Comments on the "Stormwater Analysis and Calculations Report" and Site Design Plans, Prepared by Meridian Associates for the Proposed Solar Installation in the Scarboro Brook Watershed by BWC Scarboro Brook, LLC

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<u>Summary Points</u>

1. The Scarborough watershed is prone to flooding as evidenced by recent flooding of Gulf Road and Federal Street. The proposed project will make the problem much worse.

2. The Applicant has used inappropriate infiltration estimates to predict stormwater runoff after project installation.

3. The Applicant has failed to provide the required number of soil test pits.

4. The Applicant has exceeded the maximum allowable area draining to infiltration basins.

5. The Applicant has miscalculated the maximum capacity of the proposed infiltration basins. As a result, it can be shown that the peak stormwater flow rate under the proposed conditions will exceed the existing peak stormwater flow rate for the 10-year storm, thus failing the Massachusetts Stormwater Standard.

6. The impoundment structure for infiltration pond 30-P may not be safe as presently designed. The impoundment structure for infiltration pond 30-P may need to be designed and constructed to standards necessary for a dam.

Introduction

The proposed solar installation in the Scarborough Brook watershed off Gulf Road in Belchertown by BWC Scarboro Brook, LLC ("BWC") will create safety and health concerns resulting from increased stormwater runoff, erosion, and flooding from the site for both abutters and downstream properties. The resulting damage would affect a perennial stream segment within a designated flood zone, a contributing area for a drinking water aquifer, and habitat for protected species. In light of these risks, we strongly urge the Belchertown Planning Board to not approve the special permit, nor approve the stormwater management plan and site design for this project.

Background

In addition to comments that have been previously presented to the Belchertown Conservation Commission (dated January 28, 2019), the following are presented as further evidence supporting our contention that high risks and damage will occur to downstream properties from the BWC Gulf Road project. Our overarching concerns are that Scarborough Brook, Gulf Road, Federal Street and associated properties will repeatedly suffer damaging floods that will be augmented by the stormwater from the project site. This project puts at risk the health and safety of all residents who rely on these roads which currently are affected by flooding.

1. The Scarborough watershed is prone to flooding as evidenced by recent flooding of Gulf Road and Federal Street. The proposed project will make the problem much worse.

The whole lower portion of the Scarborough Brook watershed is vulnerable to large and damaging floods. See, for example, the video of the flooding that occurred on Thursday, January 24, 2019, on both Gulf Road and Federal Street after a typical "rain-on-frozen-ground" storm event. These floods can be large and very damaging. The January event was at least the third time Federal Street has flooded at this location in the past 5-10 years and past flooding has required significant repairs to the road, shoulders, culverts, embankments, and driveways. There have been large amounts of water at a number of locations along Scarborough Brook during storm events, but particularly along the designated FEMA flood zone A that is in the lower reach of Scarborough Brook. Any additional water from the BWC Gulf Road project area to the designated flood zone along Scarborough Brook will create more frequent and damaging flooding than recent events. The project will clear-cut 40+ acres of forest and leave 20+ acres of soil open to runoff and erosion. To expect that the project design could avoid the serious risk of catastrophic flooding problems downstream in the future is pure conjecture. Indeed, since the floods over the last few years were produced by modest rainfalls (i.e., greater than a 5-year occurrence interval), then much more damaging floods can be expected from a really large event, for example, the 25-, 50-, or 100-year rainfall.

Analysis

The central problem with the stormwater design for the BWC-Gulf Road project is the 1) the increased amount of stormwater runoff produced during major storm events, (2) the limits to the amounts of water that can be stored in the project's detention and infiltration basins, and (3) the limited amount of water absorbed (infiltrated or recharged) by the soil (the overburden above the bedrock) below the basin floors. Total runoff, infiltration and peak flow rates for the project area are summarized in Table 1.

Table 1. Total Estimated Runoff Volumes (cf) and Rates (cfs) for the 24-hr Storm Event from the BWC Project Area under Existing and Proposed Conditions with Proposed Infiltration Basins
(Data from Meridian Associates Stormwater and Calculation Report, January 18, 2019)

Stormwater Component	2-year Storm (3.05 in.)	10-year Storm (4.91 in.)	100-year Storm (7.88 in.)
Proposed Conditions			
(A) Total Runoff from All Subcatchment Areas	Volume = 217,482 cf	Volume = 628,724 cf	Volume = 1,483,652 cf
(B) Total Infiltration	Volume = 72,447 cf	Volume = 172,419 cf	Volume = 249,177 cf
Total Infiltration as % of Total Runoff	33%	27%	17%
(C) Total Runoff Leaving the Project: (A)- (B)	Volume = 145,035 cf	Volume = 456,305 cf	Volume = 1,234,475 cf
Peak Flow	Rate = 16.36 cfs	Rate = 66.22 cfs	Rate = 169.73 cfs
Existing Conditions			
(D) Total Runoff from All Subcatchment Areas	Volume = 145,227 cf	Volume = 455,781 cf	Volume = 1,167,622 cf
Peak Flow	Rate = 21.91cfs	Rate = 77.80 cfs	Rate = 213.64 cfs
Difference Between Proposed and Existing Conditions			
(E) Total Runoff: (C) – (D)	Volume = -192 cf	Volume = 554 cf	Volume = 66,853 cf
Total Runoff Difference as % of Existing	-0.1%	0.1%	5.7%
Peak Flow Difference as % of Existing	-25%	-15%	-20%

The difference between the total runoff generated from all the subcatchment areas under the proposed conditions (A) and the total runoff leaving the project area (C) is the amount of infiltration (B) discarded (absorbed) in the infiltration basins 11P, 23P, 30P and 50P. This infiltration (B) varies between 33% and 17% of the total runoff for the 2, 10, and 100 year storm conditions. The figures in Table 1 for the total stormwater runoff (C) match the total in the Introduction of the Meridian Report, pages 6 and 7. Together, these figures lead to some sobering conclusions.

2. The Applicant has used inappropriate infiltration estimates to predict stormwater runoff after project installation (the proposed condition in Table 1).

The total runoff volumes leaving the project area calculated by Meridian (component C in table 1, above) are very similar to the estimated existing runoff conditions (D), and the differences are small, varying between -0.1% to 5.7%. Therefore, the estimates of infiltration from the basins are a critical element in the Meridian design to control stormwater volume. An important question is whether the estimates of infiltration rates and volumes of stormwater infiltrated by the basins are reasonable given the conditions at the project site.

Meridian used the Rawls rate (Massachusetts Stormwater Standards, Volume 3, Chapter 1, page 6) as the infiltration rate over the duration of time that water remains in the infiltration basin. This is an acceptable approach, as long as the subsurface materials can absorb the amounts of water infiltrating through the surface of the basin. There are limits, however, to the amounts of water that can infiltrate into the subsurface under the following conditions: (a) when soils are thin, i.e., bedrock is close to the surface, or (b) there is a high groundwater table and the volume of “unfilled” pore space among the soil particles is limited. Both are those conditions affect this project.

3. The Applicant has failed to provide the required number of soil test pits.

In order to determine the thickness of the soil and the depth to the water table to determine if there is any limitation to the infiltration capacity of an infiltration basin, the Applicant must provide sufficient soils test pit data. The Applicant has failed to provide a sufficient number of these data.

The site design criteria for infiltration basins are specified in Massachusetts Stormwater Standards Volume 2, Chapter 2, “Structural BMP Specifications for Massachusetts Stormwater Standards”, Table 1B.1, “Site Criteria for Infiltration Basins, pages 86-93. These criteria include a required minimum number of soil samples for each basin. The latter is stated as “One soil sample for every 5,000 ft. of basin area is recommended, with a minimum of three samples for each infiltration basin. Samples should be taken at the actual location of the proposed infiltration basin so that any localized soil conditions are detected.”

An examination of the soil test pit data for the proposed site provided on the Applicant's most recent soils report entitled "Test Pit Information," dated February 4, 2019, shows the following:

Table 2. Soil test pits required and provided.
(Data from Meridian Associates Test Pit Information sheet, February 4, 2019)

Infiltration Pond Name	Minimum Number of Test Pits Required by Mass Regulation	Number of Test Pits in Meridian Site Plan
11P	3	1
23P	3	1
30P	6	2
50P	3	1
Totals	15	5

The site design clearly has not met the minimum required number of soil samples needed to properly design the infiltration basins where, at a minimum, there should be 15 soil samples, and only 5 were provided at the pond locations on the site plan; 33% of the minimum needed.

4. The Applicant has exceeded the maximum allowable area draining to infiltration basins.

The site design criteria for infiltration basins as specified in Massachusetts Stormwater Standards, noted above, also specifies the maximum contributing area for any individual basin, 15 acres. Two of the basins, 23P and 30P, in the BWC-Gulf Road project design exceed the maximum allowable 15 acres draining to any individual basin. In the case of basin 23P, the area draining is 22.7 acres, and for basin 30P the drainage area is 24.8 acres, as shown in the Meridian stormwater report. Again, as with the number of soil samples, the applicant has not met the Massachusetts Stormwater Standards for the infiltration basin designs.

5. The Applicant has miscalculated the maximum capacity of the proposed infiltration basins. As a result, it can be shown that the peak stormwater flow rate under the proposed conditions will exceed the existing peak stormwater flow rate for the 10-year storm, thus failing the Massachusetts Stormwater Standard.

The maximum rates and amounts of water that can infiltrate into the basins can be estimated using a "Mounding Analysis", as described in the Massachusetts Stormwater Handbook, Volume

3, Chapter 1, “Documenting Compliance”, pages 28-29. In fact, the mounding analysis is required for pond 30-P as the depth from the pond bottom to the seasonal high groundwater level is less than 4 feet (see table 3 below, “failure depth”) and the pond is used to attenuate the peak discharge from a 10-year or higher storm. Meridian has not submitted the required mounding analysis for pond 30-P, and hence I did the analysis for that pond, along with the other 3 infiltration ponds in the project design (11-P, 23-P, 50-P). Factors that influence the maximum rate of infiltration in this analysis include the infiltration rate, specific yield, horizontal hydraulic conductivity, the length and width of the basin, duration of the recharge period, and the initial thickness of the saturated zone. The infiltration basins 11P, 23P, 30P, and 50P were evaluated using those variables. The data used in this analysis are shown in Table 3. Estimates of hydraulic conductivity and specific yield are based on values published in Melvin et.al. (1992)[1].

Table 3. Mounding Analysis based on Hantush (1967)[2], as implemented by Carleton (2010)[3].
Note: All calculations use a specific yield of 0.15 (ft/ft), and a hydraulic conductivity of 10 (ft/day).

	Basin			
Factor/Result	11P	23P	30P	50P
Basin Length (ft)	60	76	100	134
Basin Width (ft)	132	152	290	134
Initial Saturated Thickness (ft)	10	10	2	1
Failure Depth (ft)	4	5.6	2.5	5.5
Infiltration Rate, 24 hrs (ft/day)	0.85	1.05	0.37	0.83
Infiltration Rate, 72 hrs (ft/day)	0.45	0.52	0.14	0.29

[1] Melvin, R., and others, 1992, Hydrogeology of thick till deposits in Connecticut, U.S. Geological Survey Open-File Report 92-43

[2] Hantush, M. S. 1967. “Growth and Decay of Groundwater Mounds in Response to Uniform Percolation.” *Water Resources Research*, Vol.3, 227–234.

[3] Carleton, G.B., 2010, Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins: U.S. Geological Survey Scientific Investigations Report 2010-5102, 64 p.

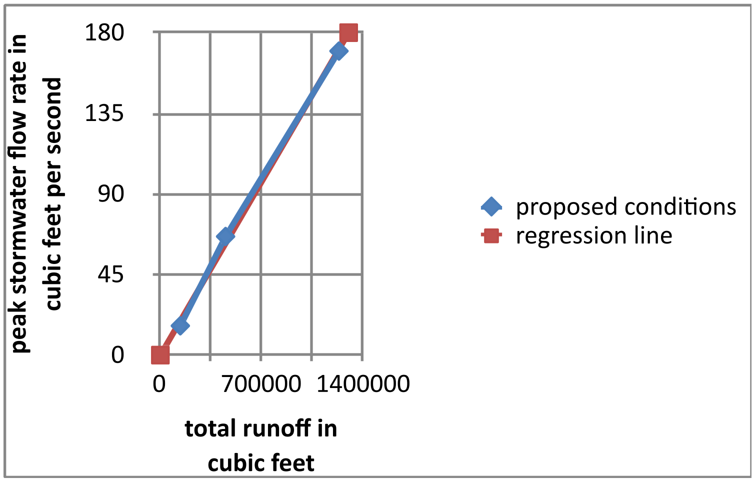
“Failure Depth” in Table 3 is the distance between the elevation of the estimated seasonal high groundwater (“E.S.H.G.W.” in Meridian’s Test Pit Information sheet) and the elevation of the basin bottom. If the 24-hour estimate of infiltration is multiplied by the area of the basin, the result is the volume of infiltration for each basin as shown in Table 4. Using these estimates (or the smaller volume for infiltration basin 11P as noted in the Meridian report), the total infiltration for the 10-year storm can be estimated as 41,336 cubic feet of water. This estimate of infiltration is significantly smaller than the estimate from the Meridian report for the same storm; 172,419 cubic feet of water. An alternative calculation of the total infiltration for the four basins can be calculated by taking the area of each basin, multiplied by the failure depth and specific yield, and summing all of these volumes. The result is 40,144 cubic feet of water, which is very close to the figure estimated from the mounding analysis. Clearly the estimate by Meridian Associates, based solely on the maximum rate of infiltration at the surface (i.e., the Rawls rate), significantly over-predicts the amount of water that can enter the subsurface beneath the basins.

Table 4. Estimates of stormwater infiltration volumes using the infiltration rates from Table 2 and areas of the basins and estimates of total infiltration volume using the basin area, failure depth, and specific yield.

Basin	*Basin Area (ft^2)* *(Basin Length x Basin Width)* *(source: Table 2)*	*Infiltration Rate, 24 hrs (ft/day)* *(source: Table 2)*	*Volume of Infiltration (ft^3)* *(using 24 hr infiltration rate)*	*Volume of Infiltration (ft^3)* *(using failure depth)*
11P	7920	0.85	6732	4,752
23P	11,552	1.05	12,130	9,704
30P	29,000	0.37	10,730	10,875
50P	17,956	0.83	14,903	14,814
Total estimated runoff volume:			44,495	40,144

With the above estimate of total infiltration (41,336 ft^3), it is possible to predict the peak stormwater flow rate using a regression analysis for the proposed conditions (post) peak stormwater flow rates. The graph below (fig. 1) shows the three peak flow rates plotted with the associated volumes of runoff (component C in table 1) for the 2-year, 10-year, and 100-year storms as predicted by Meridian Associates. A linear regression through these data points produces a regression coefficient of 0.999, indicating that there is a very good correlation between the total stormwater runoff and the peak stormwater flow rates as predicted by the model used by Meridian.

Figure 1. Regression of total runoff from the BWC-Gulf Road project for the 2-year, 10-year, and 100-year storms versus the peak stormwater flow rates for the same storms for the proposed conditions; data from the 1/18/2019 Meridian Strromwater Calculations and Analysis Report.



The total stormwater runoff from the project area can then be calculated by subtracting the infiltration volume predicted using the mounding analysis from the total runoff from all the subcatchment areas for the 10-year storm (628,724 – 41,336 = 587,388 cubic feet). The updated peak stormwater flow rate for the larger total runoff can then be predicted using the regression relation; this value is 80.7 cubic feet per second (ft^3/s), 22% greater than the original prediction by Meridian Associates. The updated peak stormwater flow rate under the proposed conditions is larger than the predicted peak flow rate of 77.8 ft^3/s for the existing condition, indicating that, in fact, the peak stormwater flow rate under the proposed conditions will exceed the existing peak stormwater flow rate for the 10-year storm, thus failing the Massachusetts Stormwater Standard that requires the proposed condition not exceed the existing condition for the 10-year storm.

6. The impoundment structure for infiltration pond 30-P may not be safe as presently designed. The impoundment structure for infiltration pond 30-P may need to be designed and constructed to standards necessary for a dam.

An examination of the BWC-Gulf Road site design plans shows that infiltration pond 30-P is located on the western side of the project area (site design sheets 9, 10). The top of the impoundment is at 390 feet, the bottom of the pond is at 384 feet, and at maximum depth the pond holds back about 6 feet of water. The elevation of the toe (bottom) of the western slope of the impoundment structure is at 374 feet, and hence the total height of the embankment is 16 feet high. The embankment is 350-400 feet in length (north-south). The information in the Stormwater Analysis Calculations Report by Meridian Associates indicates that the total storage in the pond is 189,201 cubic feet at maximum depth; this is equivalent to 4.34 acre-feet or 1,415,200 gallons of water; a little over the volume of two Olympic-sized swimming pools.

The distance from the bottom of the western side of the impoundment embankment structure for pond 30-P to the nearest home is about 500 feet due west of the pond, and the elevation of the home is at about 280 feet. If the embankment for infiltration pond 30-P were to fail when full, the 1.4 million gallons of water released from storage would run down the 100 foot slope immediately west of the pond, gaining significant velocity as it moved down the very steep slope. As the water cascaded down the slope it would scour the hillslope, entraining soil, rock, and woody debris with the 1.4 million gallons of water released from the pond. If that wall of water and debris were to impact the home at the bottom of the slope it would likely do significant damage and possibly endanger the lives of the occupants. The flood wave would then travel down Scarborough Brook and likely plug the culvert under State Route 9 with the entrained debris. After the culvert was clogged with debris the flood wave would inundate route 9 and begin to fill the lower areas south of the highway. The flood wave, if the culvert under the railroad bed isn't also plugged by the debris, would then continue downstream to flood and likely over-top the culvert under Federal Street, inundating the low-lying areas along that road.

So, how likely is this scenario? That is, is infiltration pond 30-P vulnerable to failure? An examination of the cross-section of the embankment for pond 30-P on sheet 12 of the BWC-Gulf Road site design plans shows that the clay column in the center of the embankment is to be emplaced one foot below grade. Typically an earth dam will have the low-permeability core emplaced down to bedrock. For example, the Army Corps of Engineers manual on dam construction states:

"6-3. Earth Foundations a. Introduction. All dams on earth foundations are subject to underseepage. Seepage control is necessary to prevent excessive uplift pressures and piping through the foundation. Generally, siltation of the reservoir with time will tend to diminish underseepage. Conversely, the use of some underseepage control methods, such as relief wells and toe drains, may increase the quantity of underseepage. The methods of control of underseepage in dam foundations are horizontal drains, cutoffs (compacted backfill trenches, slurry walls, and concrete walls), upstream impervious blankets, downstream seepage berms, relief wells, and trench drains." (from pages 6-1, 6-2; ; General Design and Construction Considerations for Earth and Rock-Fill Dams, ACE, EM 1110-2-230030 July 2004)

And:

"(2) Compacted backfill trench. The most positive method for control of underseepage consists of excavating a trench beneath the impervious zone of the embankment through pervious foundation strata and backfilling it with compacted impervious material. The compacted backfill trench is the only method for control of underseepage which provides a full-scale exploration trench that allows the designer to see the actual natural conditions and to adjust the design accordingly, permits treatment of exposed bedrock as necessary, provides access for installation of filters to control seepage and prevent piping of soil at interfaces, and allows high quality backfilling operations to be carried out. When constructing a complete cutoff, the trench must fully penetrate the pervious foundation and be carried a short distance into unweathered and relatively impermeable foundation soil or rock." (from page 6-2; General Design and Construction Considerations for Earth and Rock-Fill Dams, ACE, EM 1110-2-230030 July 2004).

The primary point of the above discussion is that significant seepage through the embankment for any structure that is used to store water is to be avoided as that seepage will weaken and create conditions that might lead to the failure of the structure, this would be particularly true for a structure that will hold back a large amount of water as close to a steep slope as infiltration pond 30-P. Pond 30-P has been specifically designed to allow seepage through the pond bottom and then under the constructed embankment. If it were decided that pond 30-P needed to be re-designed, and instead be constructed to standards used for dams, then the new design would likely prevent the infiltration of stormwater in pond 30-P. As the amount of infiltration from 30-P is 63% of the total infiltration for the 10-year storm (Meridian, 1/18/19 report) the loss of 30-P as an infiltration pond would substantially increase the stormwater runoff from the project site. A significantincrease in the volume of stormwater runoff will lead to an increase in the peak stormwater flow rates from the project site, as noted above (see point 5 above). For additional information on the regulations relevant to dam construction and inspections please see Massachusetts Department of Conservation and Recreation 302 CMR10.00: Dam Safety.

Conclusion

The elements as described above for the BWC-Gulf Road project will result in excess stormwater runoff and entrained sediment production from the proposed project site. The BWC-Gulf Road project site has a combination of factors including a large developed area requiring clear-cutting and stump removal, located on a significant slope, underlain by thin, easily erodible soils, and abundant water available for enhanced stormwater sunoff. It is this combination of factors that creates the problem of increased stormwater runoff from the project site. The additional water from the BWC Gulf Road project area to the designated flood zone along Scarborough Brook will create more frequent and damaging flooding than has occurred during recent flooding events. To expect that the project design with the above combination of factors could avoid a serious risk of catastrophic flooding problems downstream in the future is pure conjecture. Indeed, since the floods over the last few years were produced by relatively modest rainfalls, more extensive damage would be expected from really large events, for example, the 10-, 25-, 50-, or 100-year storms if the project were to be constructed with the design plan as shown in the 1/18/19 Site Design and Stormwater Calculations and Analysis Report.

Hence, the proposed solar installation in the Scarborough Brook watershed off Gulf Road in Belchertown by BWC Scarboro Brook, LLC ("BWC") will create safety and health concerns resulting from increased stormwater runoff, erosion, and flooding from the site for both abutters and downstream properties. The resulting damage would affect a perennial stream segment within a designated flood zone, a contributing area for a drinking water aquifer, and habitat for protected species. In light of these risks, we strongly urge the Belchertown Planning Board to not approve the special permit, nor approve the stormwater management plan and site design for this project.