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July 17, 2009

Mr. Matthew Naud, Environmental Coordinator
City of Ann Arbor
100 North Fifth Avenue
Ann Arbor, MI 48104

Re: Evaluation of the Report on Water Level Testing Under Reduced Flow Conditions, Pall Life Sciences – Evergreen Area

Dear Mr. Naud:

At your request, I have reviewed the above-mentioned report to provide my professional opinion regarding the work conducted and the findings and conclusions presented in the document. In addition to the above document, I also reviewed the following for background information:

- Shallow Potentiometric Surface, May 22, 2009
- Figures 1 through 4 of the Comprehensive Proposal to Modify Cleanup Program, 2009

This review is organized as follows:

- Background and Site Conceptual Model
- Summary and Opinion of the Work Conducted
- Interpretation of Transient Data
- Interpretation of Static Water Levels
- Opinion Regarding Findings and Conclusions

Background and Site Conceptual Model

My interpretation of the site background and site conceptual model is based on my review of the above-documents, information regarding the location and stage of the Huron River, and my professional experience at other sites in the Ann Arbor area and nationwide.

Figure 1 of the Comprehensive Proposal illustrates a 1,4-dioxane plume that extends well over a mile from the source area at the Pall Life Sciences (PLS) facility on Wagner Road to extraction well AE-3 in the Evergreen Area. This plume is reported to be in the hydrogeologic unit referred to as the D2 Unit. Figure 3 of the same report illustrates another 1,4-dioxane plume that underlies/overlaps the D2 plume but extends further east in the hydrogeologic unit referred to as the E unit. The hydrogeology of the Evergreen Area is the subject of the Water Level Testing report. Wells LB-1, LB-3, and AE-3 extract contaminated groundwater in the Evergreen Area, and treatment is provided by a system located at the PLS facility on Wagner Road. PLS is considering reducing the pumping rates in the Evergreen Area (D2 Unit) in order to provide hydraulic capacity in the transmission lines for pumping from within the plume in the E Unit. The primary objective of the Water Level Testing report is to determine if reduced extraction rates from LB-1, LB-3, and AE-3 would result in significant changes to the groundwater flow directions currently observed in the Evergreen Area. The importance of determining potential changes in groundwater flow direction is not provided in the Water Level Testing report. Based on the Figures from the Comprehensive Proposal, a potential reason is presumably due the Evergreen Area lying outside of the current "Prohibition Zone". Another potential reason is that Barton Pond, a major source of Ann Arbor's drinking water, is located approximately 2.2 miles to the northeast of the Evergreen Area. Groundwater flow to the east or southeast would be favorable for limiting plume migration outside of the Prohibition Zone and for contamination discharging to the Huron River downstream of Barton Dam. Flow to the north or northeast from the Evergreen Area would result in more extensive contamination outside of the Prohibition Zone and an increased potential for contamination to reach Barton Pond.

Geologic cross-sections provided in the Water Level Testing report illustrate geology that is comprised of extensive sand and gravel units/lenses among extensive silt and clay units/lenses. In some locations, I would expect that the sand and gravel units would "pinch out" or intersect or otherwise overly/underlay other sand and gravel units forming a continuous path for ground water to migrate toward the Huron River. Given the relatively flat topography of the area, groundwater flow would be expected to be controlled by variations in recharge, variations in the orientation and connection of the sand and gravel units, and discharge to the Huron River.

Contaminant migration as depicted in the figures from the Comprehensive Proposal and as supported by posted 1,4-dioxane concentrations in the cross-sections from the Water Level Testing report, indicate groundwater historically flowed northeast from the source area until Jackson Road (for the E Unit) and I-94 (for the D2 Unit) where it then trends directly east. As depicted, the plume in the E Unit appears to remain within the Prohibition Zone, whereas the D2 plume extends north of the Prohibition Zone into the Evergreen Area. Groundwater extraction totaling 200 gpm in the Evergreen Area from wells LB-1, LB-3, and AE-3 is presumably intended to prevent further plume migration in the Evergreen Area.

The following groundwater and elevations and distances in the region were observed:

- Groundwater in the vicinity of the Evergreen Area at the time of the water level testing was approximately 870 feet above mean sea level.
- The Huron River is approximately 1.85 miles directly north of the intersection of Dexter Avenue and Evergreen Drive.
- Barton Dam on the Huron River is located downstream, approximately 2.2 miles northeast of this same intersection.
- The water level upstream of the dam appears to be approximately 800 feet above mean seal level.
- The river flows south from the dam and is located approximately 2.1 miles directly east of the intersection of Dexter Avenue and Evergreen Drive.
- Argo dam is located at this river location directly east of the Evergreen Area, and the water level is approximately 770 feet above mean sea level upstream of the Argo dam.
- Downstream of the Argo dam, the water elevation is approximately 760 feet above mean sea level.

Therefore, the water level in the vicinity of the Evergreen Area is substantially higher than that of the Huron River to the north or east of the Evergreen Area. The average hydraulic gradient to the north between the Evergreen Area and the river is approximately 0.007 feet per foot whereas the hydraulic gradient to the east is approximately 0.01 feet per foot. For comparison, the hydraulic gradient in the Evergreen Area is approximately 0.001 feet per foot, likely the result of a very high hydraulic conductivity in this area.

Based on water levels reported in the Water Level Testing report, water levels at wells in the shallower units near the Evergreen Area are higher than the water levels in co-located wells in the underlying units, supporting the conceptual model that water from recharge migrates downward (perhaps partially impeded by low permeability silt and clay units) to preferential paths of groundwater flow through sand and gravel to the river. As such, deeper water level measurements will provide more of a regional indication of groundwater flow whereas shallower water will be higher as a result of recharge.

Summary and Opinion of the Work Conducted

The water level testing described in the subject report included manual water level measurements from 39 wells on four separate occasions and automated measurements every 2 minutes from pressure transducers at 21 of those wells over the same time period. The pressure transducer data was compensated for barometric changes through either venting the transducer to the atmosphere or monitoring barometric pressure and subtracting it from the pressure measurements of sealed transducers. The procedures for manual and automated measurements appear to have been conducted appropriately and within conventional standards. Limitations of the data, such as infiltration of storm water into open wells during the testing, were appropriately discussed in the report, and the effects of this infiltration can be considered by reviewing the automated pressure data. More specific information regarding the field activities are described in the Water Level Testing report.

Interpretation of Transient Data

Appendix 5 of the Water Level Testing report provides hydrographs of the pressure transducer data compensated for barometric pressure changes. The barometric pressure changes are also presented on the hydrographs. Review of these hydrographs indicates that the water levels in the wells were substantially affected by barometric pressure changes despite being compensated for those changes. This is likely the result of the general separation of the aquifer from the atmosphere by a thick overlying clay unit, producing somewhat confined aquifer conditions. Therefore, as a barometric low passes through the area, the aquifer does not immediately sense the low pressure except at the well where the water level rises in the well. As the low pressure is replaced by high pressure, the water level in the well is “pushed” back down. The water level in the well therefore is substantially affected by changes in atmospheric pressure. Had the barometric pressure not been compensated for, the rise of the water in the well would have been offset by the decrease in barometric pressure and the resulting processed data would more accurately depict hydraulic changes in the aquifer over time. Given the substantial changes in barometric pressure over the course of the study period and the relatively small changes in water levels associated with discontinuing pumping, the hydrograph data is relatively noisy and changes resulting from pumping are difficult to discern in many wells.

To evaluate the transient behavior of water levels in this case, it may not have been appropriate to fully compensate for barometric pressure changes because the variations within the open well are not representative of what is occurring within the rest of the aquifer. Figures 1 and 2 illustrate the pressure transducer water levels at LBOW-1 and MW-113 “corrected” for barometric pressure along with the barometric pressure signal and the uncorrected or absolute pressure measured at these two wells. It is evident that a significantly smoother trend, which is more representative of a typical water level trend, is achieved when the data are not corrected for barometric pressure. The influences of the shutdown are more clearly observed. In addition, it appears that a background trend of increasing water levels may be present, particularly when observing the time period before the extraction rates were modified (i.e., before 1/29/09).

Figure 3 presents the "corrected" and uncorrected data for MW-120S along with the uncorrected data for LBOW-1, MW-113, and MW-120D. It is evident that the MW-120S and MW-120D signals do not show an obvious influence from the change in pumping rates and that the change in water levels appears to be a consistent regional increase with some noise from the barometric changes superimposed. The difference in water levels between MW-120D and MW-120S remain constant throughout the test suggesting a relatively consistent downward gradient in this location. The difference between the water levels at the MW-120 cluster and MW-113 decrease as pumping is discontinued, indicating that pumping enhances the gradient between MW-120 and MW-113, forcing a southerly component to groundwater flow in this location during pumping.

The more significant barometric noise in the uncorrected signals for MW-120S and MW-120D likely suggests that the aquifer in this area is in better contact with the atmosphere such that the water level in the well remains relatively stable despite changes in barometric pressure. Moreover, the absolute pressure measured by the sealed pressure transducers in MW-120S and MW-120D reflect changes in barometric pressure, evidenced by the noise in the uncorrected signal slightly increasing when the barometric pressure increases. In summary, MW-120S and MW-120D behave like wells in a water table or semi-confined aquifer where as MW-113 and LBOW-1 behave like wells in a semi-confined or confined aquifer. This does not mean that MW-120S and MW-120D are not hydraulically connected to MW-113 and LBOW-1. However, the data suggest that given aquifer properties, MW-120S and MW-120D are too far from the pumping wells to yield an observable change in water levels due to induced changes in pumping rates.

Figure 4 presents the "uncorrected" water levels from MW-92 and MW-101. With the exception of anomalous data at the beginning of the MW-101 signal, the two wells show relatively equal influence from the change in pumping rates. Therefore, it is reasonable to conclude that the wells are influenced by pumping but that there is no observable change in groundwater flow direction between the two wells as a result of pumping.

Figure 5 presents the uncorrected water level trend for LBOW-1 and the same trend but with the background (as calculated by MW-120D) removed. With the background removed, it appears that the aquifer in the vicinity of LBOW-1 fully recovered during the test period. Therefore, it is appropriate to interpret the static water levels from February 16, 2009 as being under equilibrated non-pumping conditions.

For clarification, the above approach of not compensating for barometric pressure to observe the transient behavior of monitoring wells should not be used for comparing manual water level measurements with water level measurements from the pressure transducers or to cast doubt on the validity of the manual water level measurements. The manual measurements should be compared to the "corrected" water level measurements, and the manual measurements should be used for developing the potentiometric surface maps. The manual water level measurements for each individual water level event were conducted within 24 hours to minimize the transient variation in atmospheric pressure over the course of the event. As is evident in the "corrected" values on Figures 1 through 3, only minor changes in the "corrected" water elevations were observed during February 16, 2009.

In summary, the following relevant points have been made:

- When looking at the transient behavior of water levels in some of the Evergreen Wells, it is appropriate to look at the absolute pressure data and not to compensate (i.e., remove the barometric pressure signal).

- Pumping appears to increase the hydraulic head gradient between the MW-120 cluster and MW-113 (i.e., change the direction of groundwater flow to be more southerly than under non-pumping conditions).
- Pumping does not appear to influence the hydraulic head gradient between MW-92 and MW-101.
- By the February 16, 2009 event, the aquifer seems to have fully recovered from the changes in pumping.

Interpretation of Static Water Levels

The interpretation of the static water levels presented in the Water Level Testing report is highly dependent on the results from the MW-120 cluster. Given the presumed objective of the test was to demonstrate whether or not a northerly or northeasterly flow component is present in the absence of pumping, it is unclear why the MW-122 cluster was placed where it was (near other existing wells) rather than to the north. Regardless, the results from the MW-120 cluster provide useable data.

The potentiometric surface maps generated from the static water levels are highly dependent on which MW-120 well is used for contouring. As stated earlier, the shallow well will typically have a higher water level than the deeper well in this area due to the overlying contribution from recharge. The more conservative approach would be to use the results from MW-120D rather than those from MW-120S. A different interpretation of the potentiometric surface map from February 16, 2009 is presented in Figure 6. The changes are primarily the result of using MW-120D instead of MW-120S, MW-72D instead of MW-72S, and including MW-100. With this interpretation, groundwater north of the MW-77 appears to be directed to the east rather than to the south as depicted in Figure 8 of the Water Level Testing report. Yet another interpretation of the same map is presented in Figure 7 in the same manner as Figure 6, but using the average water elevation from MW-120S and MW-120D. Using this average instead of the low value from MW-120D reintroduces a southerly hydraulic gradient, though not as steep as that presented in the Water Level Testing report.

Regardless of the above interpretations, using water level information from the MW-120 cluster suggests groundwater flow north of MW-77 is more to the east or southeast rather than to the northeast in the absence of pumping during the conditions at the time of the test. The addition of the MW-123 cluster in May 2009 (after the testing) helps address some of this uncertainty and helps confirm a generally easterly or even southeasterly direction of groundwater flow in this area. Incorporating the result from MW-120S appears appropriate and suggests a convergence of flow (even in non-pumping conditions) to a preferential sand and gravel unit that is directed to the east in this area. The steep gradients further to the east (between MW-110 and MW-91) may indicate where this shallow sand and gravel unit overlies the underlying E Unit where contamination will continue migrating to the east.

Posted 1,4-dioxane concentrations from recent sampling events on the cross-sections in Appendix 1 of the Water Level Testing report, support the conceptual model that the D2 Unit plume will merge with the E Unit plume. Wells MW-101 and MW-81 have much higher 1,4-dioxane concentrations (approximately 400 ug/L) than the relatively low or undetectable 1,4-dioxane concentrations in MW-92, MW-47s/d, MW-110, MW-104, and MW-91.

It is unclear if the same trend or groundwater flow pattern occurs throughout the year. If conditions were relatively wet during the testing period (as suggested by the increasing water levels) and MW-120S and MW-120D more readily receive recharge compared to the wells to the south, then the groundwater flow directions may be biased in a southerly direction. It was noted earlier that the aquifer in the vicinity of MW-120S and MW-120D behaves more like a water table aquifer and the aquifer in the vicinity of MW-

113 and LBOW-1 behaves more like a confined aquifer. It therefore is reasonable to conclude that the MW-120 wells may more readily receive recharge relative to MW-113 and LBOW-1. During different (perhaps drier) conditions, the groundwater flow pattern may be substantially different.

Furthermore, the above-mentioned posted 1,4-dioxane concentrations are only a snap shot of the water quality in this area and do not provide an indication of the concentration trends in these wells. From the data reviewed, it is unclear if 1,4-dioxane concentrations in these wells are increasing, decreasing or remaining the same. For example, increasing concentrations in MW-92 or MW-104 could contradict the above-mentioned conceptual model. In addition, there is limited hydraulic data north and east of MW-92, and groundwater flow in this area under pumping or non-pumping conditions is open to interpretation. Thus, the above-mentioned conceptual model has not been fully confirmed by hydraulic or water quality data, particularly given 1) the relatively steep gradient between the Evergreen Area and the river and 2) the potential for various connections between sand and gravel units to provide multiple preferential pathways for contaminated groundwater to migrate to the river.

Opinion Regarding Findings and Conclusions

An easterly groundwater flow direction suggested by the potentiometric surface maps in Figures 6 and 7 is consistent with the observed 1,4-dioxane sampling results as posted on the cross-sections in the Water Level Testing report. Both pieces of evidence suggest easterly flow in the absence of pumping and are consistent with a conceptual model that the predominant preferential flow path for groundwater to reach the river is through a sand and gravel unit directed to the east in the vicinity of the Evergreen Area extraction wells. It seems reasonable that the D2 Unit plume will continue to migrate to the east and downward until it merges with the E Unit plume. Conclusive evidence of this conceptual model however is not presented in the reviewed document, and it is possible that groundwater in the D2 Unit and/or the E Unit east of MW-92 and MW-101 could migrate to the northeast if the sand and gravel units provide a pathway in this direction. It is further noted that the water level measurements and the interpreted groundwater flow directions may be dependent on the amount of recharge occurring at the time and that different groundwater flow directions may occur during different times of year or different weather conditions.

Based on the transient data presented in Figures 3 and 5, pumping likely enhances a southerly component of groundwater flow between the MW-120 cluster and MW-113 but does not result in an observable change in groundwater flow direction between MW-92 and MW-101. Therefore, if there is concern regarding potential plume migration to the north or northeast in the area east of MW-92, reducing the pumping rates at LB-1, LB-3, and AE-3 would not be expected to affect the groundwater flow direction in this area. Pumping at LB-1, LB-3, and AE-3, however, may provide a degree of plume capture that could reduce the amount of contamination migrating past MW-92. An evaluation of the degree of capture provided by the current pumping from LB-1, LB-3, and AE-3 was not performed as part of this review. Additional lines of evidence (that are perhaps available in other documents) would be needed to provide a reasonably comprehensive evaluation of plume capture.

Based on Figure 3, the conclusion that there are indications of influence of aquifer recovery at MW-120D from discontinuing pumping is questionable. It appears that MW-120S and MW-120D are too far from the extraction wells to show an observable influence from the change in extraction rates. Rather, the difference in water levels between pumping and non-pumping conditions appears to result from a background increasing trend in the regional water elevation. This contradicting finding, however, does not appear to affect the primary concern regarding flow direction under reduced or non-pumping conditions.

In summary, based on the limited data provided in the Water Level Testing report, it appears likely that groundwater in the Evergreen Area will continue to migrate to the east and likely merge with the E Unit plume, even in the absence of pumping from LB-1, LB-3, and AE-3. Additional existing data, such as water level data from a more comprehensive set of wells, water level data from other events, and water quality data over time, should be evaluated in an effort to help confirm this conceptual model. In addition, the data presented do not conclusively demonstrate that some of the contamination from the Evergreen Area or from the E Unit plume will not migrate to the north or northeast under different recharge conditions or in the area east of MW-92. Similar water level testing should be repeated during different times of year and different weather conditions to determine if the observed patterns are consistent throughout the year. Additional testing would also allow data from the new MW-123 cluster to be considered in the analysis. It is cautioned however that this additional testing will only address the groundwater flow directions west of MW-92. If there is continued concern regarding the path that contamination will follow to the Huron River and where it will discharge to the river, then additional hydraulic data to the east and northeast is appropriate. Based on the limited data provided by the MW-120 and MW-123 clusters, there is apparently a hydraulic divide between the Evergreen Area and the river. The location, extent, and seasonal persistence of this hydraulic divide are unclear based on the reviewed data.

Thank you for the opportunity to review this document. Please feel free to contact me with any further questions (732-409-0344 or dsutton@geotransinc.com).

Sincerely,

Douglas J. Sutton, Ph.D., PE
Principal Engineer

cc: Patti McCall, GeoTrans, Inc.
Tammy Rabideau, GeoTrans, Inc.

Figure 1. "Corrected" and Uncorrected Water Levels at LBOW-1

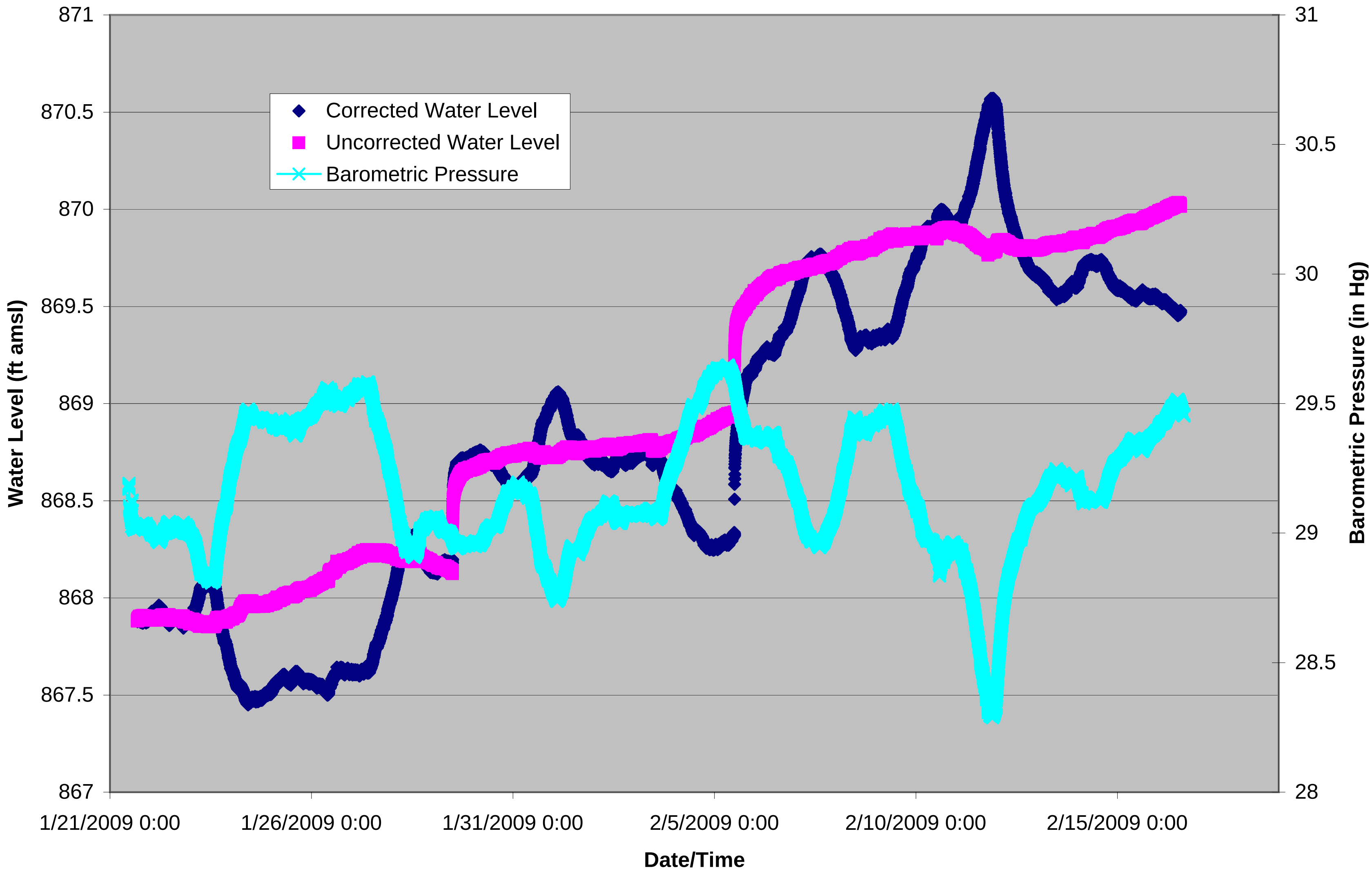


Figure 2. "Corrected" and Uncorrected Water Levels at MW-113

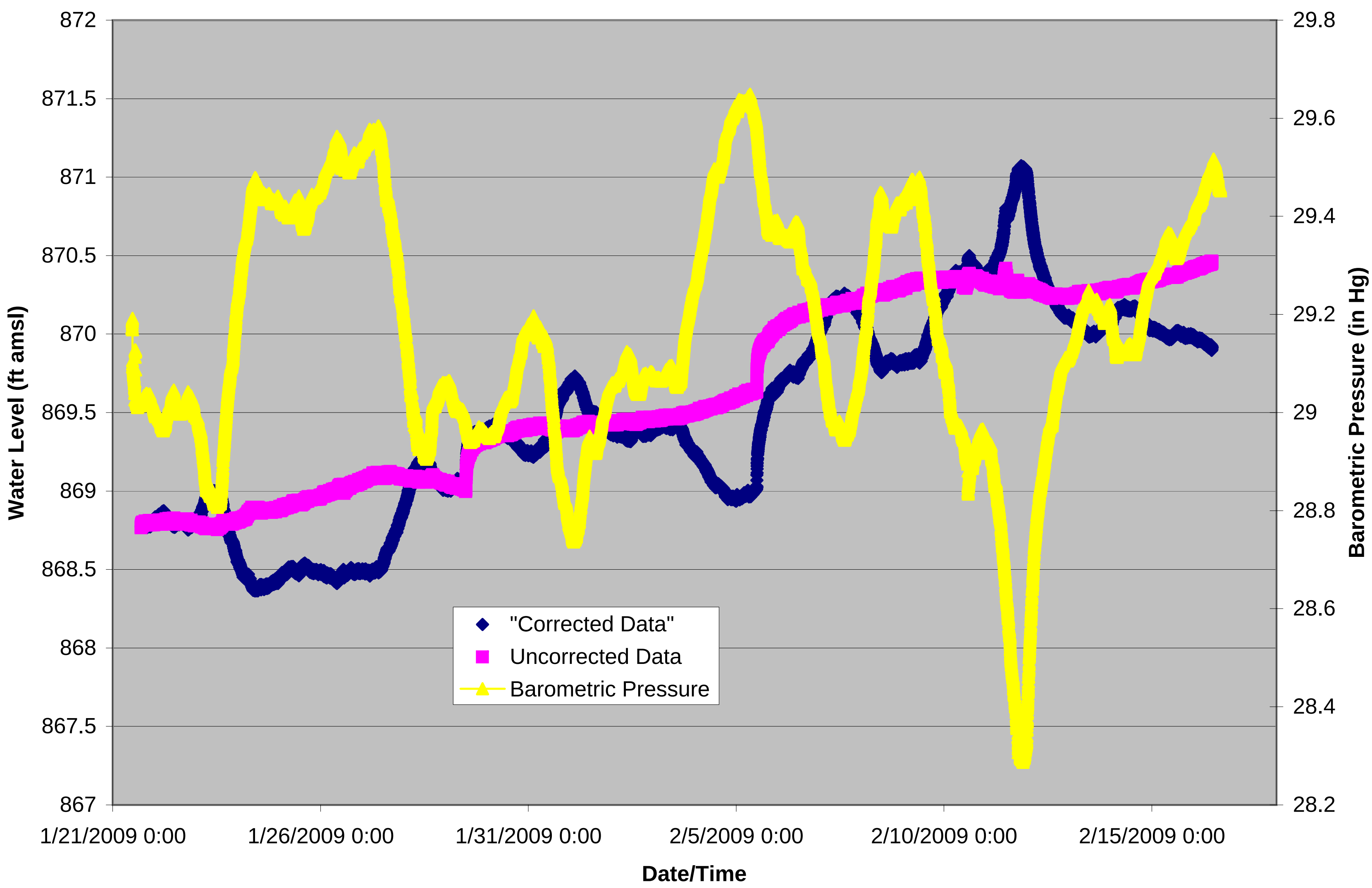


Figure 3. "Corrected" Water Levels at MW-120S and Uncorrected Water Levels at MW-120S, MW-120D, and MW-113

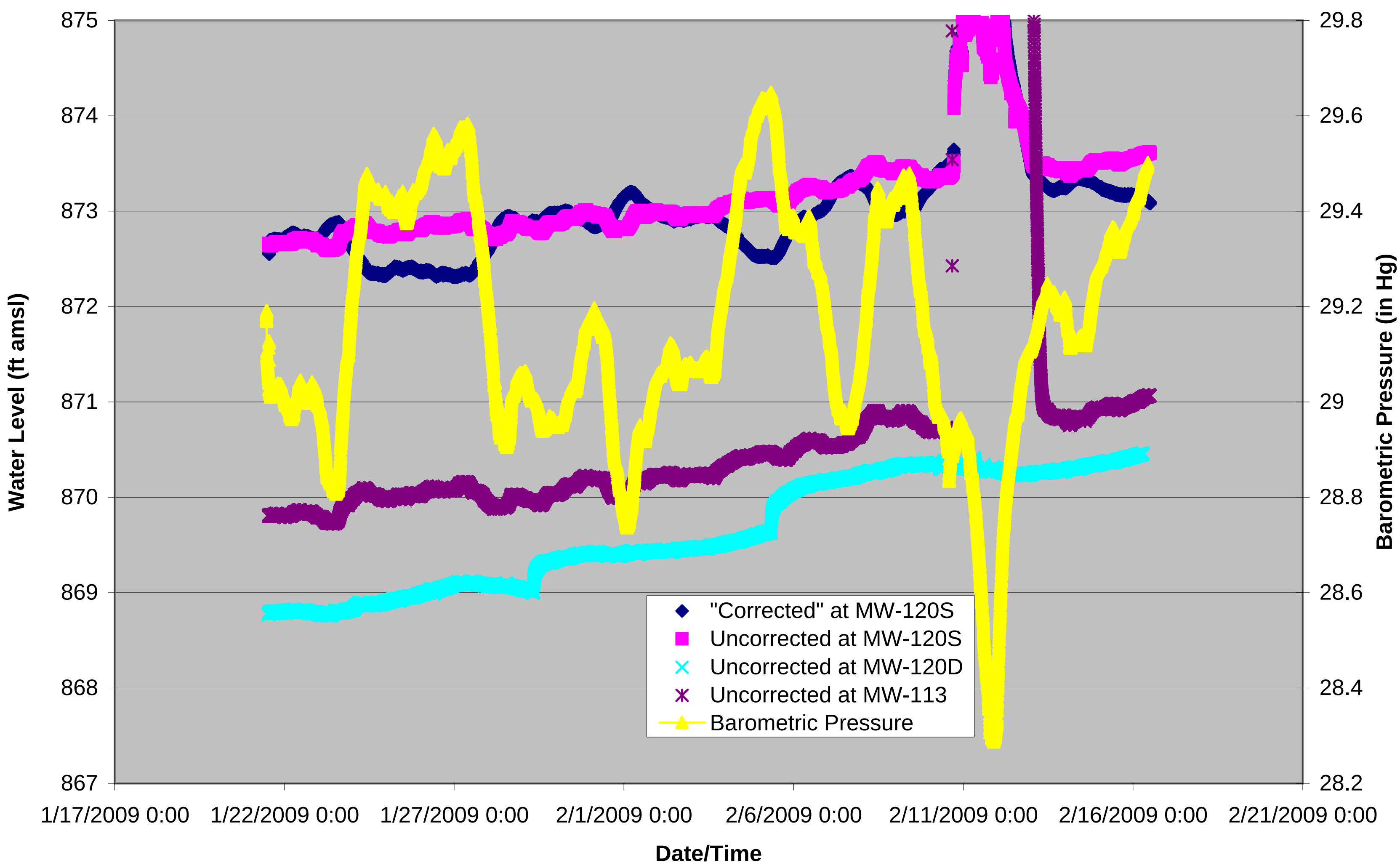


Figure 4 "Uncorrected" Water Levels from MW-92 and MW-101

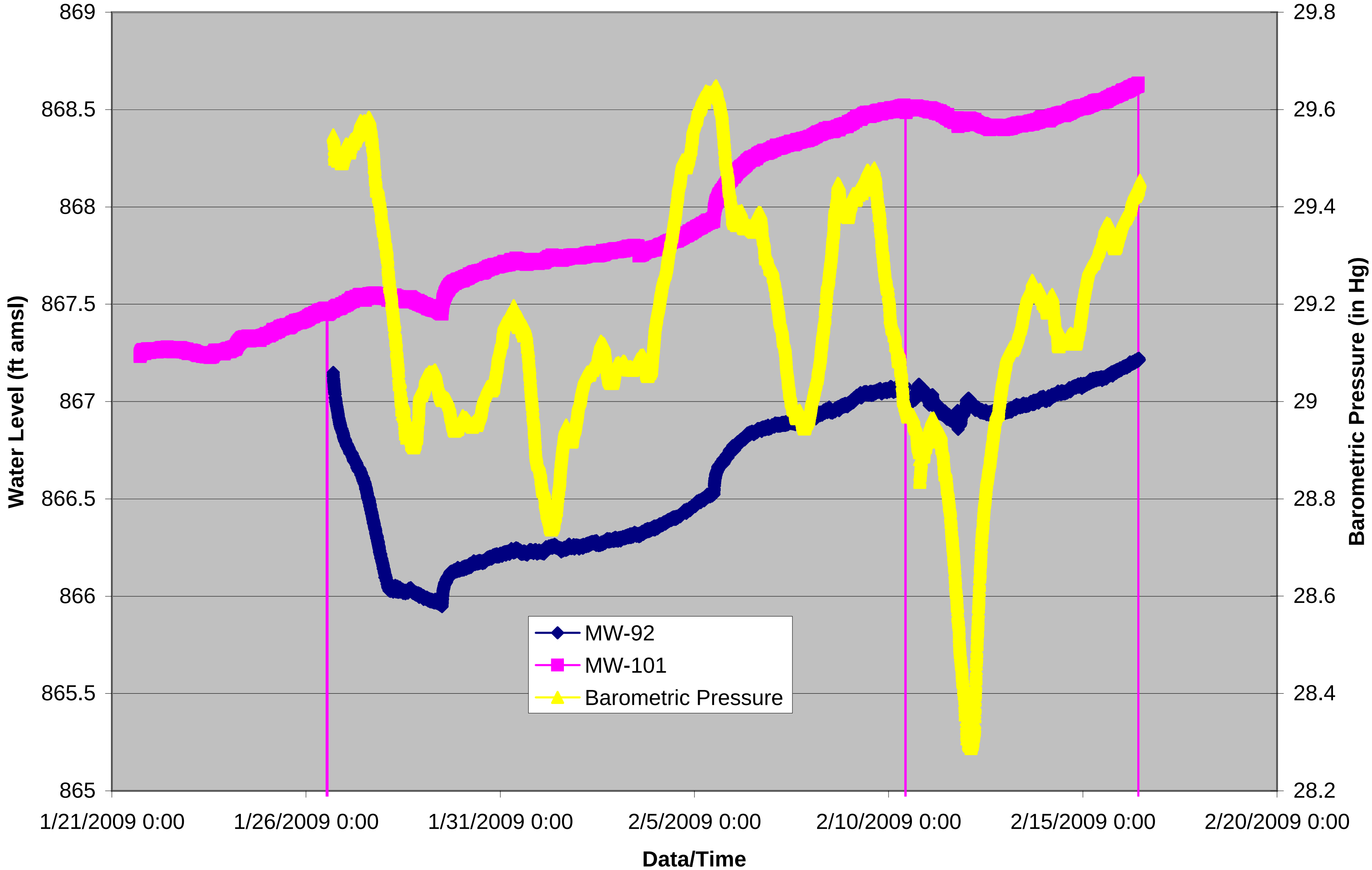
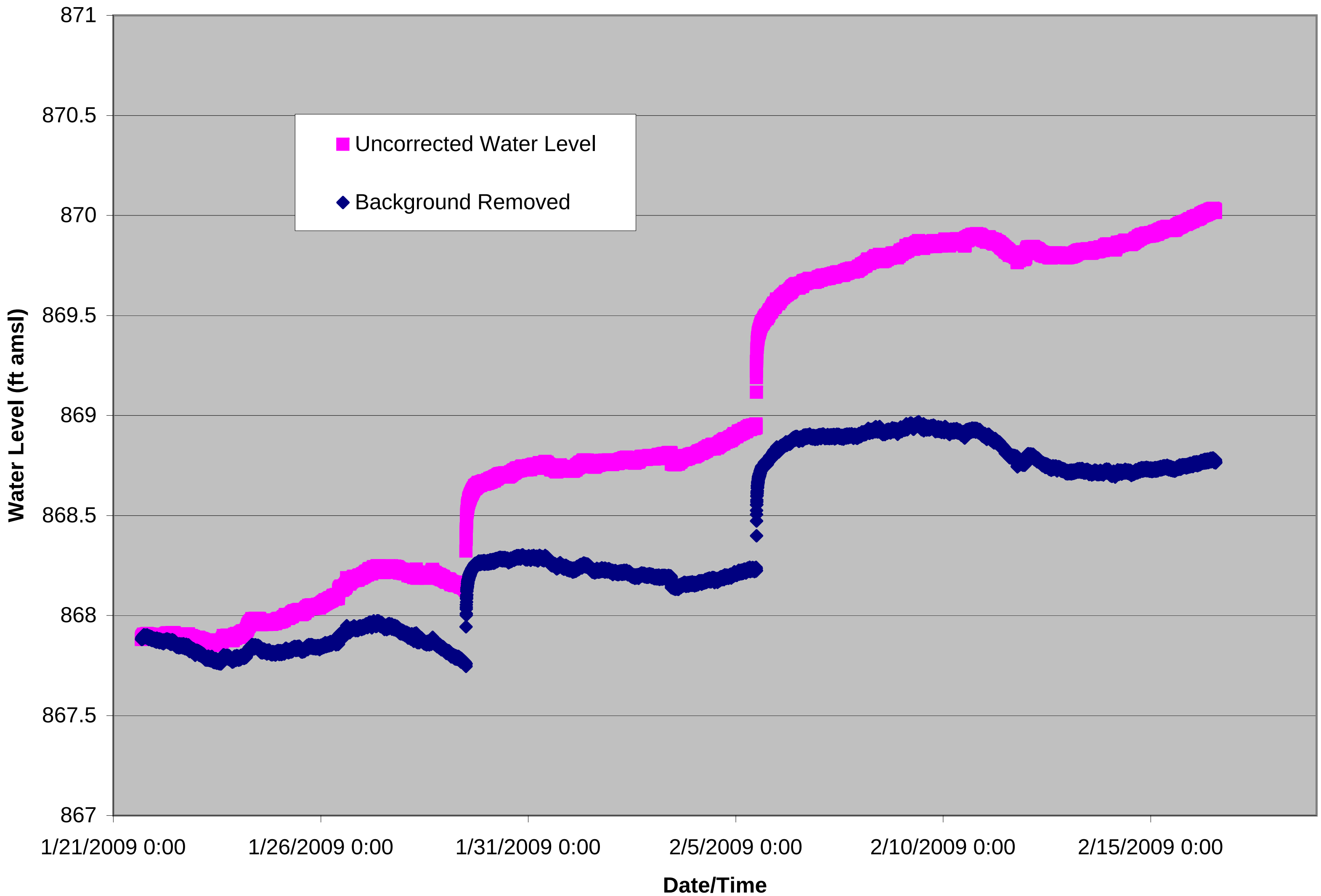
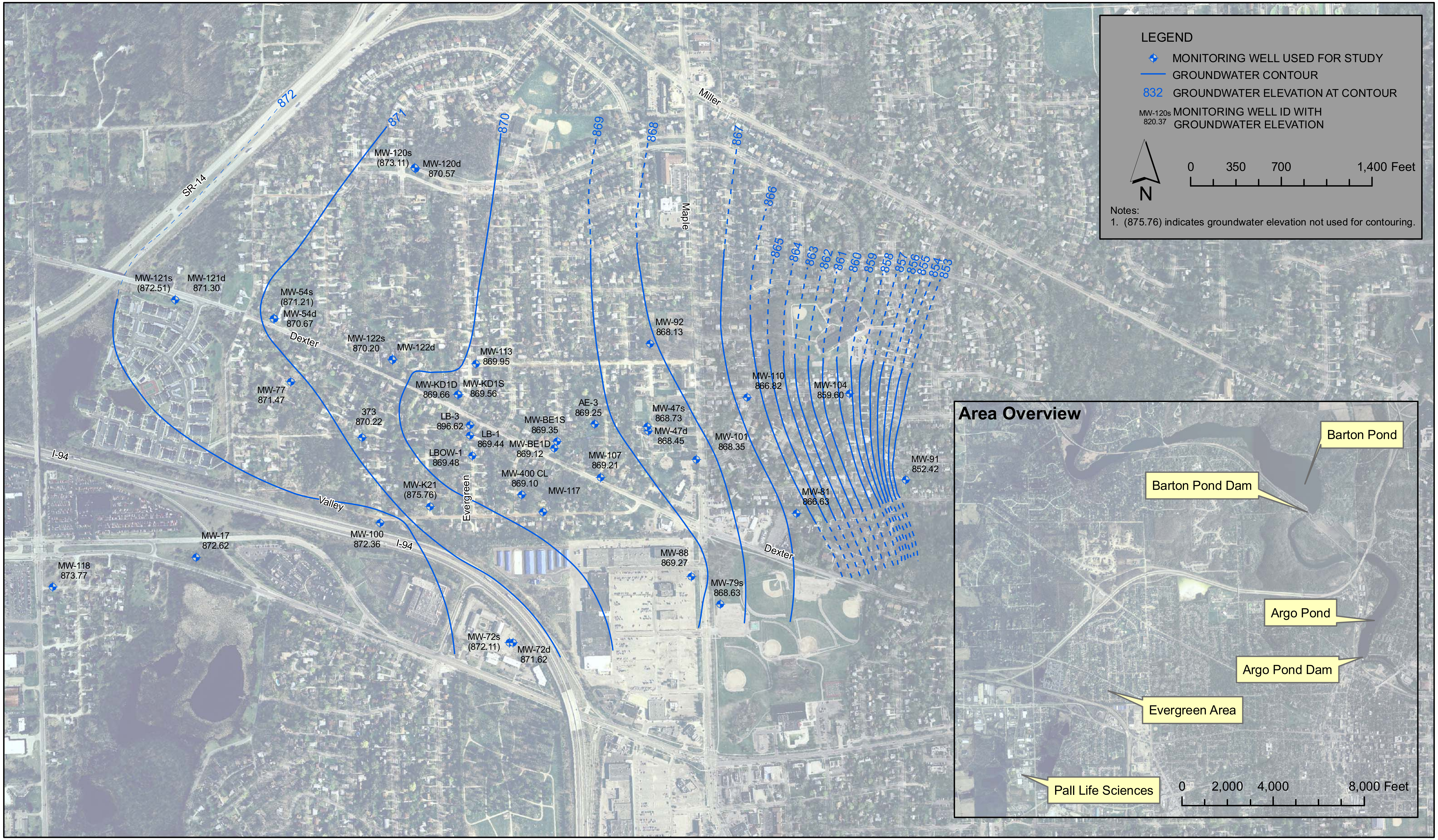


Figure 5. Uncorrected Water Levels at LBOW-1 with Background from MW-120D Removed





P:\Projects\Ann Arbor\PLS Project\GIS\Figure 6_PLS_Evaluation of Evergreen Report.mxd

SOURCE: 2005 AERIAL PHOTOGRAPH OBTAINED FROM SEMCOG

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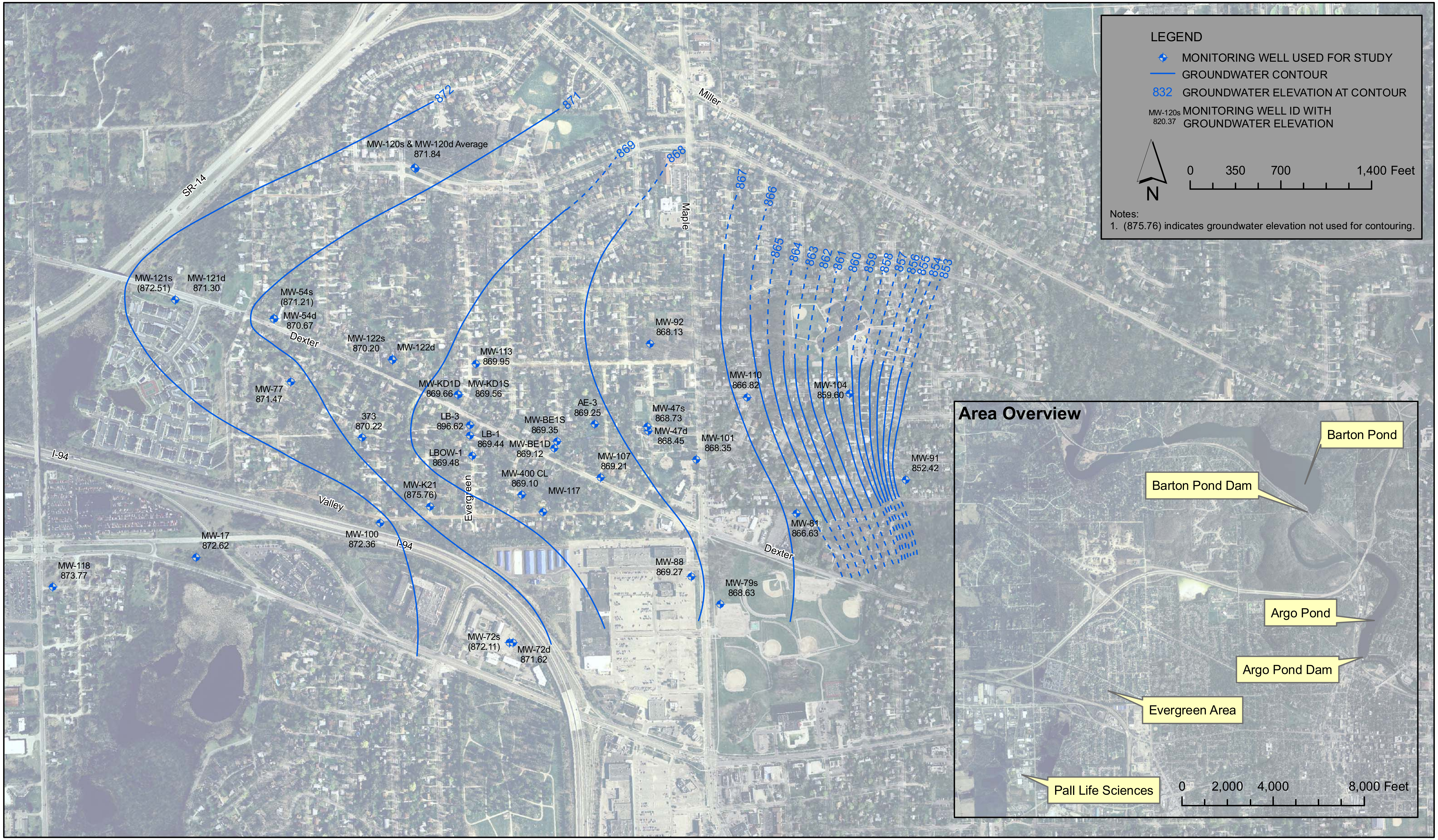
CHECKED: PJM | DATE: 6/8/2009

EVALUATION OF THE REPORT ON WATER LEVEL TESTING UNDER REDUCED FLOW CONDITIONS, PALL LIFE SCIENCES - EVERGREEN AREA
CITY OF ANN ARBOR
ANN ARBOR, MICHIGAN

INTERPRETATION A: SHALLOW POTENTIOMETRIC SURFACE TEST PERIOD 2
FEBRUARY 16, 2009

FIGURE
6



P:\Projects\Ann Arbor\PLS Project\GIS\Figure 7_PLS_Evaluation Evergreen Report.mxd

SOURCE: 2005 AERIAL PHOTOGRAPH OBTAINED FROM SEMCOG

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CHECKED: PJM DATE: 6/8/2009

EVALUATION OF THE REPORT ON WATER LEVEL TESTING UNDER REDUCED FLOW CONDITIONS, PALL LIFE SCIENCES - EVERGREEN AREA
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ANN ARBOR, MICHIGAN

INTERPRETATION B: SHALLOW POTENTIOMETRIC SURFACE TEST PERIOD 2
FEBRUARY 16, 2009

FIGURE 7