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Groundwater Management Associates, Inc.

July 17, 2009

Mr. Nat Wilson
Mr. Jeff Lautier
North Carolina Division of Water Resources
1611 Mail Service Center
Raleigh, NC 27699-1611

Re: Response to April 2, 2009 Letter on the Latest Model Results,
Martin Marietta Aggregates Proposed Vanceboro Quarry Site, Beaufort County

Dear Nat and Jeff,

On behalf of Martin Marietta Aggregates (MMA), GMA has prepared this response to your letter of April 2, 2009. Your letter provided a list of comments about updated groundwater flow modeling that GMA has performed to evaluate the volume of water and area of drawdown that are anticipated for the proposed limestone aggregate quarry. GMA and MMA have reviewed and discussed your comments, and GMA has performed additional research and model runs to help address your comments. Our goal is to come to mutual understanding about the functionality, purpose, and limitations of the modeling effort so that we can formalize our model report and move ahead with the permitting process to allow MMA to proceed with planned quarry operations.

One key point of mutual understanding is that a groundwater flow model can *never* perfectly represent all aspects of the groundwater system, especially in a geological setting as complex as the Coastal Plain of North Carolina. There will always be uncertainties in the model and areas where we would like to have closer agreement between the model and field observations. We should also be mindful that the model area is extremely large and the aquifer layers have great variability in thickness and permeability. Nonetheless, we believe that the model GMA has prepared reasonably predicts the response of the aquifer to withdrawals at the proposed quarry site, as evidenced by close calibration with on-site wells that were installed for this project. Questions that you raised are related mostly to calibration errors on the perimeter of the quarry area. As we present in this letter, adjusting the model to improve calibration on the perimeter of the quarry area had relatively small effects on the predicted total volume of water required for quarry operation, but had a greater effect on the modeled size of the area of drawdown resulting from the quarry withdrawals. Increasing recharge rates and the vertical permeability values of the Castle Hayne confining unit causes the simulated area of potential drawdown impacts to become smaller.

It must be recognized that the model GMA has prepared is a tool for evaluating the potential impacts of the proposed quarry on the aquifer system and the surrounding groundwater users. Using this tool, MMA and NCDWR can devise plans to minimize impacts through monitoring programs and operational strategies. MMA has already taken steps to inventory water-supply wells that occur within a 6-mile radius of the proposed quarry. This inventory will be the basis for devising a mitigation plan that will address potential adverse impacts of the quarry on nearby groundwater users, should adverse impacts occur.

GMA has systematically considered each point of your letter, and we present our response below in a format consistent with your letter.

1. Recharge Rate

You expressed concerns over the recharge rate applied to the model. GMA had originally modeled a recharge rate of 1 inch per year. You provided references for higher recharge rates that have been assumed by others for the Coastal Plain of North Carolina. You refer to a report by Geise and others (1991) that estimates recharge in the Coastal Plain at 12 to 20 inches per year, and you refer to Heath (1994) who estimated recharge at 4 inches per year. As you obviously recognize, recharge is a very difficult parameter to quantify over a multi-county region, and recharge is affected by precipitation, evapotranspiration, runoff, and the nature of surficial sediment types. In addition, recharge can be dramatically limited by surface water drainage features.

The area of the proposed quarry lies roughly in the middle of an approximately 38 square mile area of undeveloped woodlands and farm fields. This area is extensively ditched and drained, which lowers the water table sufficiently to allow access by machinery to farm the land and harvest timber. Without this ditching system, much of the area around the proposed quarry site would be a pocosin/swamp. For example, the 1917 Soil Survey Map of Beaufort County lists this area as Blount Pocosin. In running various simulations of the quarry site, we determined that applying recharge rates as high as 4 inches per year over this area resulted in simulated water levels in the Surficial Aquifer that are above land surface. It is unrealistic to integrate simulations of the hundreds of ditches that occur over the model area in order to more accurately simulate the Surficial Aquifer water levels. Through the process of model calibration, we settled on a "net recharge" of 1 inch per year to simulate the infiltration of water through the Surficial Aquifer to recharge underlying aquifers.

Our assumptions about limited recharge are supported by site data, including a shallow temporary monitoring well installed by GMA at the site (see attached Figure 1 log of well SAMW). You will note that GMA prepared a detailed description of shallow sediments to a depth of 13 feet below land surface at the temporary monitoring well. The upper 0.5 feet was crushed limestone fill that was likely used to construct the old airport runway at the site. Below this fill material, and extending to a depth of 5.5 feet, is a low permeability section of native sediments composed predominantly of silty peat, clayey silt, and sandy silty clay. From 5.5 to 13.5 feet depth, GMA observed silty fine sand with a minor amount of clay. The static water level in SAMW was observed to be 15.68 feet higher head than in the Upper Castle Hayne Aquifer. Clearly, the low-permeability of the Surficial Aquifer at the proposed quarry site dramatically limits recharge to the Upper Castle Hayne Aquifer. Based upon our direct observations of shallow sediments at the site, and considering the extensive artificial drainage features that occur, we assert that the net recharge rate in the vicinity of the proposed quarry is less than the areas on the perimeter of the study area (like at Wilmar and Cox Crossroads).

In light of the variations in regional permeability of the Surficial Aquifer, and considering recharge estimates by Heath and others, GMA ran some alternate simulations in an attempt to bring closer calibration to the model in perimeter areas while maintaining integrity of direct site data that we have collected. From this process, we settled on a recharge rate of 2.25 inches per year close to the proposed quarry and 3.75 inches per year at more distant areas of the model (See attached Figure 2). These increases in recharge rates were accompanied by adjustments in vertical permeability of the confining layer overlying the Castle Hayne Aquifer. Results of these adjustments and new simulations are further discussed in the following sections of this letter.

2. **Vertical Hydraulic Conductivity of the Upper Castle Hayne Confining Layer**

Your letter asserts that the vertical hydraulic conductivity (Kv) used for the confining layer above the Castle Hayne Aquifer is too low, and you state that the head differences observed at the Wilmar and Cox Crossroads stations are much smaller than we observed at the proposed quarry site. Our review of water level data for the Cox Crossroads facility indicates that this station does not include a well open to the Surficial Aquifer. The Cox Crossroads station has a well screened into the Yorktown Aquifer that has approximately 8 feet higher head than the adjacent well open to the Castle Hayne Aquifer. This condition appears to be reasonably consistent with the observations we made at the proposed quarry site, and it indicates that a significant confining layer separates the Yorktown Aquifer from the Castle Hayne Aquifer.

At Wilmar, the Surficial Aquifer monitoring well has approximately 4 feet higher head than the adjacent well in the Castle Hayne Aquifer. Because the Wilmar Station is farther from the PCS pumping center, a smaller head difference between the Surficial and Castle Hayne Aquifers is to be expected.

Your letter asserts that the data from Wilmar and Cox Crossroads indicate semi-confined conditions in the Castle Hayne Aquifer. GMA's has not performed any direct aquifer testing at these sites, and we have not seen any aquifer test data from the Wilmar or Cox Crossroads sites to support a semi-confined designation. However, we do recognize that the USGS RASA Model (Geise and Others, 1997) used a range of vertical permeability values (3.01×10^{-4} to 9.07×10^{-4}) for the Castle Hayne Confining Unit that are somewhat higher than our model. Therefore, GMA performed additional model simulations to determine the effect of increasing the vertical permeability of the Castle Hayne Confining Unit. For these simulations, Kv was set at 0.01 ft/day in areas west of the quarry site (near the up-dip limits of the confining layer). The value of Kv at the proposed quarry and areas toward Cox Crossroad was increased to 0.001 ft/day.

3. Steady State Model Calibration

You expressed concern over differences between calculated and observed head values in the model for Cox Crossroads and Wilmar monitoring stations. You assert that there is a large difference between computed and observed water levels in these areas. We would also prefer closer agreement in the model. However, we also recognize that the Wilmar and Cox Crossroads sites are each several miles away from the proposed quarry site. In addition, the Cox Crossroads station shows significant influence by the PCS pumping, and water levels in the Castle Hayne Aquifer at that site have fluctuated within a range of almost 15 feet since 1996. Likewise, water levels at Wilmar have fluctuated within a range of about 8 feet. These fluctuations should be considered in the process of determining the significance of differences between predicted and observed water levels used in the model calibration.

GMA has run additional simulations that incorporate the increases in recharge to portions of the model and higher Kv of the Castle Hayne Confining Layer. The adjustments in recharge and Kv resulted in improved calibration at the Cox Crossroads (7.08 feet difference) and near Wilmar Station (3.35 feet difference at well S30) (See Figures 3 and 4). The adjusted model still maintains good calibration in the Upper and Lower Castle Hayne Aquifer zones (Figures 5 and 6), but the model has less agreement at very distant wells (S11 and C19) located east of the PCS pumping center.

4. Size of the Cone of Depression and Volumes Predicted for Dewatering

The increases in recharge rates and Kv of the Castle Hayne Confining Unit reduced the predicted size of the cone of depression (See Figure 7). The new model simulations project an asymmetrical cone of depression that is steeper to the west and broader to the east. The projected area of 5 feet of drawdown occurs about 6 miles to the west and 7 miles to the east. The cone of depression is somewhat smaller than our prior simulation presented in March of 2009, but is reasonably consistent with the search area GMA previously presented to you in August of 2008.

As shown on Attachment A, the adjustments in recharge and Kv of the Castle Hayne Confining Unit resulted in <3% increase in projected volumes of water required for quarry dewatering. The volumes projected for dewatering range from ~11.5 million gallons per day (for dewatering 1/3 of the proposed pit) to a maximum of ~17 million gallons per day for full dewatering of the entire pit.

Simulation Name
BaseSimulation

Well ID	Pumping Rate (gpm)	MGD
East1	-600	0.864
North1	-150	0.216
South1	-400	0.576
West1	-500	0.720
West2	-600	0.864
DW1	-1500	2.160
DW2	-1200	1.728
DW3	-1500	2.160
SumpCenter	-1800	2.592
SumpEast	-1500	2.160
SumpWest	-2000	2.880
Total	-10,250	**16.920**

Results

Complete dewatering of the mine

Recharge = Increased to 3.75 inches over greater than 85% of model and 2.25 inches in the area that is extensively ditched around the potential mine site

Vertical K of confining unit overlying the Castle Hayne Aquifer increased to 0.001 near the site and 0.01 west of the site.

Previously **16.78 MGD**

West Dewater

Well ID	Pumping Rate (gpm)	MGD
North1	-150	0.216
South1	-600	0.864
West1	-150	0.216
West2	-50	0.072
DW1	-1500	2.160
DW4	-1600	2.304
DW5	-1000	1.440
DW6	-1600	2.304
DW7	-800	1.152
SumpWest	-1200	1.728
Total	-8,650	**12.456**

33% of Mine Pit Dewatered

Recharge = Increased to 3.75 inches over greater than 85% of model and 2.25 inches in the area that is extensively ditched around the potential mine site

Vertical K of confining unit overlying the Castle Hayne Aquifer increased to 0.001 near the site and 0.01 west of the site.

Previously **12.18 MGD**

Simulation Name

Dewater Center

Well ID	Pumping Rate (gpm)	MGD
North1	-250	0.360
South1	-600	0.864
DW1	-1500	2.160
DW2	-1500	2.160
DW5	-1600	2.304
SumpCenter	-2500	3.600
Total	-7,950	**11.448**

Results

33% of Mine Pit Dewatered

Recharge = Increased to 3.75 inches over greater than 85% of model and 2.25 inches in the area that is extensively ditched around the potential mine site

Vertical K of confining unit overlying the Castle Hayne Aquifer increased to 0.001 near the site and 0.01 west of the site.

Previously **11.16 MGD**

Dewater East

Well ID	Pumping Rate (gpm)	MGD
East1	-1500	2.160
DW2	-1200	1.728
DW3	-500	0.720
DW8	-1500	2.160
DW9	-1000	1.440
SumpCenter	-2000	2.880
SumpEast	-1500	2.160
Total	-9,200	**13.248**

>33% of Mine Pit Dewatered

Recharge = Increased to 3.75 inches over greater than 85% of model and 2.25 inches in the area that is extensively ditched around the potential mine site

Vertical K of confining unit overlying the Castle Hayne Aquifer increased to 0.001 near the site and 0.01 west of the site.

Remains the same at **13.25 MGD**