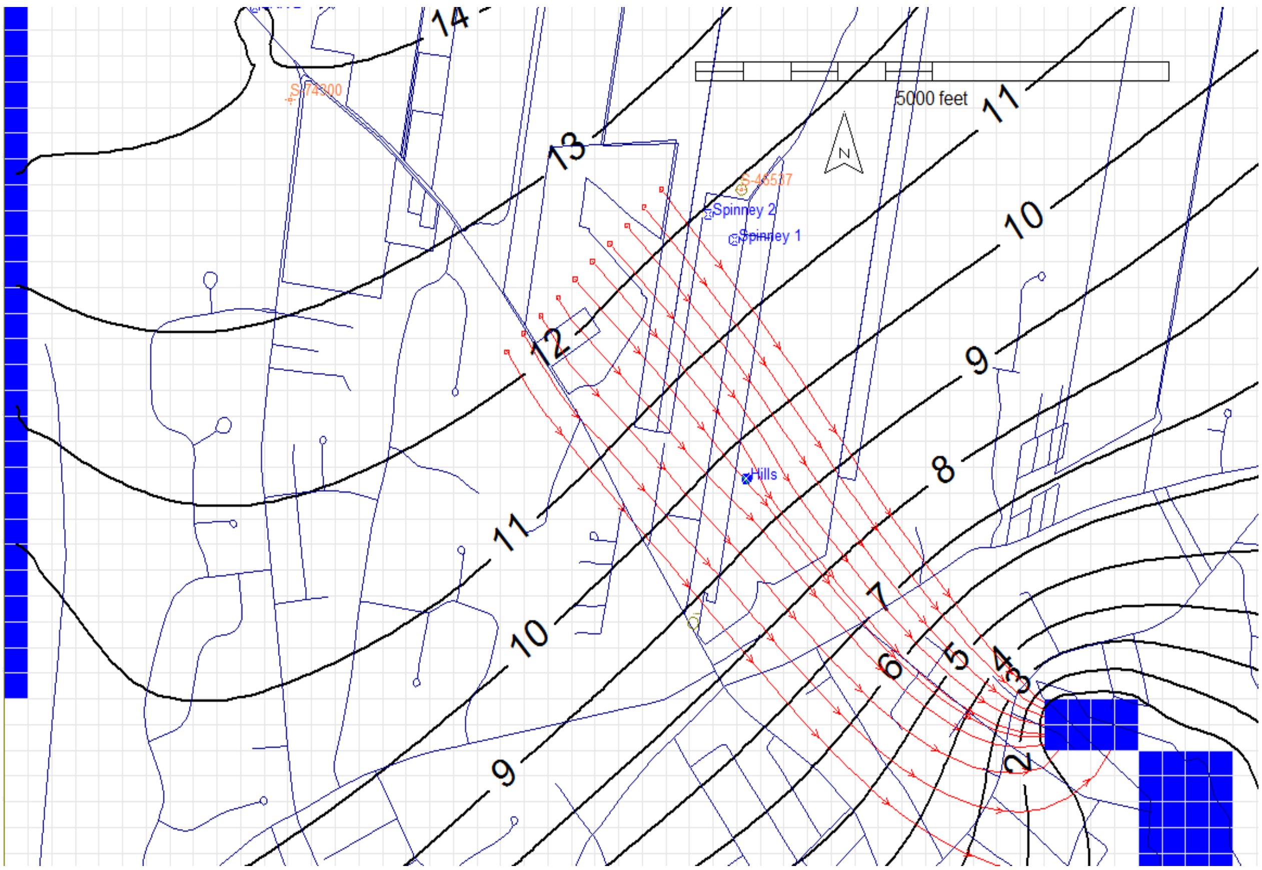

Figure 3A - Hills Irrigation Well Location and Particle Tracks: Annualized Pumping Rate 38 gpm

To substantiate this, the model was run with the same line of water table particles released without the pumping well operating. **Figure 4** below depicts this scenario.

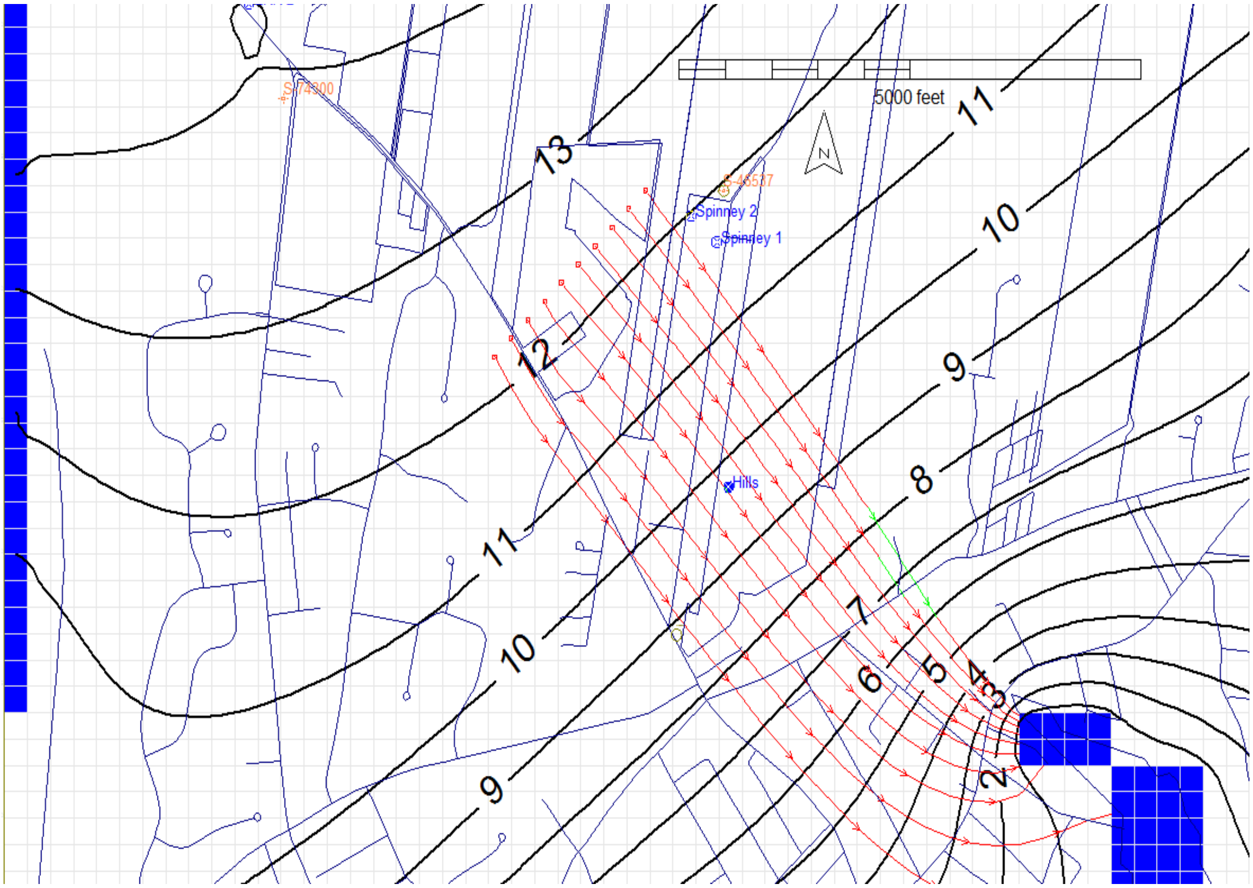

Figure 4 – Particle Tracks with the Hills Irrigation Well Not Pumping

As can be seen the entire row of particles reaches the creek without the irrigation well in their path to intercept them and without any discernible deflection as seen in **Figures 3 and 3A**. It should also be noted that from a three-dimensional perspective the particles when released anywhere across the farmland migrate downward as they travel perpendicular to the groundwater contours and eventually start to migrate back upwards as they near the creek. Thus the deeper Magothy SCWA wells on Spinney Road are estimated to start experiencing increasing nitrogen levels after 20 to 25 years of operation. The Spinney 3 well went online in 2004, so based on the modeling results sometime between 2024 and 2029 is when rising nitrogen levels are predicted to start being observed assuming the well has been and continues to operate as reported by the SCWA at an annualized pumping rate of 293.9 gpm. **Figure 5** depicts particles that were released further upgradient yet still beneath the farmland area of the model and the particle tracks change color as they travel between layers. Red denotes a particle when it is in the Upper Glacial or layer 1 of the model and green indicates when a particle is in the Magothy or layer 2 of the model. The arrowheads along the particle tracks are spaced 10 years apart for time reference.

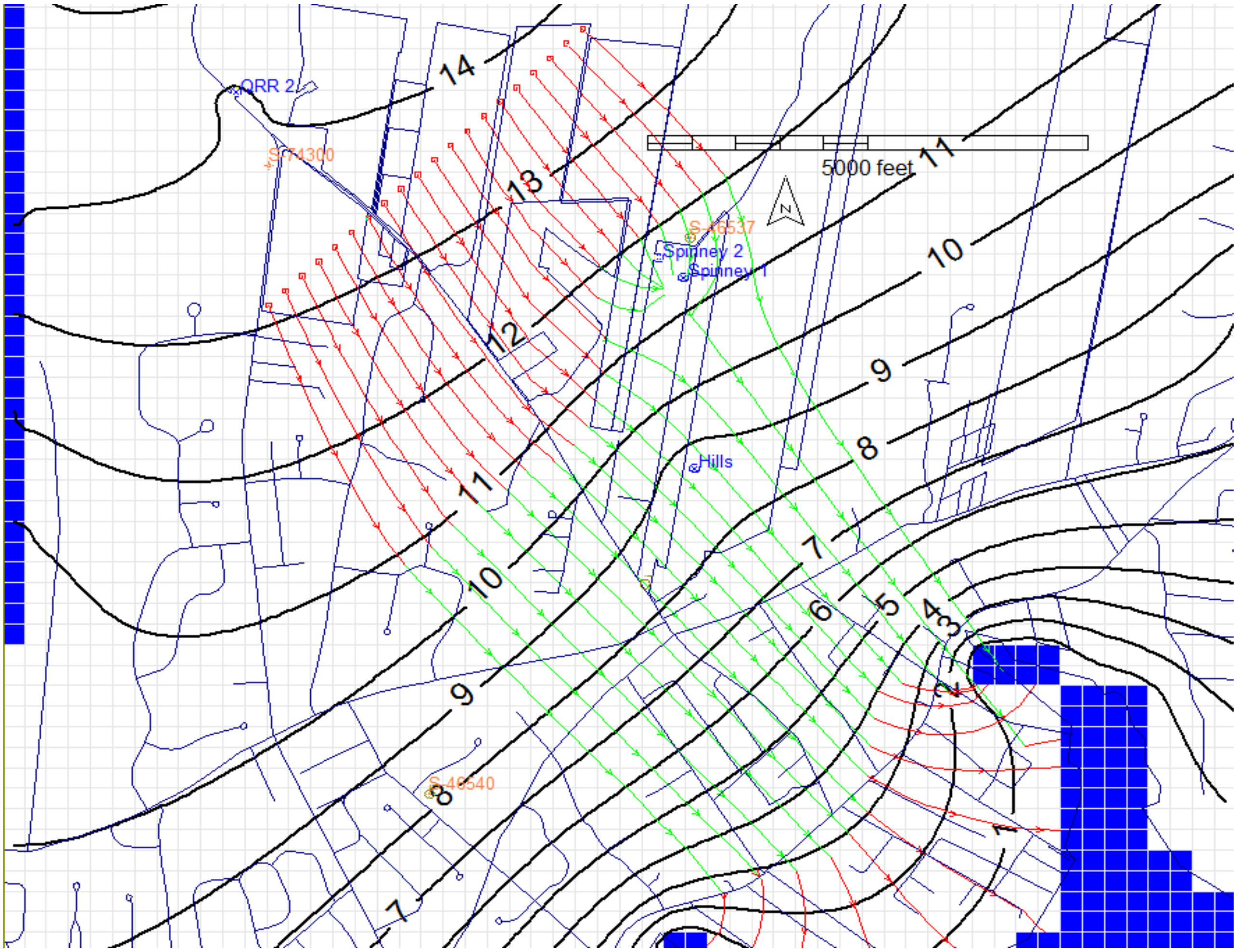

Figure 5 – Particle Tracks Traveling Between Layers

By comparing **Figures 4 and 5** it can be seen that nitrogen that reaches the water table in the northwest portion of the farmlands will travel deeper into the aquifer system while nitrogen reaching the water table closer to Weesuck Creek will remain predominantly in the Upper Glacial aquifer. The proposed Hills irrigation well in all the above figures is shown screened across the bottom 30 feet of the Upper Glacial aquifer (approximately -80 ft to -110 ft AMSL). In **Figure 3** particles released near the irrigation well remain shallow and are captured by it. In **Figure 5** particles released further upgradient of the irrigation well travel below it and are not captured. Deciding at what depth to screen the well may come down to where the greater levels of nitrogen contamination reside. As the deeper contamination is taking considerably longer to reach the irrigation well and the longer and further it travels the more dilution is occurring due to advection, dispersion and diffusion, the lower the concentrations are likely to be. Therefore higher concentrations of nitrogen would be expected to be found in the Upper Glacial aquifer as opposed to the Magothy. A vertical profile and test well would provide significantly more data to verify this expectation and to help determine where to exactly screen the proposed Hills irrigation well for the greatest effect with regards to nitrogen recovery.

Conclusion and Recommendations

Three-dimensional sub-regional numerical groundwater modeling was used to optimize the location of the proposed Hills irrigation well with regards to intercepting nitrogen contaminated groundwater originating from farm fields to the west of the Hills property. The sub-regional model is a refined and calibrated version of the Suffolk County regional groundwater model. A sub-regional model was created for a higher degree of accuracy as only a very small portion of the County needed to be studied. Steady state modeling runs were carried out using particle tracks to optimize the irrigation well location.

The model results predict that the most effective place to locate the proposed irrigation well is at the southern end of the Hills property and directly upgradient hydraulically of Weesuck Creek **(see Figures 3 thru 5)**. The model also estimates that screening the well across the bottom 30 feet of the Upper Glacial aquifer will have the most influence with regards to intercepting the nitrogen contaminated groundwater. A vertical profile and test well are recommended to be conducted to verify the modeling results and to best determine where the greatest levels of nitrogen concentrations are at the proposed well location to better delineate a screen zone for the well.