January 16, 2017
File No. 89220
Via Email and U.S. Mail

Town of Carlisle, Zoning Board of Appeals
ATTN: Steve Hinton
66 Westford Street
Carlisle, MA 01741
shinton@mindspring.com

Re: Response to NGI 1/4/17 Report
Independent Hydrogeologic Study
100 Long Ridge Road, Carlisle, MA

Dear Mr. Hinton:

Nobis Engineering, Inc. (Nobis) is pleased to present this report to the Town of Carlisle Zoning Board of Appeals (Town; ZBA) as part of Phase 4 of an independent hydrogeologic study of potential impacts related to a proposed 40B housing development on the Brem property at 100 Long Ridge Road in Carlisle, Massachusetts ("Site"). The Site is Carlisle tax lot 1-72-33K, with the subtraction of a lot for a new home at 90 Long Ridge Road. This report is an additional deliverable item for Phase 4 of the project under Nobis' contract with the Town, dated January 2015 (Town of Carlisle document # Brem 151 01-14-2015), with Amendment 5, dated August 8, 2016 to the existing contract and additional work added via Amendment 6, dated October 24, 2016, and informally, by email on December 27, 2016 and January 10, 2017. (Phase 2 included additional hydrogeologic work conducted by Nobis in 2015, and Phase 3 included Nobis support at the Housing Appeals Committee (HAC) mediation in 2016; these were covered by previous amendments.)

A report dated September 30, 2016 (Brem 310 – 314 09-30-16) was the primary deliverable product under Amendment 5, and Technical Memoranda dated October 25, 2016 (Brem 322 10-25-2016) and December 8, 2016 (Brem 330 12-08-2016) were submitted to the Town under Amendment 6. Nobis submitted a letter report dated January 3, 2017 (Brem 335 01-04-17); that report consisted of a review of a report submitted by Northeast Geoscience, Inc. (NGI) on behalf of the developer, Lifetime Green Homes (Applicant) dated December 23, 2016 (Brem 334 12-24-16).

The current letter report is authorized and requested by the email dated January 10, 2017. The current report presents new analyses by Nobis and also review of a new report by NGI dated January 4, 2017 (Brem 336 01-04-17) and presented to the ZBA on that date.

1.0 INTRODUCTION

Nobis understands that the 9.84-acre Site is proposed for development by a private owner and that the Town's concerns include potential impacts of proposed, on-Site, wastewater disposal systems on proposed on-Site and existing off-Site drinking water wells, and potential yield and water level effects between the proposed new wells and the existing off-Site wells. Also, potential interference effects between the proposed new wells are a concern.

Nobis Engineering, Inc.
18 Chenell Drive
Concord, NH 03301
T (603) 224-4182

The Town granted conditional approval for the proposed 40B housing development in 2015. However, the developer, Lifetime Green Homes (Applicant), appealed the Town's decision to the HAC, seeking relief from the conditions. The Town and the Applicant met with a mediator assigned by the HAC in March 2016. In April 2016, the Applicant submitted a modified proposal whose significant differences from the original proposal were summarized in Nobis' September 30, 2016 report (Brem 310 – 314 09-30-2016).

The proposed new wells and new SDAs are shown on a map entitled "Plan P – Public Water Supply, The Birches", dated February 2, 2016 and revised August 18, 2016 (Brem 300 08-22-2016, included as Attachment A in Nobis' September 30, 2016 report).

Phase 4 included Tasks intended to address the following objectives:

- Assess the potential impacts of the re-configured septic systems on existing neighbors' wells;
- Assess the potential impacts of the re-configured septic systems on proposed new wells for the Birches PWS; and
- Assess the potential impacts of pumping the proposed new PWS wells on existing neighbors' wells and on each other.

The objective of this letter report is to comment on selected aspects of the NGI report dated January 4, 2017, "Additional Solute Modeling, 100 Long Ridge Road, Carlisle, Massachusetts" (Brem 336 01-04-17). An additional objective is to perform additional dispersion analyses to the northeastward from proposed Septic Disposal Area 3 (SDA3). The ZBA has requested these analyses because a potential sensitive receptor (well at 55 Suffolk Lane Extension) is located northeast of SDA3, and the proposed project has changed substantially since Nobis performed dispersion analyses in this area in 2015 (Nobis Phase 2 report dated May 1, 2015).

2.0 BACKGROUND

See Nobis' September 30, 2016 report for project background and a summary of previous investigations. See Nobis January 3, 2017 report for comments on selected hydrogeologic aspects of the Site and proposed development and on modeling approaches used as of the report date. These include mass balance (Title 5 AOI method) models and dispersion models based on Domenico (1987).

3.0 DISCUSSION OF NGI REPORT DATED JANUARY 4, 2017

The following discussion is arranged by topic, in the approximate order that these topics were discussed in the NGI report.

3.1 Updated Groundwater Elevations and Flow Directions Near SAS #1

The NGI Report, Section 1.0 describes groundwater level measurements taken by NGI on 12/30/16 near proposed SDA1 (SAS #1), located in the southern portion of the Site (Figure 1).

The measurements were made in order to construct a groundwater contour map for the southern portion of the Site and to determine the likely groundwater flow direction in the area. Previous reports and discussions at ZBA meetings indicated uncertainty as to whether groundwater flows eastward, southward, or southwestward from proposed SDA1.

NGI used water levels measured in MW-1-15. MW-1-14, and PVC "wells" installed in three backfilled test pits. The locations of these measurement points are shown in NGI's Figure 1. A log for MW-1-15 is provided in NGI's report dated March 15, 2015. Nobis has not seen a log for MW-1-14, but has been informed that this is a screened monitoring well, but it was installed in a test pit (as opposed to installation by drilling; see Attachment 1). The other test pit "wells" consist of PVC drain pipes that were either factory slotted or perforated before installation and that were placed in test pits as they were backfilled. Of six such pipes monitored, three produced water level measurements and three were dry, for reasons articulated by NGI in the first paragraph of Section 1.0 and in Attachment 1. Nobis agrees with NGI's assessment that water level measurements obtained from the "wells" installed in test pits are less reliable than the water level measured in MW-1-15. However, the new water level measurements provide increased detail and information for the southern part of the Site, indicating that overburden groundwater flow from proposed SDA1 is southward.

Potential inaccuracy for all the water level measurements except that obtained from MW-1-15 lends inaccuracy to the contours shown in Figure 1 of the NGI Report and to the groundwater flow direction. The actual flow direction may vary by several degrees (in either direction) from that shown on NGI's Figure 1. Nobis agrees with NGI (Section 1.0, second paragraph) that the well at 200 Long Ridge Road is probably not directly down gradient of SDA1. However, Nobis does not believe that the groundwater flow direction is known with sufficient accuracy to determine that the well at 68 Garnet Rock Lane is or is not directly down gradient of proposed SDA1. Therefore, it is not possible to say whether nitrate concentrations in overburden groundwater (predicted by dispersion analyses) would be lower than concentrations calculated along a plume center line or not.

In the second paragraph of Section 1.0, NGI includes proposed SDA2 within the southward groundwater flow domain. However, there is no groundwater level data in the vicinity of SDA2, and the contouring shown by NGI in their Figure 1 does not extend far enough north to make this determination. Topographic slopes are very gentle in this area, lending uncertainty to groundwater flow directions estimated using topographic maps. Nobis believes, as discussed in previous reports and at ZBA hearings, that overburden groundwater flow from SDA2 could be to the east, the south, or both.

3.2 Additional Solute Modeling Results

The NGI Report, First Section 2.1 (Domenico Dispersion Model) describes two new calculations performed by NGI using the Domenico dispersion model (the same general approach used by Nobis in 2015 (Brem 212 05-01-2015) and NGI in 2016 (Brem 297 08-08-2016). Nobis agrees that the groundwater flow direction in the vicinity of SAS #1 (SDA1) is toward the south as depicted on NGI's Figure 1, and that the private well for #200 Long Ridge Road appears to be cross-gradient from SAS #1. Therefore, we agree that it is unlikely that groundwater flow from SAS #1 would reach #200 Long Ridge Road in the overburden. In addition, the assumptions and input parameters in the additional Domenico methods calculations appear to be reasonable.

As discussed above, Nobis does not believe that the groundwater flow direction is known with sufficient accuracy to accept the lower-concentration result in NGI's Table 1D that assumes that the well at 68 Garnet Rock Lane is off the center line of the plume. Further, as discussed above, results that assume combined southerly flow from both SDA2 and SDA1 should be interpreted with caution because the flow direction from SDA2 is unknown.

Finally, it must be remembered that all of the analyses presented pertain to overburden groundwater. Whether impacted groundwater would reach wells at 200 Long Ridge Road or at 68 Garnet Rock Lane would depend on the orientation and characteristics of the particular bedrock fractures that supply water to those wells.

The Domenico section of the NGI Report also references a dispersion model sensitivity analysis, whose results are presented graphically in Appendix A of their report and presented in a table submitted separately to the Town (Brem 339 01-05-2017). The NGI graph in Appendix A shows that the model is sensitive to two variables, source depth and lateral dispersivity. See a follow-up email from NGI to Nobis further discussing these points (Attachment 2). The model is relatively insensitive to other variables, especially when using long time frames (i.e. 30 years) in the calculation.

The NGI Report, Second Section 2.1 (AT123D Modeling) describes a dispersion model that is an alternative to the Domenico model described above and used previously for this Site by both Nobis and NGI. The AT123D model is an appropriate alternative to the Domenico equation. Because it uses different transport functions, it may be used as an independent check on values derived by the Domenico method.

Note that the effective porosity used as an input in the program by NGI is 0.35. Nobis had previously (Nobis, May 1, 2015 Report) used an effective porosity of 0.2. We requested that the model be re-run using this porosity, and the off-set value for #68 Garnet Rock Lane did increase slightly to 4.46 mg/L. (See Attachment 2 for details of the revised calculation by NGI). Literature values for effective porosity vary, but the sands and silts expected at the Site can be expected to range from about 0.15 to 0.35. Manuals for different programs/models recommend a default value of 0.25 (BIOCHLOR), 0.23-0.28 (California Regional Water Quality Control Board), and 0.3 (Pennsylvania's Quick Domenico) for sandy soils. Therefore, the Nobis and NGI values bracket the expected range of porosities, and the values used by NGI are reasonable for the AT123D modeling.

Note that, as described above, Nobis does not believe that the generally southerly groundwater flow direction is determined with sufficient accuracy to indicate whether an off-set or center-line calculation is more appropriate for the 68 Garnet Rock Lane calculation. (A center line calculation gives a higher predicted concentration than an offset calculation, if all other input parameters are equal.) Also, it should be noted, as described above, that the results only apply to overburden groundwater, not bedrock groundwater.

The NGI Report, Section 2.2 (EPA Dilution-Attenuation Factor) describes an attempt to use a model that includes the effects of both dilution and dispersion. The documents used as the basis for this discussion are soil screening guidance by the EPA to evaluate the potential human health risk posed by contaminants in soil. The dilution-attenuation factors (DAFs) are discussed in Section 2.5 of the EPA Guidance referenced by NGI, which describes migration of contaminants from soil to groundwater (leaching of contaminants already in the soil). The governing equations are based on sorption/desorption mechanisms. Note that the septic systems are designed to release water to the subsurface, with a nitrate load that is already dissolved, for the purpose of delivering the nitrates and other constituents to groundwater.

One of the input parameters required for the analysis is infiltration rate (I); the value for "I" used in the calculation by NGI (Report Appendix C) is the annual recharge from precipitation. As intended by the method, "I" should be the amount of "clean" water available to dilute the concentrations as they are leached from contaminated soil. The annual recharge for sites with no additional water sources can be used as the model input for "I", but only recharge that occurs directly beneath or through the footprint of contaminated soil (or in this case, a leach field) is included in the dilution calculation as infiltrated water. (This is in contrast to the mass balance/AOI method, which accounts for both the input of impacted effluent and dilution of water recharged over the entire AOI.) The recharge or "I" is inserted in the denominator of the equation, so that smaller recharge results in a bigger ratio and lower result if the equation is used to predict concentration at a receptor.

A major factor in estimating the amount of dilution is a mathematical formula for estimating the depth of mixing below the source (contaminated soil or an SDA). For 100 Long Ridge Road, if the proposed project is built, excess water (septic effluent) containing nitrate will enter the saturated overburden from the proposed SDAs. The equations have no way to account for this additional contaminated water entering the system. Only for the version of the calculation that includes dispersion accounts for the distance between the source (SDA) and receptor. For this calculation, effects of dispersion along this distance are added to the effects of dilution due to mixing over a depth range beneath the source.

Because this method was developed as a screening method to determine whether sites with contaminated soil present a serious risk and should be subjected to further investigation, Nobis questions whether this method is appropriate for predicting nitrate concentrations in overburden groundwater due to discharge from the proposed SDAs. Further, because nitrates are delivered in water infiltrated over the same footprint as that for which a statewide average recharge rate is used in the equation by NGI, Nobis questions the applicability of this method for the purpose used in the NGI report.

Finally, regardless of the above discussion, the results pertain only to concentrations of nitrates in overburden groundwater, not bedrock groundwater.

3.3 NGI Conclusions

The NGI Report, Section 3.0, Conclusions contains five bullet point conclusions (also presented in NGI's December 23, 2016 Report. Below, please find Nobis' comments on these conclusion bullets:

- NGI's first bullet states that "No direct impacts to private wells from existing land uses … have been shown." Nobis agrees with this conclusion, but points out that most of the water tests on local wells were taken when the wells were new and the septic system, at least for that lot, probably had not yet been operating. Also, the wells typically had not been pumping for long periods of time, as the wells were generally tested right after drilling.

Of two wells cited by NGI as evidence of no impact, Nobis believes that only one of these wells provides evidence of lack of connection between overburden and bedrock groundwater. This point was discussed in detail in Nobis' Technical Memorandum dated December 8, 2016 (Brem 330 12-08-2016) and in Nobis' Report dated January 3, 2017, page 8 (Brem 335 01-01-2017).

- NGI's second bullet states that "No water quality impacts to private wells are likely based on groundwater flow directions and a variety of solute transport modeling methods for groundwater in the overburden aquifer." Nobis does not believe that present information justifies this conclusion. For SDA1, overburden groundwater flow to the south is fairly well confirmed, although the precise direction is less definite than implied by NGI's Figure 1, in Nobis' opinion. More importantly, the modeling approaches used by NGI and Nobis only pertain to overburden groundwater, whereas the private wells obtain their water from bedrock fractures that may or may not be impacted, depending on where they reach the overburden/bedrock interface. There is no evidence of a hydraulic barrier between bedrock and overburden in the southern part of the Site. For SDA2, the conclusion is not justified because the groundwater flow direction in this area is not known. For SDA3, no water quality impacts are likely to overburden groundwater in the vicinity of private wells, based on probable groundwater flow directions, distances to downgradient wells, presence of clay and dense glacial till in the subsurface at SDA3's proposed location, and topographic considerations (see Section 4, below). However, there is not enough evidence to say that no impacts to private wells are likely, because such impacts depend on flow through specific bedrock fractures that may supply water to any particular well. Also, the low permeability layers likely terminate to the east (Nobis Technical Memorandum dated December 8, 2016), and a component of flow from SDA3 may be directed eastward. Overburden groundwater in the vicinity of the northernmost proposed Public Water Supply wells may be impacted in this area.

- NGI's third bullet states that "No direct evidence of communication between the overburden and bedrock aquifers has been shown using both water quality and water level data." Nobis believes that boring results show that such communication is likely in the southern part of the Site. Such communication also may occur east of a likely pinch-out of low permeability deposits that occur beneath proposed SDA3, as discussed in Nobis' Technical Memorandum dated December 8, 2016. Also, small water level fluctuations noted in MW-1 (near SDA1) and MW-5 (east of SDA3) may be evidence of hydraulic communication between overburden and bedrock in these areas. Although the evidence is not conclusive, two points indicate such an interpretation: first, the fluctuations are absent in the other three wells monitored, indicating that the fluctuations are not simply a background condition that prevails throughout the Site; second, the locations where these fluctuations were observed coincide with locations where boring results do not show the presence of a low-permeability layer on top of bedrock. Hydraulic communication between bedrock and overburden groundwater may be more evident when wastewater impacted with nitrates and other constituents is discharged to the groundwater from the proposed SDAs and/or when increased pumping stress is initiated with the operation of the proposed Public Water System wells. Present evidence indicates that communication is neither proven nor disproven but is fairly likely to occur in some parts of the Site.

- NGI's fourth bullet states that "Groundwater mounding estimates have been shown to be within septic design parameters." Nobis disagrees with this conclusion; mounding results presented in our September 30, 2016 Report (also summarized on p. 2 – 3 of our January 3, 2017 Report indicate that predicted mounds may have less than 5 feet, or even 4 feet below the bases of the proposed SDAs at two of the three locations. (Title 5 requires minimum separations of either 4 or 5 feet, depending on the soil infiltration rate.) Boring results indicate greater saturated thickness in the aquifer than previously estimated at some locations; mound heights should be recalculated to determine whether this alleviates the previously apparent inadequate separation between the top of the predicted mound and the bottom of the SDA.

- NGI's fifth bullet states that "The AOI method should not be used as a predictive tool for non-credit land projects such as this …." Nobis disagrees and has pointed out that Massachusetts Title 5 Guidelines present a situation in which an "Approving Authority" may require a site specific mass balance analysis, with no mention of credit land (Nobis January 3, 2017 Report, p. 4). Even if no authority requests or requires a mass balance analysis (such as the "AOI method"), Nobis believes that the method can be useful, if interpreted with appropriate caution, and especially if considered in combination with other models and investigations. NGI also states, in the fifth bullet, that a three-dimensional model … should be used as required by the by-law. Nobis agrees that three dimensional models can be very helpful, especially if the model is supported by adequate, site-specific data. This does not mean that one- or two-dimensional models are useless or should not be considered.

4.0 NEW DISPERSION CALCULATIONS

At the ZBA's request, Nobis conducted two dispersion analyses using the Domenico method. The analyses were along flow lines extending northeastward from SDA3 (Figure 1). Flow line 24 extends northeastward from SDA3 to the well that serves 55 Suffolk Lane Extension; flow line 25 is shorter and terminates in a gentle topographic low associated with a wetland at the headwaters of a brook that flows southeastward into the Site. (Flow line numbering is sequential, following previous flow lines numbered by Nobis and NGI and used for previous dispersion analyses. The new analyses were requested because previous dispersion analyses in this area were performed according to the 2015 plan which proposed to place SDA2 and SDA3 adjacent to each other.

The results of both analyses are less than 1.0 mg/L of nitrate, somewhat less than the result for flow line 11 (Table 5 in Nobis' May 1, 2015 Report) and near probable background levels for overburden groundwater. See Attachment 3 for details regarding the method, assumptions, input parameters, and results.

Of the two new analyses, the result for flow line 25 is probably the more realistic result, because this line ends in a topographic low, and the well at 55 Suffolk Lane Extension (end of line 24) is topographically higher than the end of line 25 (although the end of line 24 is lower than SDA3). It is more likely that overburden groundwater flow that includes effluent from SDA3 would discharge into the wetland/brook at the end of line 25 than that it would continue to flow northeastward.

However, these details regarding groundwater flow directions cannot be determined for sure without taking water level measurements in a series of monitoring wells in the area.

In conclusion, it is unlikely that the well at 55 Suffolk Lane Extension would be impacted by SDA3 unless a bedrock fracture that is hydraulically connected to the well reaches the top surface of the overburden, closer to SDA3 and in an area where the clay layer and dense glacial till noted in a boring at the SDA3 location are not present.

We have enjoyed working with you and the Town on this project. Thank you for the opportunity to be of service. If you require additional information, please do not hesitate to contact us at (603) 224–4182.

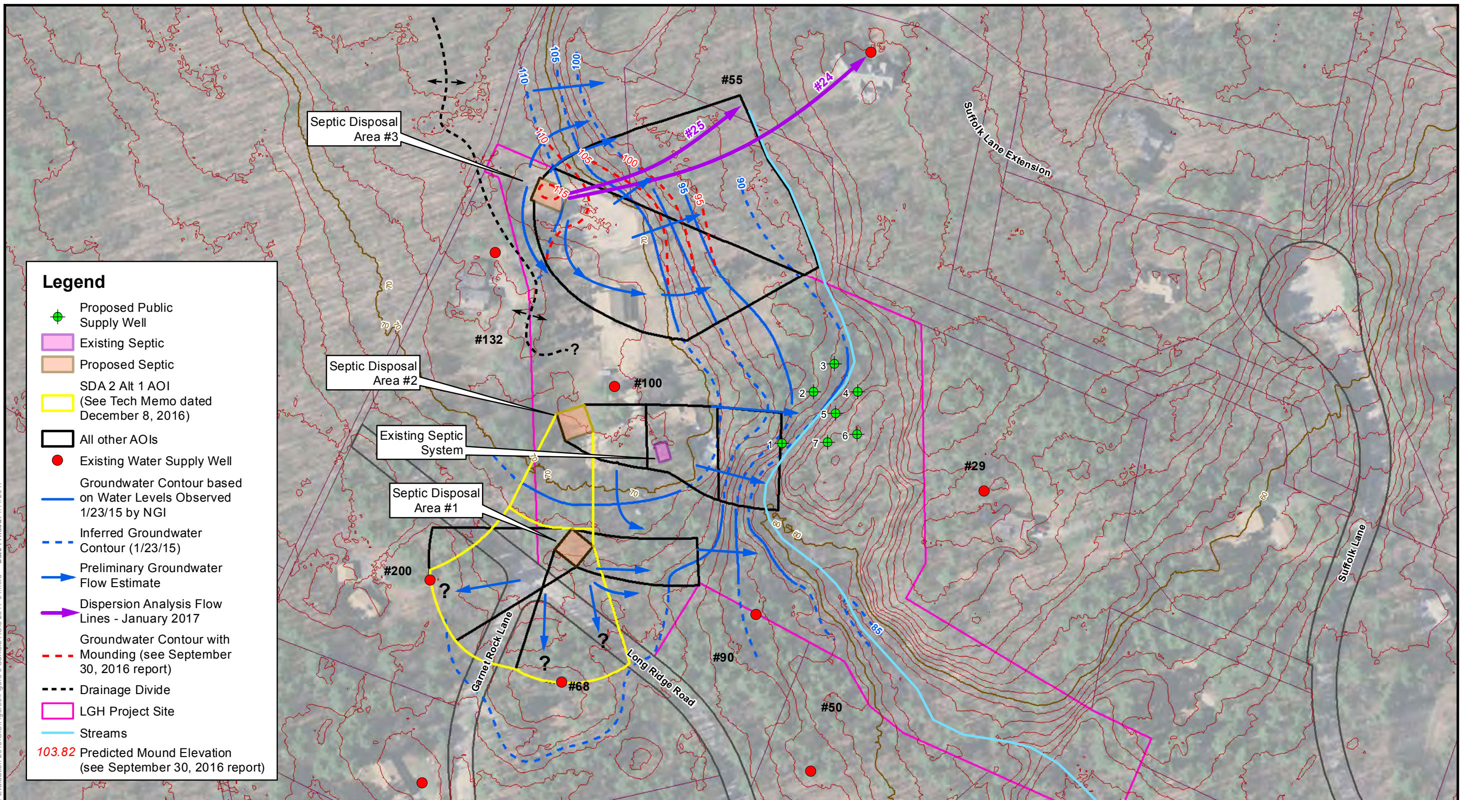
Very truly yours,

Nobis Engineering, Inc.

James H. Vernon

James H. Vernon, Ph.D., P.G.
Senior Hydrogeologist

Cc: Chris Heep



Notes:

1. See text for explanation of Dispersion Analysis Flow Lines.

2. Proposed well and septic locations from a plan titled 'Plan P - Public Water Supply' by Meisner Brem Corp., February 2, 2016.

3. Assessor's parcels are from the Town of Carlisle. Aerial photography from MassGIS web map server, 2013. Lot line for #90 Long Ridge Road is Approximate.

4. All elevations are based on a relative datum, not sea level.

5. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

0 75 150 300

Feet

1 inch = 150 feet

N

Nobis

Engineering a Sustainable Future

Nobis Engineering, Inc.
585 Middlesex Street
Lowell, MA 01851
T(978) 683-0891
www.nobiseng.com

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FIGURE 1

2017 DISPERSION ANALYSES
PROPOSED SEPTIC DISPOSAL
AREAS AND WELLS
100 LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 89220.00	DATE: JANUARY 2017

Path: J:\89220.00 - Carlisle Hydrogeo Evaluation 2015\GIS\Figures\Figure 3 Carlisle AOIs 2017-01.mxd Date Printed: 1/11/2017

ATTACHMENT 1

NGI EMAIL DATED 1/9/17

TEST PIT MONITORING WELL INFORMATION

James Vernon

From: Joel Frisch <jfrisch@ngeo.net>
Sent: Monday, January 09, 2017 3:11 PM
To: James Vernon
Subject: Re: 100 Long Ridge questions
Attachments: Soil Testing - Brem.pdf

Hi Jim,

MW-1-14 is a 2-inch diameter PVC well screen and riser that was put in with a backhoe during test pit work. The pipes in TP-305 and TP-306 are 4-inch diameter flexible drain pipes with slotting cut during the manufacturing process and they have open ends… these are the most like monitoring well screens but don't have as much open screen area as a well screen. The other pipes are 4-inch diameter drain pipes with some holes cut during manufacture and are open ended… these don't have a ton of open area but should allow groundwater to seep in. Since most of these pipes were put in with a backhoe they are not the best monitoring wells, but we wanted to get some field data in order to estimate the groundwater flow direction. The data is not optimal but is the best we have. Also, it's common practice for engineers or surveyors to drop stones down these wells to see if they have water in them… so I wouldn't be surprised if they are obstructed.

I've attached what I have for test pit logs. I'm not sure what's there and/or what missing. The BOH should have all the logs since they observed the work.

The pipe in TP-306 is around 8.5 feet deep and sticks-up less than 1 ft above grade.
The pipe at the SE corner of the SDA is around 9.5 feet deep and sticks-up around 4 feet above grade
The pipe in TP-302 is around 9 feet deep and sticks-up around 1-2 feet above grade.

Let me know if you have any other questions.

Thanks,

Joel Frisch
jfrisch@ngeo.net

Northeast Geoscience, Inc.
97 Walnut Street
Clinton, MA 01510

978-365-9045 Office
978-660-2896 Cell
978-365-9378 Fax

www.ngeo.net

On Jan 8, 2017, at 11:48 PM, James Vernon <jvernon@nobiseng.com> wrote:

1/8/17

Hi Joel,

The Town of Carlisle has asked me to review and comment on your 1/4/17 report. it looks like you have done some really interesting modelling work for the site!

I have some questions, so far, and may have some more as we conduct our review.

1. Your map, Figure 1, shows a monitoring well that is unfamiliar to me – MW-1-14. Can you send me a log for that well?
2. For the test pit monitoring wells, do you know if they consist of simple PVC pipes, open only at the end, or do they have saw cuts or perforations?
3. Do you know how far into the pits the pipes extend? I am interested in the ones for which you measured water levels as well as the ones that were dry/
4. Can you direct me to a plan that has the test pit logs, or can you send them to me? Again, I am interested in the ones that were dry on 12/30/16 in addition to the ones that had water.

Thanks,
JIm

James H. Vernon, Ph.D.
Senior Hydrogeologist
JVernon@nobiseng.com

<image007.png>

Nobis Engineering, Inc.
18 Chenell Drive
Concord, NH 03301

Main: (603) 224-4182
Direct: (603) 513-7331
Cell: (603) 731-8839

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Follow Nobis: <image008.png> <image009.png>

ATTACHMENT 2

NGI EMAIL DATED 1/11/17

SOLUTE TRANSPORT MODELLING INFORMATION

AND

ADDITIONAL AT123D MODEL RUN

From: Joel Frisch [mailto:jfrisch@ngeo.net]
Sent: Wednesday, January 11, 2017 11:15 AM
To: James Vernon <jvernon@nobiseng.com>
Cc: Jennifer Lambert <jlambert@nobiseng.com>
Subject: Re: additional questions

Hi Jim,

Please see my responses below...

Thanks,

Joel Frisch
jfrisch@ngeo.net

Northeast Geoscience, Inc.
97 Walnut Street
Clinton, MA 01510

978-365-9045 Office
978-660-2896 Cell
978-365-9378 Fax

www.ngeo.net

On Jan 10, 2017, at 2:27 PM, James Vernon <jvernon@nobiseng.com> wrote:

1/10/17

Hi Joel,

1. The report states that the SEVIEW 7.1 software reporting package uses the AT123D model. Please confirm that the software used a continuous (non-decaying) source for the nitrate concentrations.

Yes. The source was continuous, non-decaying based on a mass derived from 1,980 gpd at 19 mg/l/.

2. Nobis had used an effective porosity of 0.2 and a total porosity of 0.35. The "porosity" listed in the tables in the NGI Report appears to correspond with the total porosity value. The SEVVIEW program uses effective porosity for its program input. However, the input parameters listed in Appendix B include a value of 0.35 for effective porosity.

a. Varying the porosity does not have a significant impact on the Domenico equation used because it impacts only groundwater flow rates, which do not significantly change the output with the small variability in effective porosity. Is the same true for the AT123D analysis?

I re-ran AT123D with a porosity of 0.20 and the result is attached. Using an offset for the well at #68… (i.e. not a centerline calculation) I get 4.46 mg/l with ne = 0.20 versus 3.91 mg/l from the original model run with ne = 0.35.

b. Please confirm the input parameters and values used for the SEVIEW 7.1 software.

I attached a screen shot of the aquifer input parameters for AT123D.

c. If 0.35 was indeed used for effective porosity, can you re-run the program to determine the difference (if any) between using 0.2 and 0.35 for the ultimate output?

Done. See above and attached.

3. In Appendix A, the sensitivity analysis graph, it appears that Source Depth and Transverse Dispersivity are the only two parameters for which the model is sensitive. Are we reading the graph correctly?

Yes. That's correct. I suspect the source depth sensitivity is a result of the fact that the vertical dispersion is low and the added source depth reduces the vertical spreading along the centerline. The Domenico model uses seepage velocity and time to propagate the mass through the model. If you assume no mixing with the underlying groundwater and you use Darcy's Law to back calculate the depth of the source, so that you get the same daily mass of nitrogen...the source depth ends up being less than 6 feet (actually 4.37 feet)… so using a 6 ft source depth overestimates the daily mass in the model.

For example: 1,980 gpd at 19 mg/l gives you ~142,000 mg/day nitrogen. The mass calculated from using a 6 foot deep source area in the Domenico model, using Q = KiA where A equals the source width x the source depth you get = 10.2 ft/day x 0.079 x (75 ft x 6 ft) = 362.6 ft^3 /day = 10,267 l/day x 19 mg/l = 195,000 mg/day. So the Domenico model source is overestimating the nitrogen input by about 37%.

The sensitivity of the Domenico model to transverse dispersivity is not surprising, since this is the main feature of the model. In permeable soils longitudinal dispersion is limited since advection is dominant in the direction of groundwater flow, so transverse dispersion will drive the overall plume dimensions.

4. Is "Source Depth" defined as the depth to the bottom of the Septic Disposal Area, or is it the separation between the bottom of the SDA and the water table, or is it something else?

Source depth in the Domenico Model is a vertical plane perpendicular to groundwater flow on the downgradient edge of the source from the top of the water table downward.

5. In Appendix B, is the “Organic Carbon (percent)” truly 0.02%, or is it 2%? More importantly, is your analysis conservative, or are you assuming some breakdown of nitrates along the way?

The Organic Carbon % is a default input parameter but isn’t used with a conservative solute. We assumed a conservative solute so that value is irrelevant. There is no reaction or decay assumed.

The main differences with the AT123D model and the Domenico model include:

- The Domenico model uses a vertical plane perpendicular to groundwater flow as the source and the plane is the starting point of the model… AT123 can simulate multiple point, line, plane and volume sources; we used a plane source at at the water table to simulate flow from the septic system to the aquifer, which is more similar to how a septic system actually works.

- The Domenico model calculates the concentration at a point by determining the seepage distance from the source plane for a given time and then then spreads the constant source based on the dispersion terms...AT123D calculates a uniform flow field based on the aquifer parameters and then propagates the mass from the source through the flow field, spreading the mass based on the dispersion terms… this allows for you to model multiple sources of different dimensions and with different source concentrations at the same time.

As you can see from the above descriptions, the models are very different and simulate solutes in different ways. Using these different approaches really makes you think about the problem in different ways and gives you a better understanding of the problem overall. As a result of all of the modeling we did and the confusion that it can cause with folks not familiar with the limitations and sensitivity, I can up with (yet another model!) a more simplified way to think about the site based on mixing of the wastewater with the daily aquifer discharge, which I will send over for you to consider as soon as I finish the write-up. I think this approach is a good way to think about the problem and is easy to understand.

Please let me know if you need any more information or if you have any questions.

Regards,

Joel

Thanks,
Jim

James H. Vernon, Ph.D.
Senior Hydrogeologist
JVernon@nobiseng.com

<image002.png>

Nobis Engineering, Inc.
Main:
(603) 224-4182
18 Chenell Drive
Direct:
(603) 513-7331
Concord, NH 03301
Cell:
(603) 731-8839

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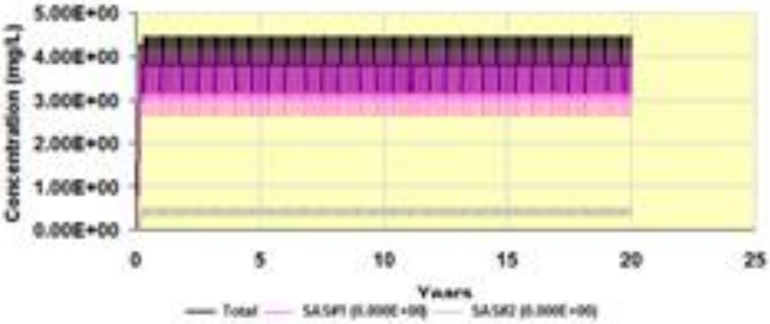
<image004.png>

<image006.png>

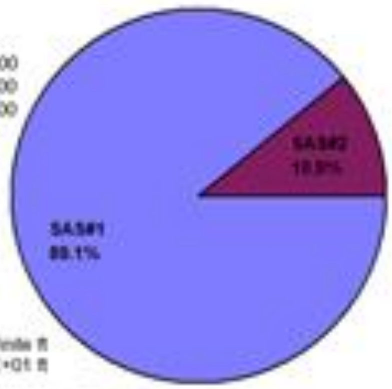
Thanks for the good well and test pit info you sent yesterday. Here are some more

questions:



Maximum Concentration: 4.462E+00 mg/L
Year of Maximum Concentration: 0.33

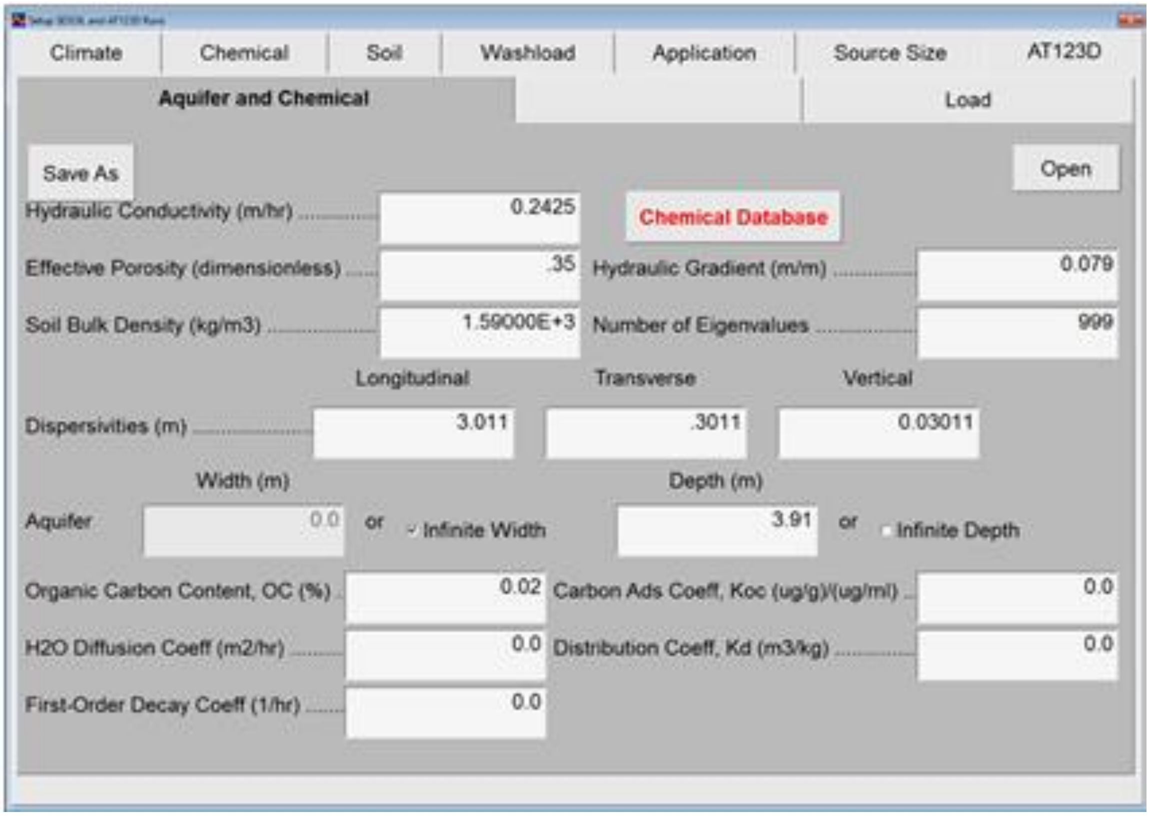
INPUT PARAMETERS



Organic Carbon (percent):	0.02000
Effective Porosity:	0.20000
Hydraulic Gradient (m/m):	0.07900

Dispersivities	Meters	Feet
Longitudinal:	3.011E+00	9.878E+00
Lateral:	3.011E-01	9.878E-01
Vertical:	3.011E-02	9.878E-02

Aquifer Width:	Infinite m	Infinite ft
Aquifer Depth:	3.910E+00 m	1.282E+01 ft
Retardation Factor:	1.000E+00	
Soil Bulk Density:	1.590E+03 kg/m3	1.590E+00 g/cm3
Molecular Diffusion:	0.000E+00 m2/hr	0.000E+00 cm2/sec
Decay Coefficient:	0.000E+00 1/hr	0.000E+00 1/day
Hydraulic Conductivity:	2.425E-01 m/hr	6.736E-03 cm/sec
Carbon Adsorption		0.0000E+00 (ug/g)/(ug/ml)
Kd:	0.000E+00 m3/kg	0.000E+00 (ug/g)/(ug/ml)
Retarded Darcy Velocity:	9.579E-02 m/hr	2.660E-01 cm/sec
Retarded Longitudinal Disp. Coefficient:	2.884E-01 m2/hr	8.011E-01 cm/sec
Retarded Lateral Dispersion Coefficient:	2.884E-02 m2/hr	8.011E-02 cm/sec
Retarded Vertical Dispersion Coefficient:	2.884E-03 m2/hr	8.011E-03 cm/sec


Climate
Chemical
Soil
Washload
Application
Source Size
AT123D
Aquifer and Chemical
Load
Save As
Open
Hydraulic Conductivity (m/hr)
0.2425
Chemical Database
Effective Porosity (dimensionless)
.35
Hydraulic Gradient (m/m)
0.079
Soil Bulk Density (kg/m3)
1.59000E+3
Number of Eigenvalues
999
Longitudinal
Transverse
Vertical
Dispersivities (m)
3.011
.3011
0.03011
Width (m)
Depth (m)
Aquifer
0.0
or
Infinite Width
3.91
or
Infinite Depth
Organic Carbon Content, OC (%)
0.02
Carbon Ads Coeff, Koc (ug/g)/(ug/ml)
0.0
H2O Diffusion Coeff (m2/hr)
0.0
Distribution Coeff, Kd (m3/kg)
0.0
First-Order Decay Coeff (1/hr)
0.0

ATTACHMENT 3

NOBIS 2017 DISPERSION ANALYSES

MEMORANDUM

To: File 89220

From: Jennifer Lambert

Subject: Carlisle: updated dispersion estimates from Septic Disposal Area #3

Date: January 11, 2017

The Town of Carlisle has requested that Nobis perform additional nitrate dispersion estimates for nitrates emanating from septic disposal area #3 (SDA3). The two additional flow lines have been labeled as Line 24 and Line 25 to avoid confusion with other evaluations that have been conducted by Nobis and NGI. These flow lines are shown in Figure 1. Flow line #24 ends at the water supply well at #55 Suffolk Lane, and flow line #25 ends at the stream located between #55 Suffolk Lane and SDA3. Note that the water supply well is at a higher elevation than the stream; therefore, nitrates from the septic disposal area travelling to the northeast are likely to be intercepted by the stream and be transported to the southeast with the stream.

The septic disposal in the northern corner of the subject property has been changed from two to one disposal cell since Nobis provided our original calculations (May 1, 2015 Report). In addition, the groundwater contours have also been revised to incorporate revised data associated with the new SDA configuration proposed in 2016.

As described in Nobis' 2015 report, we used a one-dimensional, time-dependent variant of the Domenico equation (Domenico, 1987) to determine nitrate concentrations at downgradient locations, based on an assumed initial concentration of 19 mg/L. This equation is as follows:

$$C(X,0,0,t) = \frac{C_0}{2} exp\left\{\left(\frac{X}{2\alpha_x}\right)\left[1-\left(1+\frac{4\lambda\alpha_x}{v_x}\right)^{\frac{1}{2}}\right]\right\} \times erfc\left\{\frac{X - v_x t\left(1+\frac{4\lambda\alpha_x}{v_x}\right)^{\frac{1}{2}}}{2(\alpha_x v_x t)^{\frac{1}{2}}}\right\}$$

$$\times\, erf\left\{\frac{Y}{4(\alpha_y x)^{\frac{1}{2}}}\right\} \times erf\left\{\frac{Z}{4(\alpha_z x)^{\frac{1}{2}}}\right\}$$

Where:

C = predicted concentration at given location (x,0,0) and time (*t*)

C_0 = initial concentration at source

Nobis Engineering, Inc.
18 Chenell Drive
Concord, NH 03301
T (603) 224-4182

X = distance from source (source dimension in the x direction)

α_x = longitudinal dispersivity

λ = decay constant (λ = 0.693/half-life)

v_x = groundwater velocity

α_y = horizontal transverse dispersivity

α_z = vertical transverse dispersivity

Y = source dimension in the y direction

Z = source dimension in the z direction

The calculated concentrations for the ends of flow lines 24 and 25 are shown in Table 1. Nobis used the same parameters and supporting calculations as before, with the following exceptions:

1. The source width, X, was reduced to 18.1 m to reflect a single septic disposal area (SDA3 as proposed in 2016).
2. The flow line length, Y, is based on the distance to the receptors as described above.
3. The gradient (ΔH) is based on the mounded water elevations. To be conservative, the water elevation at the water supply well is assumed to be the same as that of the stream, although it actually is higher, as it is uphill of the stream.
4. Other parameters are dependent on X, Y, and ΔH and vary based on their values.

The revised concentrations at these two targets are below 1 mg/L.

References:

Domenico, P. A. (1987). An analytical model for multidimensional transport of decaying contaminant species. Journal of Hydrology, 91: 49-58.

Table 1
Nitrate Dispersion Analysis - Additional Flow Lines
100 Long Ridge Road
Stratford, Connecticut

Line No.	Start	End	K (m/yr)	X (m)	Y (m)	Z (m)	ΔH	v_X (m/yr)	α_X (m)	α_Y (m)	α_Z (m)	C_0 (mg/L)	T (yr)	C (mg/L)	Target
24	Septic 3	Higgins #55 well	1145	182.3	18.1	1.8	0.05	274.8	5.9469	0.5947	0.595	19	30	0.43	5
25	Septic 3	Stream to northeast	1145	103.9	18.1	1.8	0.08	482.03	4.5137	0.4514	0.451	19	30	0.91	5

Aquifer Properties

n = 0.35
n_e = 0.2
ρ_d (g/cm^3)= 1.59

	K (ft/day)	K (m/yr)
MW-1	23.8	2642
MW-1A	14.4	1600
MW-2	12.1	1347
MW-2A	7.86	874
MW-3	8.84	983
MW-3A	12.4	1377
MW-4	2.09	232
MW-5	6.06	674

	source H (ft)	end H (ft)	length (ft)	ΔH
Line 24	115.68	90	535.0	0.048
Line 25	115.68	90	305.0	0.0842

Notes:
Kd = solute-specific distribution coefficient, T = arrival time
C_0 = source concentration, C = predicted concentration
V_C substituted for V_X in equation below to incorporate retardation
$V_C = V_X/(1+[(1-n)/n*K_d*\rho_d])$
$v_X = \Delta H * K/n_e$

050916 changes:
corrected formula to covert K values in cells G16-G23; did not change C results
in denominator in column S, changed 2 to 4