August 19, 2008

Mr. John Oborne
Community Development Department, Contra Costa County
651 Pine Street
Martinez, California 94533

Re: Issues with water well tests performed for proposed Creekside Memorial Park Cemetery, Tassajara Road, Contra Costa County, California

We have serious concerns with the reports prepared for Contra Costa County by ENGEO Incorporated (ENGEO 4/2007, revised 6/2008) and Aqua Systems Engineering (ASE 2005, 8/2007 and 2/2008) regarding the water supply for the proposed Creekside Memorial Park cemetery. We have already documented several of these concerns (Newman 7/2007, 10/2007, 3/2008 and 7/2008).

Accurate assessment of the water availability should be a top concern for the developer as well as for Contra Costa County in order to ensure the success of the project. We believe the tests that have been performed to date are inconclusive as to whether there is really enough water at the site to support the proposed land use, for the following reasons:

1. The well tests had a number of flaws, in that ASE did not follow the procedures recommended by Driscoll (1986) as ASE said would be done. Also, because of the partial nature of the time-drawdown test of well PW-4, it is impossible to verify the data or the true performance of the well.

2. There is no conclusive evidence presented that the aquifer is as large in extent (i.e. 31 acres by 60 or 80 feet thick) as ENGEO and ASE claim.

3. There is no conclusive evidence that the aquifer parameters determined for well PW-4 are uniform over the entire aquifer.

We suggest that the well tests be specified and reviewed before they are performed to ensure that proper testing procedures, documentation of what was done and the data collected are all accurate.

We also suggest that a more thorough verification of the presence of the volume of water claimed on the property be performed. The current claims are based on a single test well, which when pumped for 24 hours measured the performance of the aquifer for a 36 foot radius around the well, or about 0.1 acre. To extrapolate these results over the entire 31 acres claimed for the aquifer (i.e. 300 times this size) is not reasonable. The size of the aquifer could be demonstrated by drilling additional test wells distributed over the entire 31 acres, and pumping them for a length of time commensurate with the claimed size of the aquifer. For example, if a well similar to PW-4 were pumped at a constant rate of 20 gpm for approximately 720 hours (30 days), and its results were consistent with the well equations described in Driscoll (1986), it would verify the aquifer’s extent, key parameters and connectivity for about a 200 foot radius, or about 3 acres. Roughly ten test wells would cover the entire 31 acres.

In the appendix of the letter we present the detailed analysis that went into making the above statements.

In conclusion, we believe that it is far better to perform additional tests now and verify water availability than to have the cemetery run out of water after construction begins. In view of the fact that the proposed cemetery is a land use which requires a special permit from the county, it is fair to request that the applicant take special steps to insure sufficient water is available.

In an area that has supported only “dry farming” activities such as cattle ranches and walnut orchards for the last 100 years, we find it hard to believe that just now ASE and ENGEO have discovered such an extremely large water source.

Thank you for your time.

Bill & Holly Newman
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APPENDIX

In this appendix, we detail our concerns with the actual well tests on which the reports made by ASE and ENGEO were based, including how the tests were performed and the number of tests made.

A standard reference for performing well tests and interpreting their results is Groundwater and Wells by F.G. Driscoll (1986). ASE's proposal to Contra Costa County (8/2007) states that "Two 24 hour pump tests will be performed in accordance with the protocol presented by Driscoll, F.G. (Groundwater and Wells, 1986)." David Abbott of Todd Engineering also cites Driscoll (ref David Abbott to W.F. Rusk, 11/16/07, included as Attachment B in ASE 2008).

In the balance of this letter, we will use Driscoll to develop the following: (1) background information on aquifer testing, (2) protocol for obtaining accurate drawdown data, (3) comparison of ASE aquifer tests to Driscoll's protocol, (4) pumping test time and drawdown data quality, and (5) aquifer test procedure.

(1) Background

ASE and ENGEO assess water availability by estimating three parameters: aquifer inflow, groundwater recharge and potential site storage. In order to determine these three parameters, the following information is required:

1. Coefficient of transmissivity (T) – this measures the rate at which water flows through the aquifer; it is based on the slope of well water level when pumped at a constant rate plotted versus time on a logarithmic scale; this is referred to as a time-drawdown graph (Driscoll p. 220).

2. Coefficient of storage (S)(also called storativity) – this measures how much water can be absorbed by the aquifer; it is based on the coefficient of transmissivty (T) and the zero-drawdown intercept of the time-drawdown graph (Driscoll p. 221).

3. Overall aquifer size – this establishes the total volume of water available; aquifer boundaries can be inferred from deviations of the time-drawdown graph from its expected straight-line form. In other words, the time-drawdown graph should be a straight line for a time period commensurate with the expected size of the aquifer.

4. Soil surface and site geography – knowledge of soil surface properties and soil compaction behavior, as well as surface topography and the type of surface cover, is essential to determine groundwater recharge. We have documented our concerns with ASE/ENGEO's data in this area in an earlier letter (Newman 7/2008).

To determine the aquifer characteristics listed in items 1 through 3, pump tests are used. When aquifer properties are being determined these pump tests are usually called "aquifer tests". Per Driscoll (p. 534): "An aquifer test consists of pumping a well at a certain rate and recording the drawdown in the pumping well and in nearby observation wells at specific times."

Aquifers can be tested either with a constant yield method (pumped water level in the well no longer changes) and the well is said to be in the "equilibrium" state, or with a timed constant rate method (pumped water level in the well is changing, but in a predictable manner) and the well is said to be in the "non-equilibrium" state.

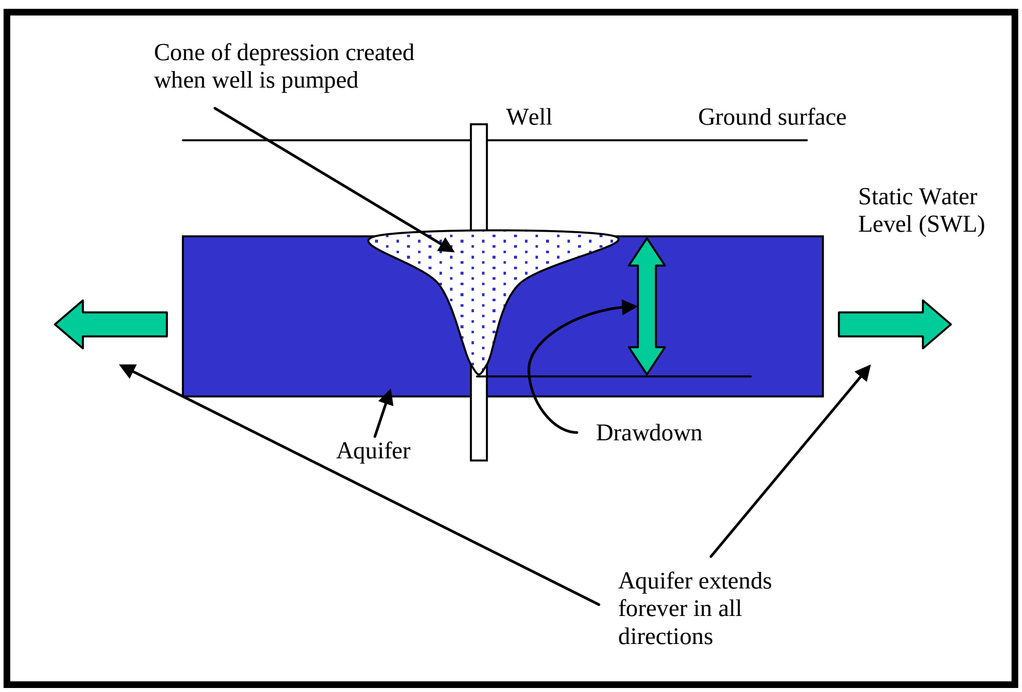
ASE/ENGEO use the timed constant rate method and modified non-equilibrium well equations, which allow a simplified calculation of the well yield. With these equations the drawdown theoretically can be predicted at any time after pumping begins; in practice, Driscoll recommends that at least 72 hours of drawdown data be collected for unconfined aquifers before using that data to predict overall well performance. The reason for this test length is to define more reliably the slope and position of the line of best fit for the plotted points (Driscoll p. 223). ASE/ENGEO concur that the aquifer is unconfined, since they estimate that the coefficient of storage (S) is 0.06 (ASE 2008 p.19), while it would range from 0.001 to 0.00001 (Driscoll p. 210) for a confined aquifer. However, ASE ran the aquifer test for barely 24 hours, which is not long enough to obtain reliable data.

In order to use these modified non-equilibrium well equations, the two most significant assumptions which must be met are the following (Driscoll p. 214 and p. 218); we believe that both of these assumptions were violated and we will discuss below.

1. There is no recharge to the aquifer from any source

2. The water is being drawn from an aquifer that is infinite in areal extent; although in reality no aquifer is infinite, it is sufficient for the aquifer to be larger than the area affected by the well test

As a well is pumped, a "cone of depression" grows in size around the well. The measurement of the depth of this cone over time (drawdown) allows the transmissivity and storage coefficients to be calculated, which then allows the drawdown to be estimated for any time in the future. The sketch below illustrates these terms:



When the aquifer is larger than the cone of depression, then the cone of depression will expand in a way that can be predicted by the modified non-equilibrium well equations (Driscoll p. 219). When the well drawdown level is plotted versus time on a logarithmic scale, the result is a straight line (Driscoll, p. 220, figure 9.13).

Driscoll describes many practical situations where deviations occur from a "straight line on semilogarithmic graph paper" as a result of violations of the above assumptions, such as when the aquifer is finite in size or when recharge is occurring during the test. These deviations provide information that can reveal the true nature of the aquifer.

Driscoll's figure 9.13 (p. 220) shows how to calculate the slope (Δs) and intercept (t_0) from which transmissivity T and storativity S can be determined. Note that these values are average values and are only valid in the region near the cone of depression around the pumped well. In order to determine the size of the entire aquifer and its associated T and S, it is necessary for the pump test to be of sufficient duration to enlarge the cone of depression to a size that is commensurate with the expected size of the aquifer.

In addition, if drawdown data can be obtained from observation wells that are near the pumped well, it is possible to obtain a good confirmation of the data. Note that Driscoll assumes that an observation well is being used in every case since "drawdown data can be taken from both the pumping well and appropriately placed observation wells, but the accuracy of data taken from the pumping well is usually less reliable because of turbulence created by the pump. Thus, at least one observation well should be used when applicable. Furthermore, drawdown data from an observation well are required to calculate the storage coefficient accurately, whereas transmissivity values may be calculated on the basis of drawdown data taken from either a pumping well or observation well" (Driscoll p. 547-548).

To summarize, the goal for aquifer tests is to obtain accurate drawdown data which can be used to determine the transmissivity and storage coefficients. In addition, aquifer tests can be used to verify the size of a given aquifer through comparison of the actual drawdown data with that predicted by the non-equilibrium well equations.

(2) Driscoll's protocol for obtaining accurate drawdown data

To get valid drawdown data, one must be very careful when conducting the well test. The following is excerpted from Driscoll, p. 535 - 536:

"Pumping tests will not produce accurate data unless the tests are carried out methodically, carefully recording the time, discharge, and depth measurements. Certain preliminary steps should be taken to assure the reliability of pumping test data recorded during the actual test. For instance, several days before the test is to be conducted, the test well should be pumped for several hours to determine the following:

1. The maximum anticipated drawdown. (For most pumping tests, a major portion of the drawdown will occur in the first few hours of pumping.)

2. The volume of water produced at certain engine (pump) speeds and drawdown.

3. The best method to measure the yield.

4. Whether the discharge from the pump is piped far enough away to avoid recharge.

5. Whether the observation wells are located so that they exhibit sufficient drawdown to produce usable data.

"Prior planning and experimentation with the equipment and personnel during preliminary testing can eliminate potential errors that may occur during the actual pumping test. Never begin the actual pumping test, however, until the water level in the aquifer has returned to the normal (pretest) static level following preliminary testing. About 24 to 72 hours should be allowed, depending on the type of aquifer. Beginning a pumping test when the static water level is below normal may eliminate early data that show discharge or recharge boundaries. Without the early drawdown data, it may be impossible to obtain the correct transmissivity and storage parameters for the aquifer.

"The accuracy of the drawdown data taken during a pumping test depends on the following:

1. Maintaining a constant yield during the test.

2. Measuring the drawdown carefully in the pumping well and in one or two properly placed observation wells.

3. Taking drawdown readings at appropriate time intervals.

4. Determining how changes in barometric pressures, stream levels, and tidal oscillations affect drawdown data.

5. Comparing recovery data with drawdown data taken during the pumping portion of the test.

6. Continuing the test for 24 hours for a confined aquifer and 72 hours for an unconfined aquifer during constant-rate tests. If other wells are being pumped within the potential cone of depression of the well to be test pumped, these wells must be pumped at a constant rate throughout the duration of the test. For step-drawdown tests, 24 hours is usually sufficient for either type of aquifer."

(3) Comparison of ASE aquifer tests to Driscoll's protocol

ASE's aquifer tests & analysis for PW-4 had a number of significant differences from Driscoll's protocol:

1. Incomplete recovery – the test started with water level of 35 feet when the documented Static Water Level (SWL) of the well was 19 feet. This is in direct conflict with Driscoll's recommendation that the continuous pump test should be started with the well at the SWL. (Driscoll p. 535)

2. The path of the discharge water was not documented. This is important since it is necessary to ensure that the discharge water does not inadvertently recharge the aquifer.

3. ASE did not determine the sustainable pumping rate for the well before the 24 hour test began. Instead, the test started (10:30 am) at over 40 gpm and

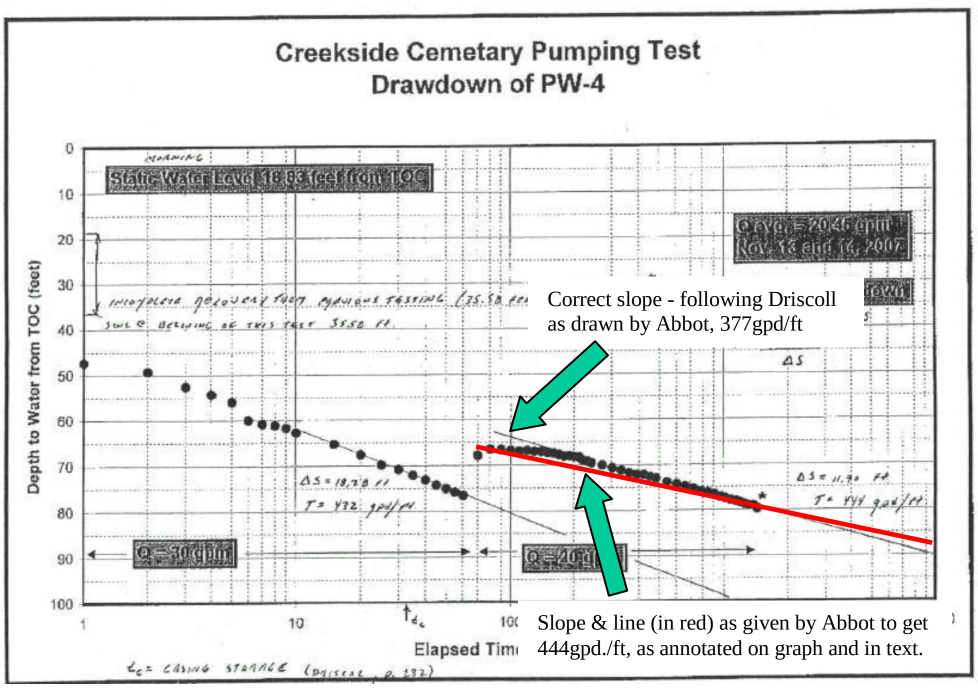
2.5 hours later, in an attempt to reduce the rate to 20 gpm, the pump broke and the test stopped at 1 PM. The test was resumed at 5 PM with a new pump at 30 gpm for one hour, then cut back to 20 gpm for the balance of the test. First of all, Driscoll recommends that the test be performed at a constant rate. Second, pumping at different rates at the outset of the test obscures the initial drawdown data which is critical for validating the test.

4. Information as to how the pumping rate was measured or regulated was not included, nor were any actual measurements.

5. Driscoll recommends 72 hours for a constant rate test on an unconfined aquifer, but ASE only ran the test for 24 hours.

6. There was insufficient monitoring of the other wells on the site, which could have provided valuable information about the storativity S and the extent of the cone of depression when pumping. Well PW-3 was 129 feet away, and had ASE run the test sufficiently long to get reasonable drawdown data, the true storativity S of the aquifer in that area could have been estimated, rather than guessed at as Abbott has done (he assumes S = 0.1) or as ASE estimates S = 0.0625 (ASE 02/2008, p. 19).

7. David Abbott's calculations for estimating the transmissivity of the well appear to be improperly applying Driscoll's definition of Δs. From



Abbott's figure "Pumping test drawdown of PW-4" (ASE Appendix B, 2008), there is a line through the points from about t=200 minutes to t=1440 minutes. If you use this line to calculate T you get a drawdown of 68 feet at 200 minutes and a drawdown of 82 feet at 2000 minutes, which gives Δs of 14 ft and Q = 20 gpm. Then applying the formula T = 264 Q/Δs (Driscoll p. 221, equation 9.7) gives T = 264 * 20 gpm / 14 ft = 377 gpd/ft.

But on the graph Abbott says that T = 444 gpd/ft, not 377 gpd/ft. Using 377 gpd/ft instead of 444 gpd/ft in the rest of Abbott's calculation

(Driscoll p. 1021, equation 3 – for unconfined aquifers) finds Q/s_{max} = T/1500 = 377 gpd/ft / 1500 = 0.251 gpm/ft. **With this Q/s_{max} of 0.251 then the recommended yield as calculated by Abbott becomes 0.251 gpm/ft * 41 ft = 10.3 gpm, not 13.5 gpm as Abbott claims, a reduction of 30%.**

Also note that although Abbott recognizes that incomplete recovery of PW-4 occurred (Abbott 11/16/07) and cites Driscoll p. 259 Figure 9.44 (on plot "Recovery of PW-4" ibid.), he does not mention Driscoll's interpretation of this condition as "incomplete recovery due to limited extent of aquifer".

(4) Pumping Test Time and Drawdown Data Quality

There are several examples in chapters 9 and 16 of Driscoll that show how to interpret results where the semilogarithmic drawdown plot departs from a single straight line. The two examples that follow discuss specific irregularities in the time drawdown graph that are relevant, especially when the aquifer size is unknown.

The first example is a well drawdown curve which becomes much steeper after the well has been pumped for about two hours, which indicates a limited aquifer (Driscoll p. 231, figure 9.20). This example shows that if the pumping test does not last long enough, the extent of the aquifer can not be accurately determined.

Driscoll reminds us of the importance of having a test of sufficient duration on page 553: "To gain enough information for unconfined aquifers, 72 hours are usually required to dewater the materials within the cone of depression, because of the slow downward percolation of water in many stratified deposits. This time can be reduced if equilibrium conditions are established before 72 hours have elapsed. **In no event, should pumping tests be terminated prematurely, however, because the limited data collected may not reveal the true nature of the aquifer.**" (bold added)

For a test well in this unconfined aquifer, with corrected S and T values (see section 3, point 7) based on Abbott's calculations, the radius of the cone of depression will be 200' after pumping for 720 hours. On the map below, a 200' radius circle is included to give a sense of scale to the cone of depression. Note that even at 200', the well may not encounter aquifer barriers. This example points out the scale and timeframes that are required to get meaningful results. The 720 hour estimate comes from the same source that Abbott uses to calculate his 36 foot radius of depression after 24 hours, namely Driscoll p. 237, equation 9.12 ("intercept of extended straight line at zero drawdown" shows where the cone of depression extends from the pumped well at the top of the aquifer).

$$r_0 = (0.3 * T * t/S)^{1/2}$$

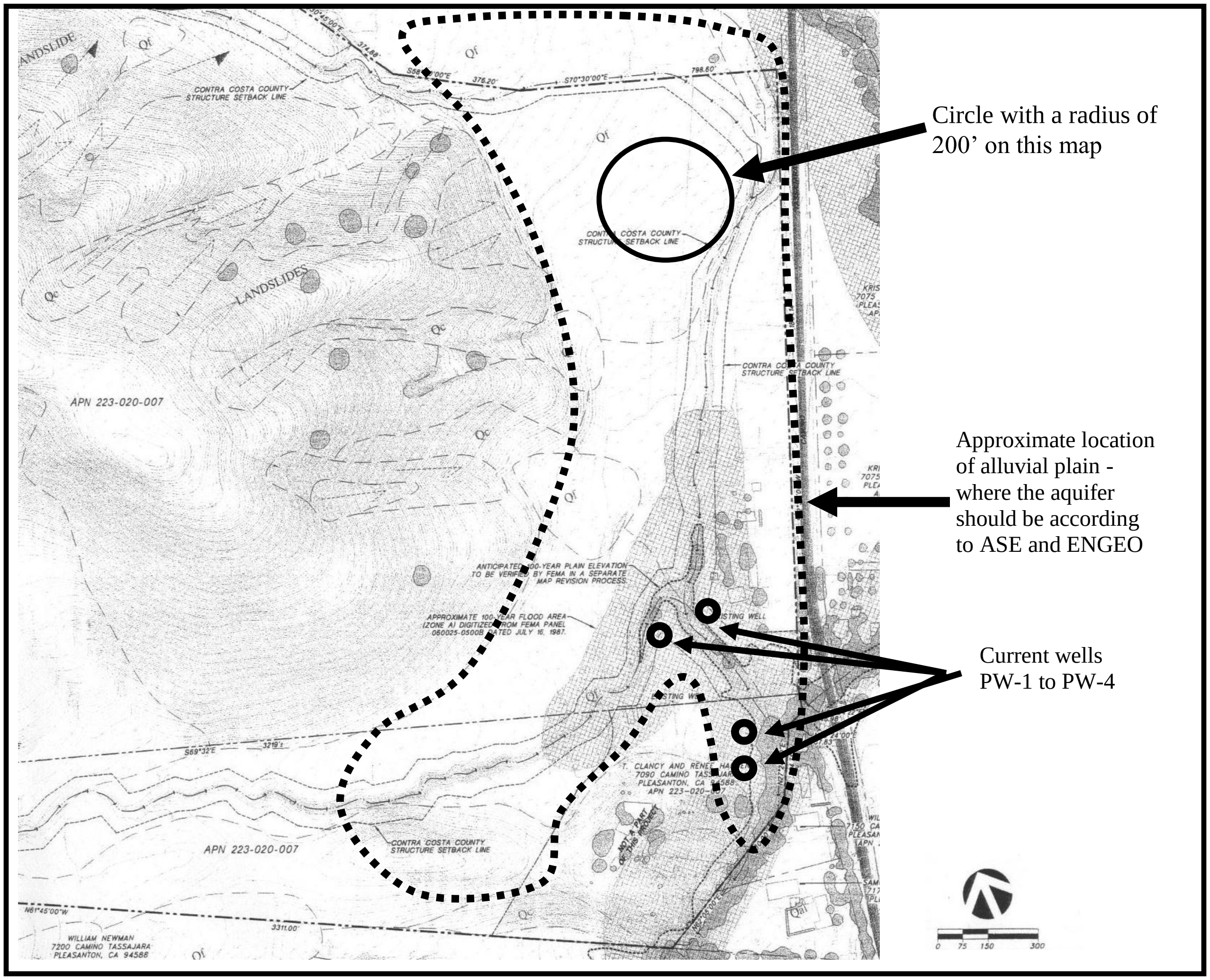
where

r_0 = intercept of extended straight line at zero drawdown
T = 377 gpm/ft (corrected per discussion above),
t = time since pumping started in days
S = storage coefficient (Abbott says 10%, ASE says 6%)

To get an r_0 = 200' the pumping duration needs to be

$$t = r_0^2 * S / .3 * T$$
$$= (200\ ft * 200\ ft * 0.1) / (0.3 * 377\ gpm/ft)$$
$$= 35\ days$$

Reducing the target radius to 100' would lead to a pumping time requirement of 8.8 days. In any case, these calculations demonstrate that getting a cone of depression of sufficient size to reveal the extent of the aquifer takes much longer than 24 hours.



Also, Driscoll maintains that the use of an observation well improves the data quality as cited above. Driscoll goes on to state (p. 548), "For unconfined aquifers, observation wells should be placed no further than 100 to 300 ft (30.5 to 91 m) from the pumped well." So observation wells located, say, 150' from the pumped well should be included and drawdown data from the two wells will provide a much more accurate idea of the aquifer properties. More observation wells would improve the credibility further.

The radius of depression for a single well can be quite large, but it is not practical to cover the entire 31 acre expanse with a single well, so several additional test wells (and the associated observation wells) should be required. Note that the current four wells are all situated on the lower 25% of the 31 acres as shown in the figure above, and so do not provide sufficient information regarding the extent of the aquifer.

Since we want to establish the size and properties of the entire aquifer, one way to conclusively prove the size of the aquifer would be to install three or four wells and pump them simultaneously until each cone of depression is large, say a 200′ radius. If an anomaly shows up in the drawdown graphs we'll know if the aquifer is limited in extent. If the plot stays linear throughout the timeframes where the cones of depression cover a significant portion of the 31 acre aquifer, then the aquifer is more likely to be the size claimed by ASE and ENGEO.

The second example is when the aquifer receives recharge during the test (Driscoll p. 225, figure 9.15). The drawdown curve flattens out at the end, leading to an overestimate of the extent of the aquifer, because somewhere a recharge source is supplying water to the aquifer.

For this reason it is imperative that the area be monitored before, during and after the test to insure that recharge is not taking place from any source (e.g. rain, hoses left running, test well discharge) and that recharge flow onto the site from the north is minimal (e.g. perform the test at the end of summer).

(5) Aquifer test suggestions

In order get results which can establish the aquifer properties and size, we believe that aquifer test procedures should be specified and discussed with all parties involved before the test is started.

We suggest that test wells be located throughout the claimed aquifer, and pumped for a duration sufficient to get a meaningful cone of depression around them. Use of observation wells would improve the reliability of the results.

We also suggest that ASE document more completely how they do the test; in particular:

1. Routing water correctly away from the pumped well(s)
2. Observation of well(s) before and after test
3. How water volumes are measured

A thorough aquifer test should include at least the following:

Test and observation well locations and testing procedures

- Locate the pumped wells for adequate coverage of the 31 acres
- Locate observation wells properly in relation to pumped wells
- Agree on well drilling and logging procedures
- Specify and agree on pump test procedures, logging intervals, and length of time to run the test
- Agree on when to conduct the test, to ensure that aquifer recharge does not occur (e.g. do it in the dry part of the year)
- Schedule the test so that each test well starts from its static water level

Pre test

- Determine static water level (SWL) for each well
- At least three days prior to start of test, monitor and document that no recharge or discharge takes place.

- Perform pump test prior to establish an N hour sustainable rate, where N is the number of hours required to get the desired cone of depression size

During test
- Monitor & document that no other sources of recharge or discharge take place
- Pump the well(s). Make sure well pumping starts when well is at SWL
- Log the drawdown of the pumped and observation wells

Post test
- Log recovery, for as long as it takes
- Monitor & document that no recharge or discharge takes place

REFERENCES

1. Groundwater and Wells, F.G. Driscoll, 1986

2. Water Well Pump Tests, Corrie Ranch, 7000 Camino Tassajara Rd, Contra Costa County, Aqua Systems Engineering (ASE), May 9, 2005, time stamped December 15, 2005

3. Initial Groundwater Assessment, Creekside Memorial Park, Tassajara Road, Contra Costa County, California, ENGEO Incorporated, April 6, 2007

4. Response from Bill and Holly Newman to Ryan Hernandez, Senior Planner, Community Development Department, Contra Costa County, with comments and concerns regarding ENGEO (4/6/2007) cited above, dated July 6, 2007

5. Response from Aqua Systems Engineering (ASE) to Ryan Hernandez, Senior Planner, Community Development Department, Contra Costa County, titled "Reply to your June 6, 2007 Memo "Request for additional information" on the proposed Corrie Creekside Memorial Park", dated August 14, 2007

6. Response from Bill and Holly Newman to Ryan Hernandez, Senior Planner, Community Development Department, Contra Costa County, with comments and concerns regarding ASE (8/14/2007) cited above, dated October 11, 2007

7. Groundwater Availability at the Creekside Memorial Park, Aqua Systems Engineering (ASE), time stamped February 5, 2008

8. Response from Bill and Holly Newman to Ryan Hernandez, Senior Planner, Community Development Department, Contra Costa County, with comments and concerns regarding ASE (2008) cited above, dated March 3, 2008

9. Initial Groundwater Assessment, Creekside Memorial Park, Tassajara Road, Contra Costa County, California, ENGEO Incorporated, April 6, 2007, revised June 10, 2008

10. Response from Bill and Holly Newman to John Oborne, Community Development Department, Contra Costa County, with comments and concerns regarding ENGEO(June 10, 2008), cited above, dated July 28, 2008