NGI

NORTHEAST GEOSCIENCE INC

*Water Supply and Environmental Consulting*

January 17, 2017

Mr. Jeffrey Brem
Lifetime Green Homes
100 Long Ridge Road
Carlisle, MA 01741

Re: Mixing-Zone Dilution Analysis
100 Long Ridge Road
Carlisle, Massachusetts

Dear Mr. Brem:

Nobis Engineering, Inc. conducted a variety of mass-balance nitrogen loading analyses based on the method described in the MassDEP Guidelines For Title 5 Aggregation Of Flows And Nitrogen Loading 310 CMR 15.216, in order to assess the potential impact of wastewater disposal on existing and proposed water supply wells in the vicinity of the 100 Long Ridge Road property. In addition, recent site work by Nobis showed that, unlike at Disposal Area #2 and #3, no basal till deposit is present at Disposal Area #1 and the permeable nature of the deposits in that area both raise concerns about the potential impacts to the wells south of the site (specifically at 68 Garnet Rock Lane and 200 Long Ridge Road).

In response to these and other concerns raised by Nobis we have presented a variety of nitrate modeling analyses including a property-wide mass-balance analysis (Frimpter), dilution-attenuation factor analysis (EPA), analytical dispersion analysis (Domenico) and semi-analytical dispersion analysis (AT123D). These models assessed the relative pre- and post-development nitrogen inputs to the site (Frimpter) or predicted nitrate concentrations at downgradient points of compliance (property lines, wetlands, water supply wells, etc.). The models showed general agreement that nitrogen inputs to the site will decrease relative to existing land uses and that predicted nitrate concentration at nearby water supply wells will not exceed the drinking water standard of 10 mg/l. To address the specific case of Disposal Area #1 noted above, we offer the following analysis to further illustrate that the proposed wastewater disposal areas are unlikely to impact existing or proposed wells on or near the site.

The mass-balance model employed by Nobis combines nitrogen inputs and groundwater recharge to the Area of Influence (AOI) to arrive at what has been called an average concentration within the AOI. However, as we have pointed out, the mass-balance model ignores several hydrogeologic factors that if considered, would significantly reduce the estimated concentrations. An additional factor that was not previously considered but is an important factor to understand the likely impacts to wells at or near the site is the mixing of wastewater discharges with groundwater flowing beneath the discharge areas. As we will show using Darcy's Law, this mixing reduces the nitrogen concentrations at Disposal Area #1 to below the drinking water standard.

The highest concentration of wastewater constituents at the site are expected directly beneath the disposal areas. Assuming that a bedrock fracture is located directly beneath Disposal Area #1, that the fracture is hydraulically communicating with groundwater in the overburden, and that the fracture is hydraulically connected with and providing water to a nearby water supply well, nitrate concentrations exceeding 10 mg/l beneath the disposal area could pose a threat to the nearby well(s) (Nobis correspondence and testimony). However, wastewater discharged at the site mixes with groundwater flowing beneath the disposal area. In order for the wastewater to enter a bedrock fracture beneath the disposal area, it must mix with the groundwater flowing beneath. By combining the daily wastewater discharges and nitrogen mass with the daily aquifer discharge beneath the disposal area (and ignoring aquifer recharge from precipitation in the disposal area, which would further dilute the wastewater), it is possible to estimate the maximum concentration of nitrate leaving this mixing zone either vertically into a bedrock fracture/aquifer or horizontally into the overburden aquifer. The attached analysis shows that the maximum concentration of nitrate entering a bedrock fracture beneath Disposal Area #1 is less than 10 mg/l and is probably closer to 5 mg/l (see attached assumptions, calculations and schematic). This analysis shows that impacts to private wells under the scenario described by Nobis are unlikely.

It is also important to note that, based on the above analysis we reviewed the dispersion analysis conducted by NGI and by Nobis (Domenico equation). These models assumed a source depth of six feet. Using the Darcy's Law approach described here, the nitrate mass assumed by the model runs was overestimated. In the case of Disposal Area #1, the overestimate was on the order of +37% (i.e. the groundwater discharge out of the Domenico source area at 19 mg/l in Disposal Area #1 yields ~195,000 mg/day versus the actual nitrogen mass of ~142,000 mg/day). In addition, all of the modeling approaches have assumed no wastewater treatment in the vadose zone and full Title 5 flows, both of which overestimate likely groundwater impacts.

If you have any questions or require additional information, please do not hesitate to contact me.

Sincerely,
**Northeast Geoscience, Inc.**

Joel Frisch
Hydrogeologist

# *Mixing-Zone Dilution Analysis*

**Assumptions**:

1) The area beneath a septic disposal area is expected to have the highest concentration of nitrogen and other wastewater constituents.

2) Disposal Area #1 at 100 Long Ridge Road has no basal till present and, bedrock fractures, if present and communicating with the overburden in that area, could contribute elevated nitrates to private wells hydraulically connected to such fractures (Nobis correspondence and testimony).

3) Daily wastewater discharges mix with daily aquifer flow beneath the disposal area.

4) The aquifer discharge according to Darcy's Law can be calculated based on Q = KiA where K = hydraulic conductivity, i = hydraulic gradient and A is the cross-sectional area of the aquifer.

5) There are two potential cross-sectional areas to consider: 1) if we are to assume flow into a fracture beneath the disposal area then we would need to assume mixing of the full depth of the aquifer beneath the disposal area ($A_1$); and 2) due to site specific hydrogeologic conditions, the septic discharge might not fully mix with the entire saturated thickness beneath the disposal area, so we would need to determine the mixing zone depth ($A_2$) to determine the likelihood.

6) The mixing zone depth (d) can be estimated as follows (EPA Dilution Factor Model; note: values of length in meters and rate in meters/year):

$$d = (0.0112L^2)^{0.5} + d_a\{1-exp[(-LI)/Kid_a)]\}$$

7) Combining the daily septic discharge volume and the daily aquifer discharge volume (Darcy flux estimate) with the daily nitrogen mass (assuming 19 mg/l) yields an estimate of the nitrogen concentration beneath the disposal area in groundwater.

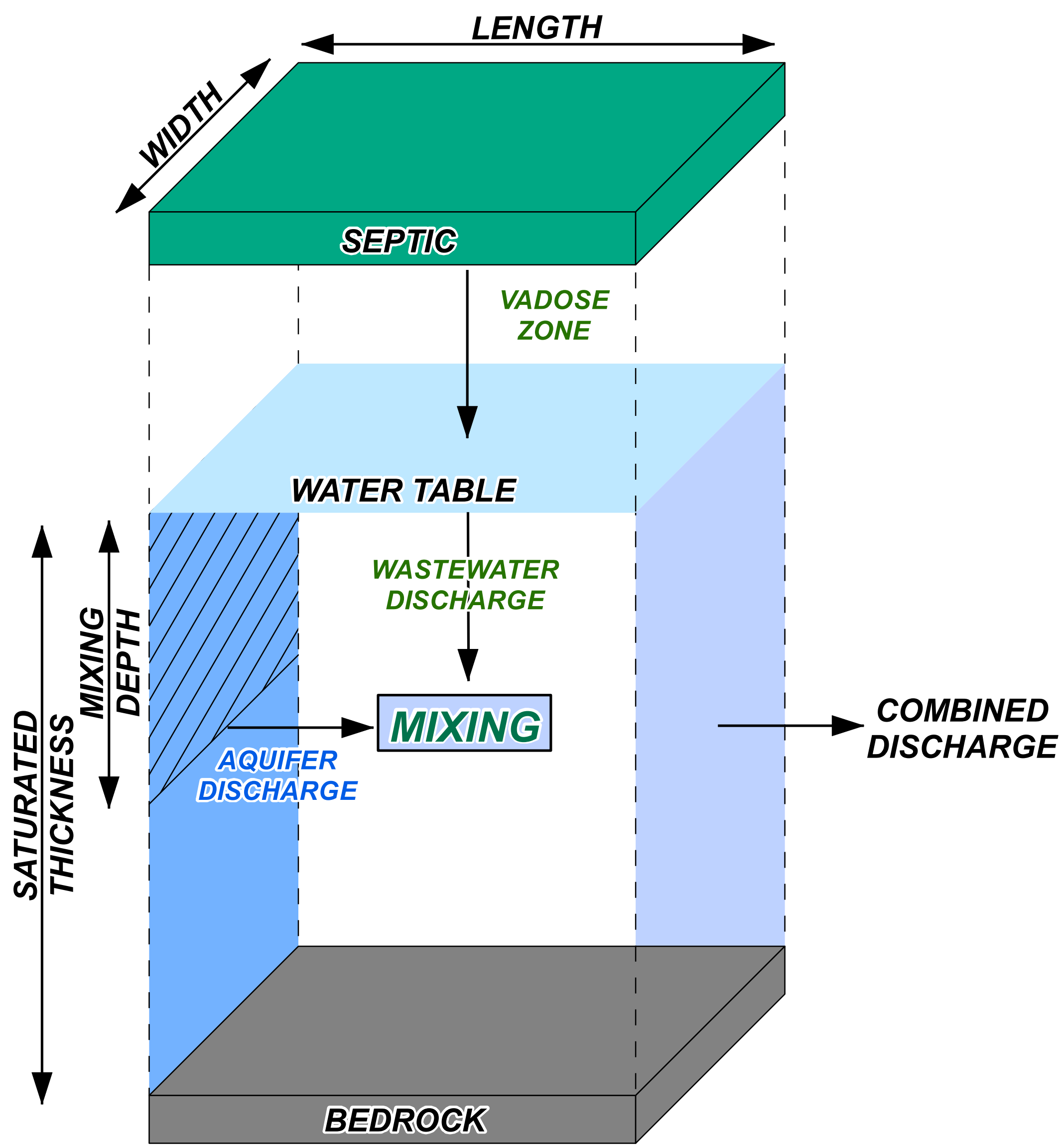
8) No recharge occurs in the disposal area (further diluting the source), no mounding occurs (increasing in aquifer cross-section, increasing flux and causing more dilution), dispersion is minimal (further reducing concentrations), no treatment occurs within the vadose zone (reducing pathogen and nitrate concentrations) and wastewater flows equal Title 5 estimates (which overestimate the expected mass to the system).

## **Calculations**:

*K = 10.2 feet/day (average value) (3.11 m/day)*
*$d_a$ = 10 feet (saturated thickness ESHWT)(3.05 feet)*
*i = 0.079 (measured on 12/30/16)*
*$A_1$ = 75 feet (SDA width; 22.86 m) x 10.00 feet ($d_a$; 3.75 m) =*
*$A_2$ = 75 feet (SDA width; 22.86 m) x 4.69 feet (d calculated from eq. above, 1.52 m) =*
*L = 45 feet (SDA length; 13.72 m)*
*I = 18 inches/year (assumed; 0.00125 m/day)*
*WW Volume = 1,980 gpd (7,494 l/day) at 19 mg/l (142,386 mg/day)*

Concentration in Mixing Zone (depth = 4.69 fee; $A_1$)= $\frac{142{,}386 \text{ mg/day}}{8{,}705 \text{ l/day} + 7{,}495 \text{ l/day}}$ = 9.12 mg/l

Concentration at Full Depth (depth = 10.00 feet; $A_2$) = $\frac{142{,}386 \text{ mg/day}}{17{,}279 \text{ l/day} + 7{,}495 \text{ l/day}}$ = 5.74 mg/l

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WASTEWATER DILUTION SCHEMATIC
LIFETIME GREEN HOMES
100 LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

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| NGI REF: NgiDilutionModelSketch.mxd | |
| Drafted By: JAF | Date: 01/17/2017 |
| Source: | |

FIGURE 1