PRAIRIE ISLAND NUCLEAR GENERATING PLANT (PINGP) GROUND WATER INVESTIGATION: AN IMPROVED FLOW NET TO EVALUATE PATHWAYS FOR A POTENTIAL GROUND WATER RELEASE

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Prairie Island Nuclear Generating Plant (PINGP) Ground Water Investigation: An Improved Flow Net to Evaluate Pathways for a Potential Ground Water Release.

Background

A flow net is one method to determine the groundwater path way between two points.

An improved flow net was sought to identify potential receptors in the event that a hypothetical ground water release were to occur at the Prairie Island Nuclear Generating Plant (PINGP). A flow net is a static 'snap shot' of a dynamic system. It is constructed using ground water elevations collected from onsite wells for a specific date. To improve upon the current flow net, perspective was needed: How representative is the "snap shot" for the entire year.

Recent studies (USGS 1997) suggested large rain events could cause short term deviations from the existing flow net. In light of this information, Xcel Energy developed a study to identify the magnitude and quantify the duration of such changes in flow direction.

Project Design

The premise of this investigation was to identify short term changes in flow direction due to the influence of flooding or large rain events. Seven (7) wells were equipped with water level transducers and data loggers. Hourly ground water elevations were collected in these seven wells from March 30, 2009 thru December 16, 2009. Using methodology developed by Pinder (*Velocity Calculation From Randomly Located Heads, Pinder et al. 1981)*, hourly flow directions were calculated for pre-defined areas.

To improve the PINGPs flow net, two methods were employed. Surfer, a commercially available interpolation program was used to produce a more accurate prediction of ground water flow paths but it does not lend itself to processing large amounts of time variable data. The methodology developed by Pinder lends itself to processing large volumes of data, and thus identifying short term upsets; however it is less accurate than other methods. The two methods complement each other by putting the more accurate "snap shot" in to perspective for the full year.

Results

Figure 1 depicts the PINGP site, and identifies which wells were equipped with data loggers. Figure 2 presents the hydrographs for the hourly data from seven wells plus Mississippi River and Vermillion River elevations. Figures 3 thru 6 depict ground water elevation contours for the site when all wells were sampled and the approximate no-flow boundary. The no-flow boundary is the approximate northern and western limit of flow originating from the PINGP. Figure 7 illustrates the individual flow elements(areas) that were used to calculate the hourly flow directions. Figure 8 illustrates flow direction vs. time for each area. Figure 9 is a delineation of ground water which is down gradient from the PINGP using a compilation of all data generated in this investigation.

DISCUSSION

Hydrograph Aspects

As shown on Figure 2, the study period extended from March 30, 2009 thru December 16, 2009. Stage data from the Mississippi and Vermillion Rivers were available starting on February 6, 2009. As intended, this period included several significant events including the spring flood, and several large rain events in July and August. The following observations were made:

- Typical (non-flood) flow is from Mississippi River (highest head) to the groundwater under the Prairie Island Plant to the Vermillion (lowest head). This condition occurs over about 90% of the study period.
- The hydrographs indicate ground water elevations do respond to spring flooding. There is a short lag time between flooding and the rise in ground water elevations. Ground water elevations are also slower to recede.
- Ground water elevations were higher than the Mississippi River and the Vermillion River for about four weeks during the spring flood period. This suggests that a brief reversal of flow (from groundwater toward the rivers) occurs over about 10% of the study period. Groundwater flow during this period would likely be radially outward from groundwater to surface water.
- Several large rain events (1" to2"/day) occurred in August. Ground water elevations rose several inches in response to this precipitation. However all wells responded in a similar fashion, suggesting no mounding of ground water.

Ground water Elevation Contour Maps

Ground water elevations were interpolated using Surfer for four sampling events. Mississippi River and Vermillion River elevations were included in the surfer applications; the inclusion of these data resulted in the depiction of a strong southwesterly flow direction. Because water flows from areas of higher head to areas of lower head elevation, this southwesterly flow direction appears to be a reasonable characterization of actual flow conditions throughout the majority of the study period. This characterization is also supported by the hydrograph data and the apparent higher head in the Mississippi River relative to the Vermillion River during the majority of the study period. The following observations were made:

- Ground water flow paths (flow direction is perpendicular to elevation contours) generally trend southwest as described above
- Radial flow is exhibited near P-10 due to localized mounding of the water table. The mounding influence may be due the presence of several water features such as the cooling tower canals, a

surface drainage ditch and septic drain fields. The observed mounding diminishes within a short distance from the well, returning to the predominant southwesterly flow direction.

- Ground water gradients are depicted in Figures 3-6. The length of the vector arrow tails are proportional to the gradient; the longer the tail, the steeper the gradient. Assuming similar geology, this generally indicates faster travel velocities.

Hourly Flow Directions

Flow directions were calculated hourly, for four areas. Figure7 illustrate the areas represented by theses hourly directions. Figure 8 illustrates flow direction vs. time. The following observations were made:

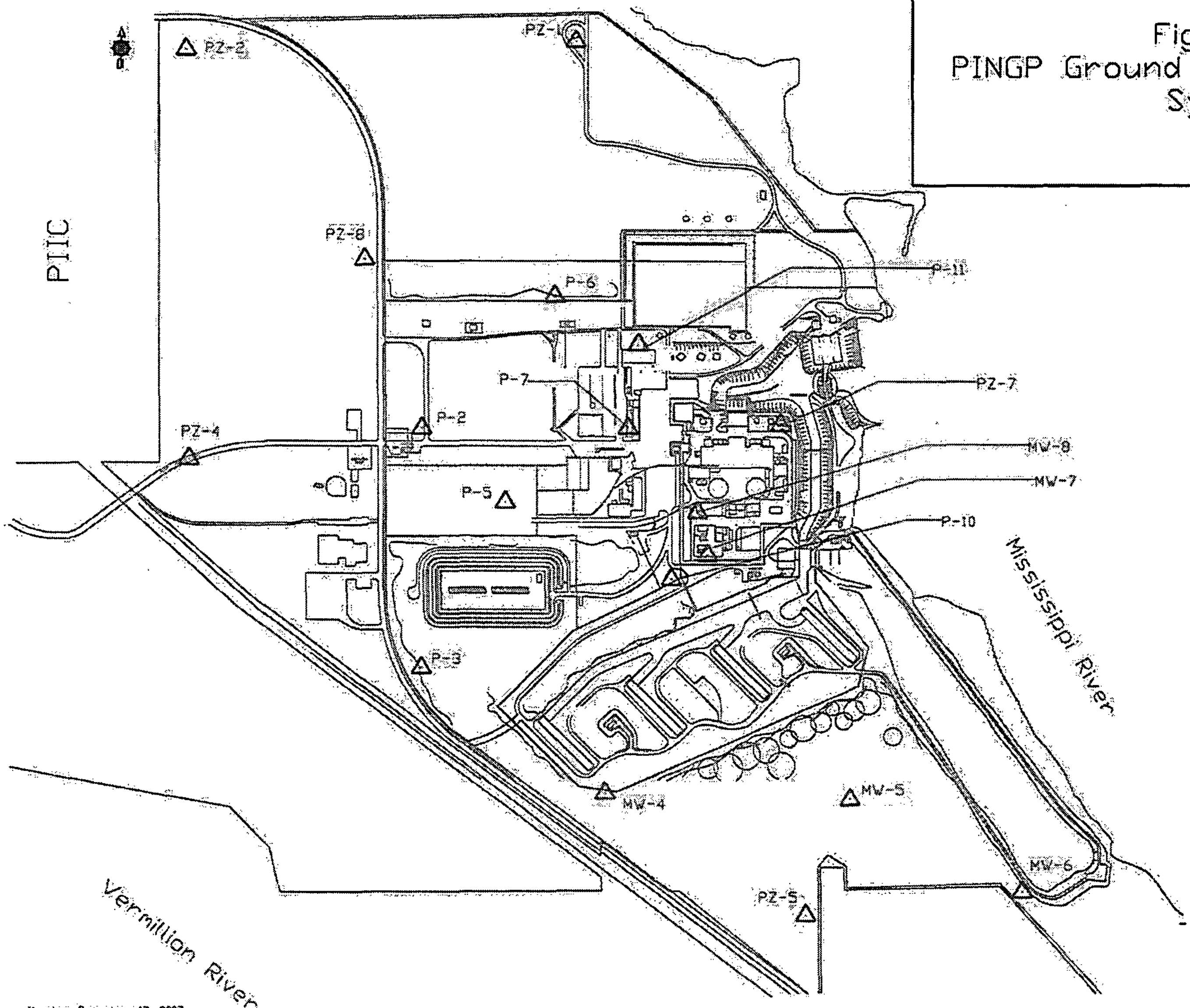
- The predominant flow direction, spatially and in terms of duration, is southwest (225 deg from north). The greatest deviation from this predominant trend occurred within 4-8 weeks after the spring flood.
- During the months of April and May, Area 1 and Area 4 reported westerly flows, however ground water gradients were significantly less during these times and the duration of time was short. Therefore the actual distance traveled, in a westerly direction, is small due to lower gradients and the short duration of the deviation.
- The four static flow nets depicted in figures 3-6 correspond to stable flow conditions, observed for the majority of the year. These flow nets are representative for the site throughout the year with the possible exception of 4-6 weeks after the spring flood.

CONCLUSIONS

- No evidence of ground water mounding was observed which correlated to large rain events.
- Mounding was observed near P-10. Radial ground water flow was noted. The numerous infiltration sources, (septic drain fields, drainage ditch, and cooling tower canals) are believed to contribute to the mounding effect.
- The inclusion of river elevations with ground water elevations improves the interpolated ground water contours and hence the flow net.
- The spring flood demonstrated the largest influence upon ground water flow directions. Flood influences extend 4-6 weeks after the flood recedes.
- With the exception of the 4-6 weeks after the spring flood, ground water flows southwest towards the Vermillion River.
- The flow nets presented in this report (Figures 3-6) represent flow paths for approximately 10 months out of the year.
- Given the short duration and limited areal extent of the flow reversals, a hypothetical release from the Prairie Island Plant could move only a relatively short distance from the plant during a spring flood event before it would be redirected to the predominant flow direction (to the southwest).
- The data collected during this investigation suggest that there is no direct ground water pathway connecting the PINGP and neighbors to the north and west of the plant. .

- Calculating hourly flow directions identified the months of April and May as having the greatest potential for westerly flow. Although the significance of these westerly flows is considered small, it is recommended to construct additional flow nets, using all wells, during this period of flux.

Figure 1.
PINGP Ground Water Monitoring System



Well Locations Surveyed by
Johnson & Scofield Inc
November 21, 2007

Well	North	East	Top of Riser Pipe Elev
MW-4	592236	2355090	693.02
MW-5	592201	2356566	686.83
MW-6	591642	2357597	682.33
MW-7	593685	2355714	695.54
MW-8	593944	2355654	697.47
P-10	593538	2355497	693.16
P-11	594949	2355297	698.19
P-2	594449	2354002	697.72
P-3	592998	2353997	698.19
P-5	594002	2354501	695.51
P-6	595250	2354802	699.3
P-7	594449	2355235	697.97
PZ-1	596790	2354934	682.91
PZ-2	596743	2352589	689.05
PZ-4	594262	2352598	696.53
PZ-5	591502	2356299	695.93
PZ-7	594469	2356158	697.85
PZ-8	595471	2353662	696.52

△ Well equiped with a data logger

Monday, December 17, 2007
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Figure 2. PINGP 2009 Hydrographs

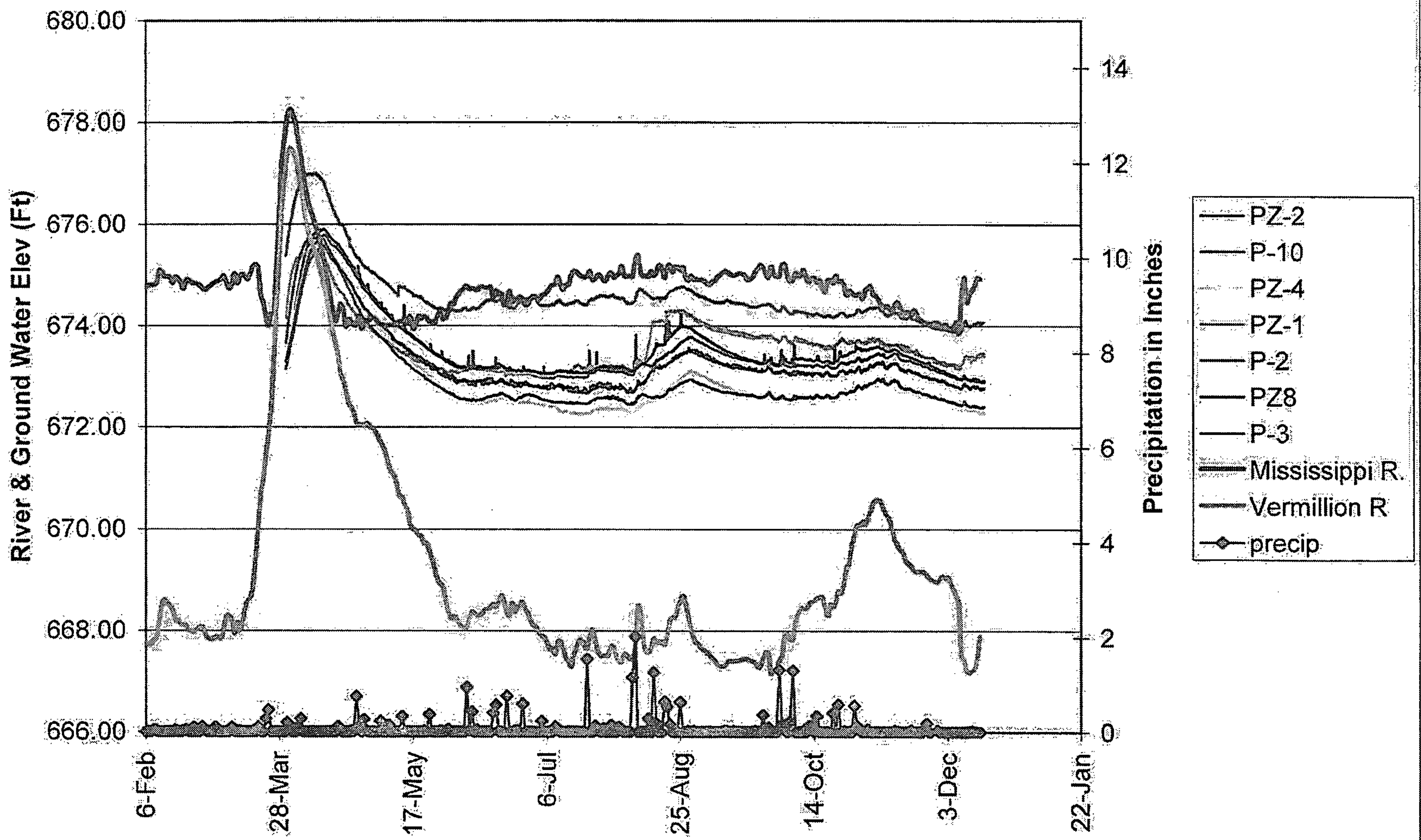
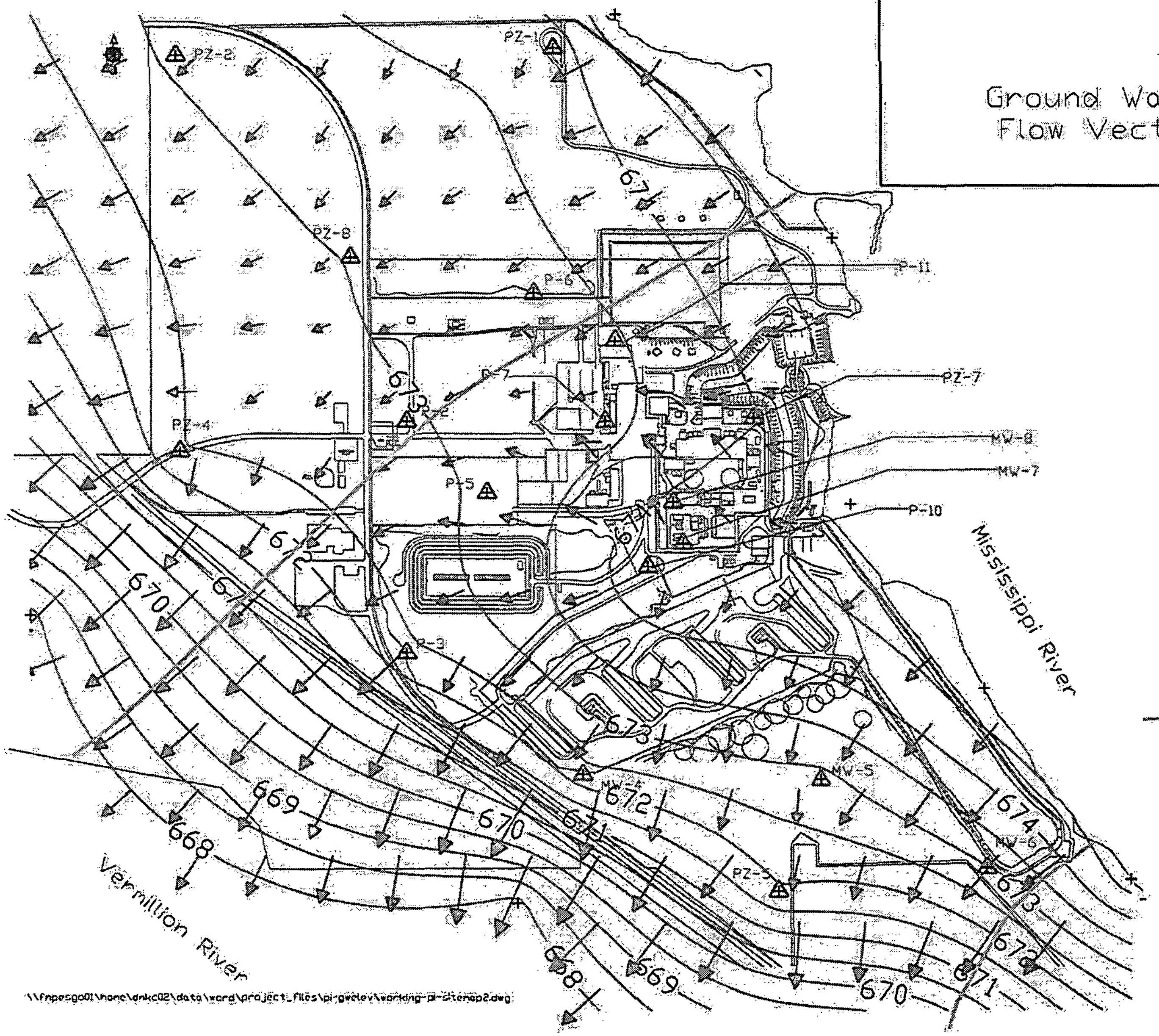


Figure 3. Ground Water Elevations and Flow Vectors for 7/11/2006



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No-flow boundary: The approximate northern and southern limits of flow originating at PINGP for a specific day.

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Figure 4
Ground Water Elevations and Flow Vectors for 7/9/2008

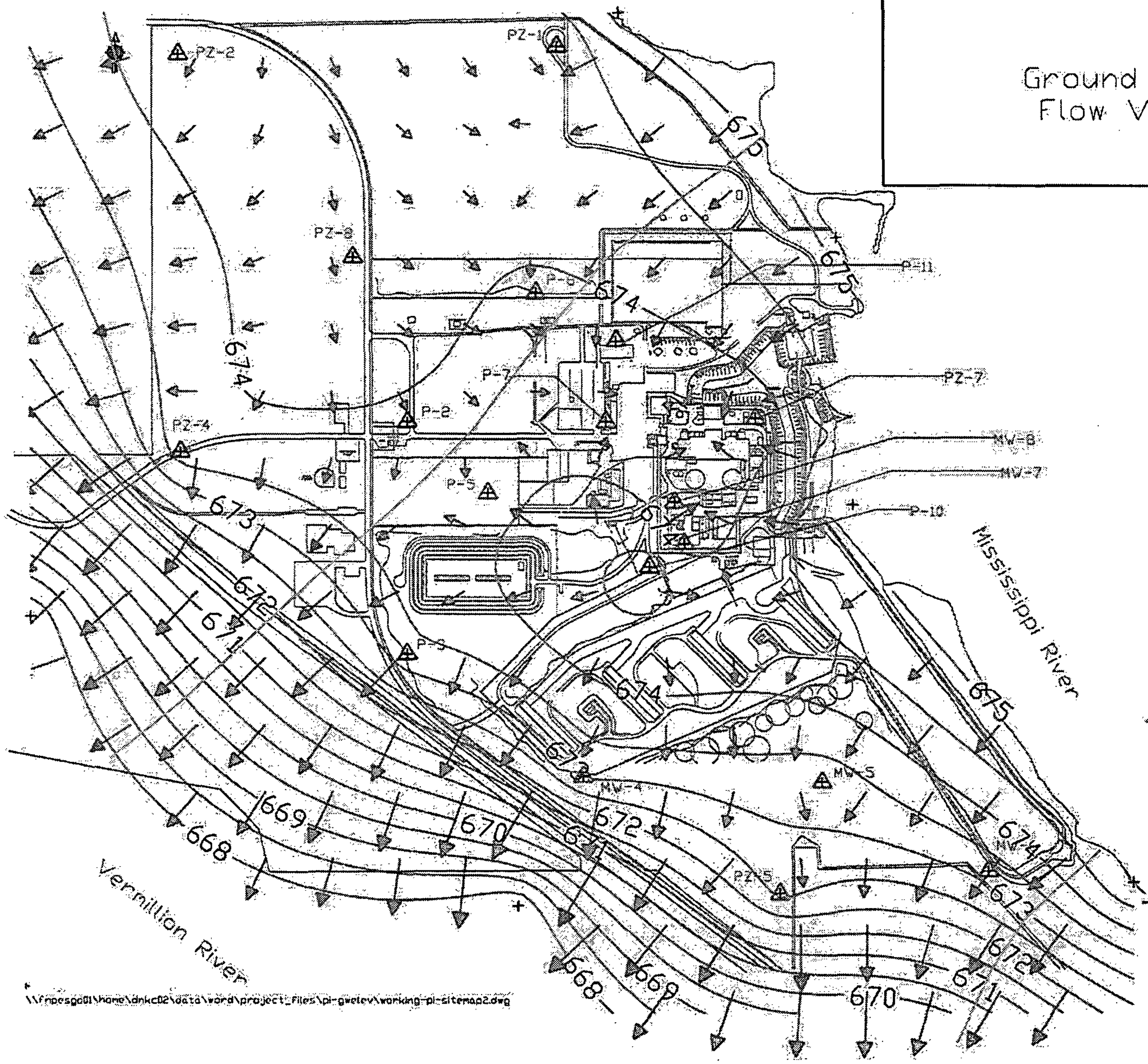

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Figure 5. Ground Water Elevations and Flow Vectors for 7/8/2009

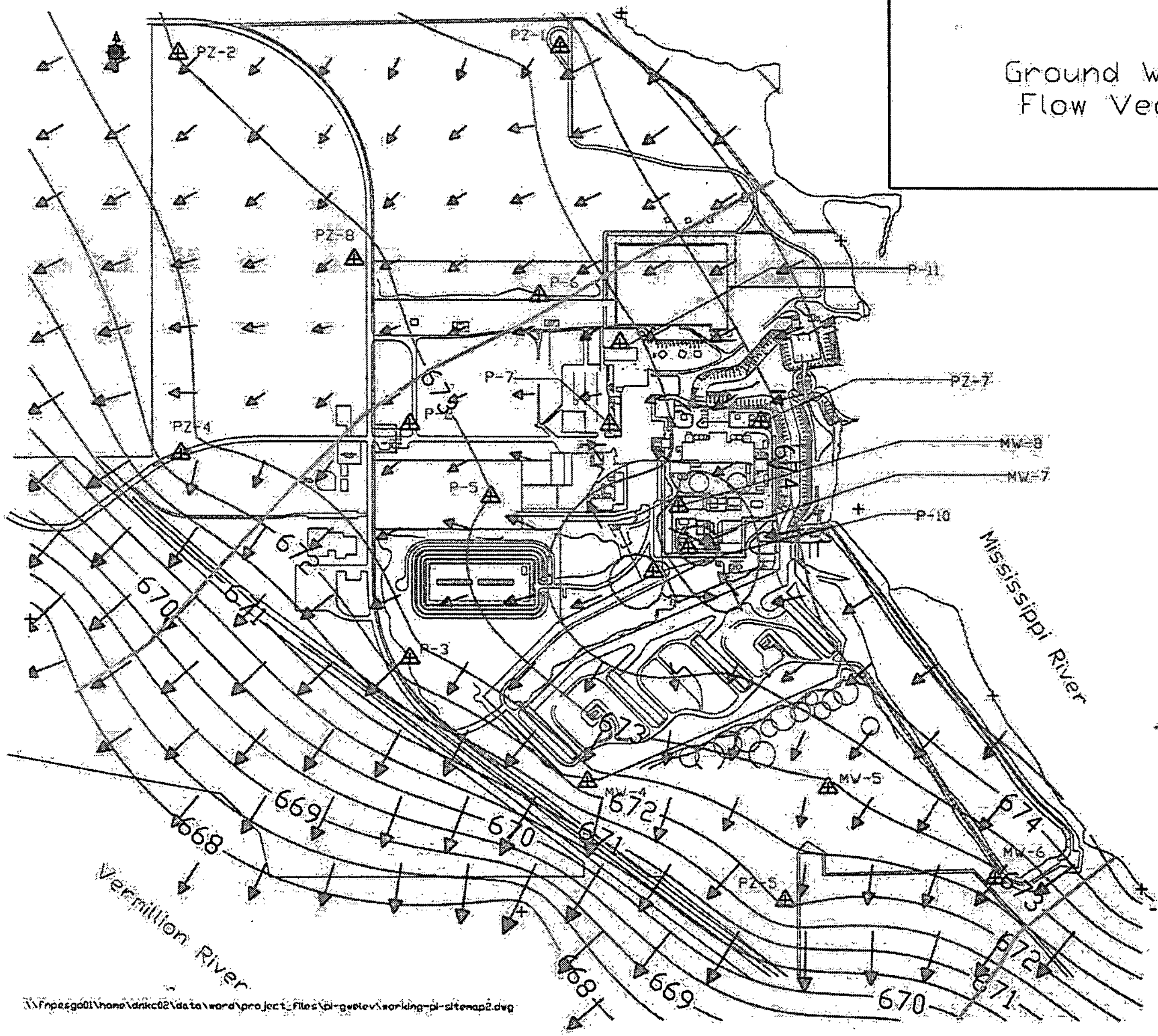

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Figure 6.
Ground Water Elevations and Flow Vectors for 12/16/2009

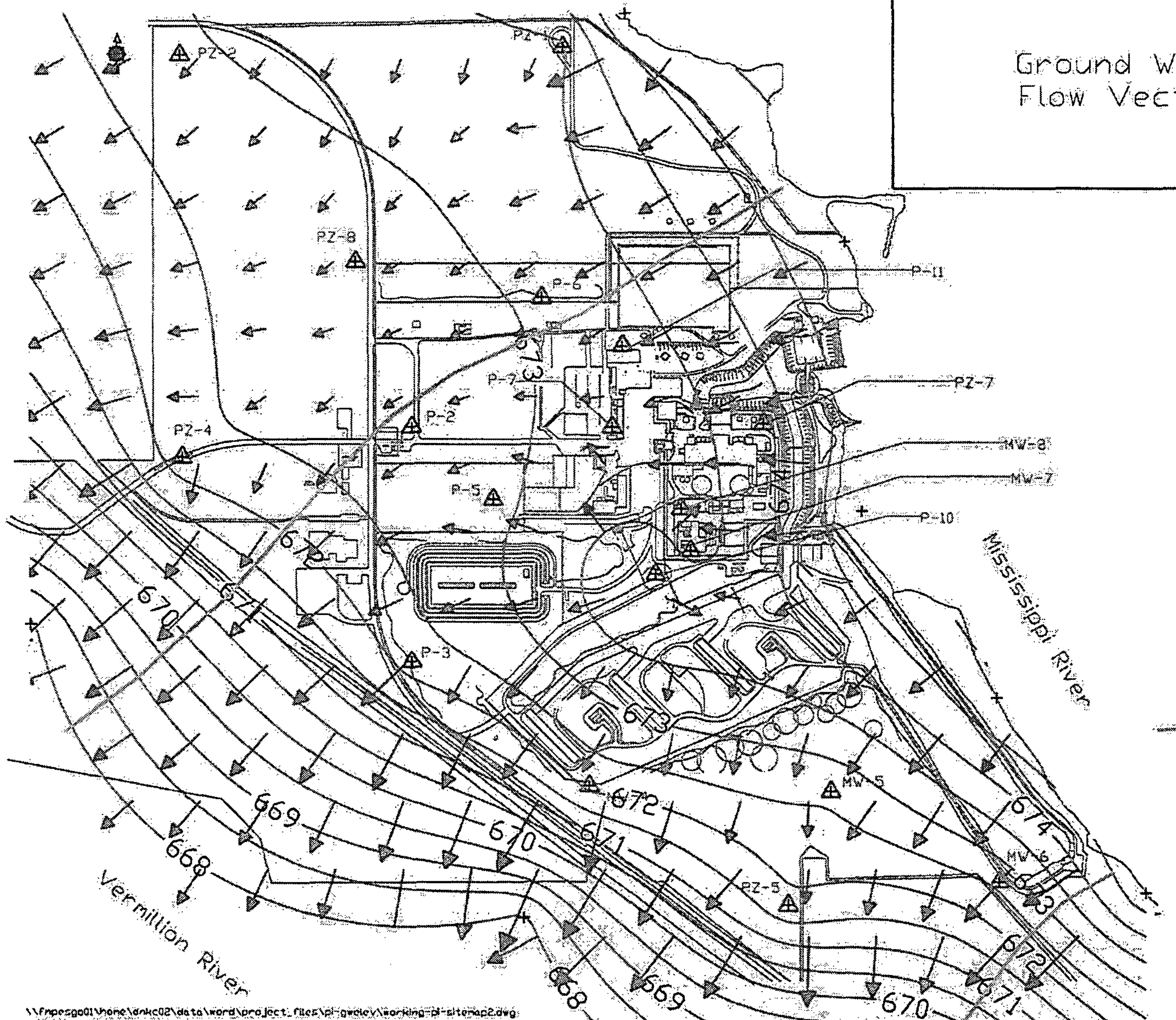

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Figure 7.
PINGP Ground Water Monitoring System Areas Hourly Flow Direction is Calculated

(see Figure 8 for results)

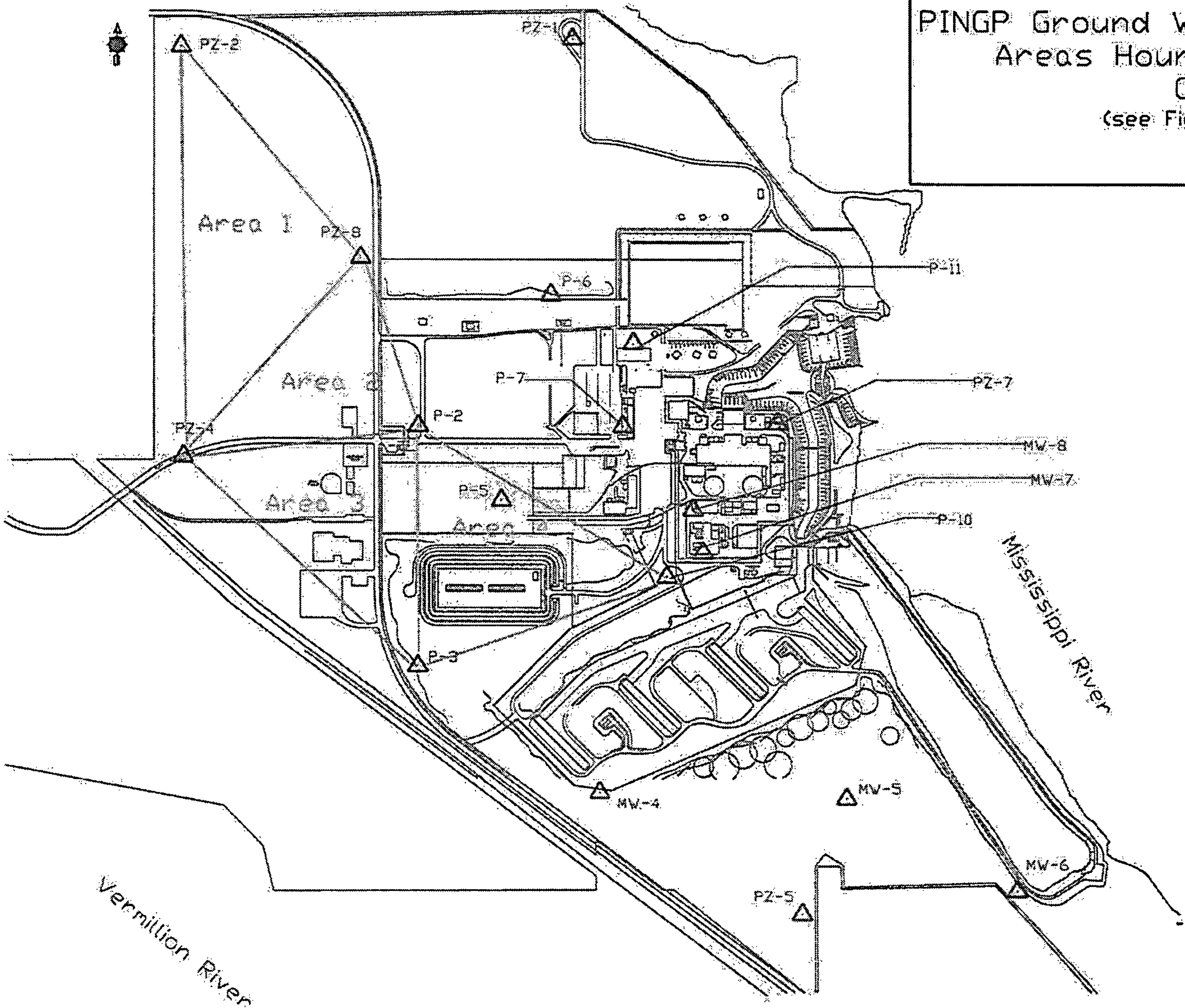

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Figure 8. PINGP Flow Direction vs Time

(See Figure 7 For Area Locations)

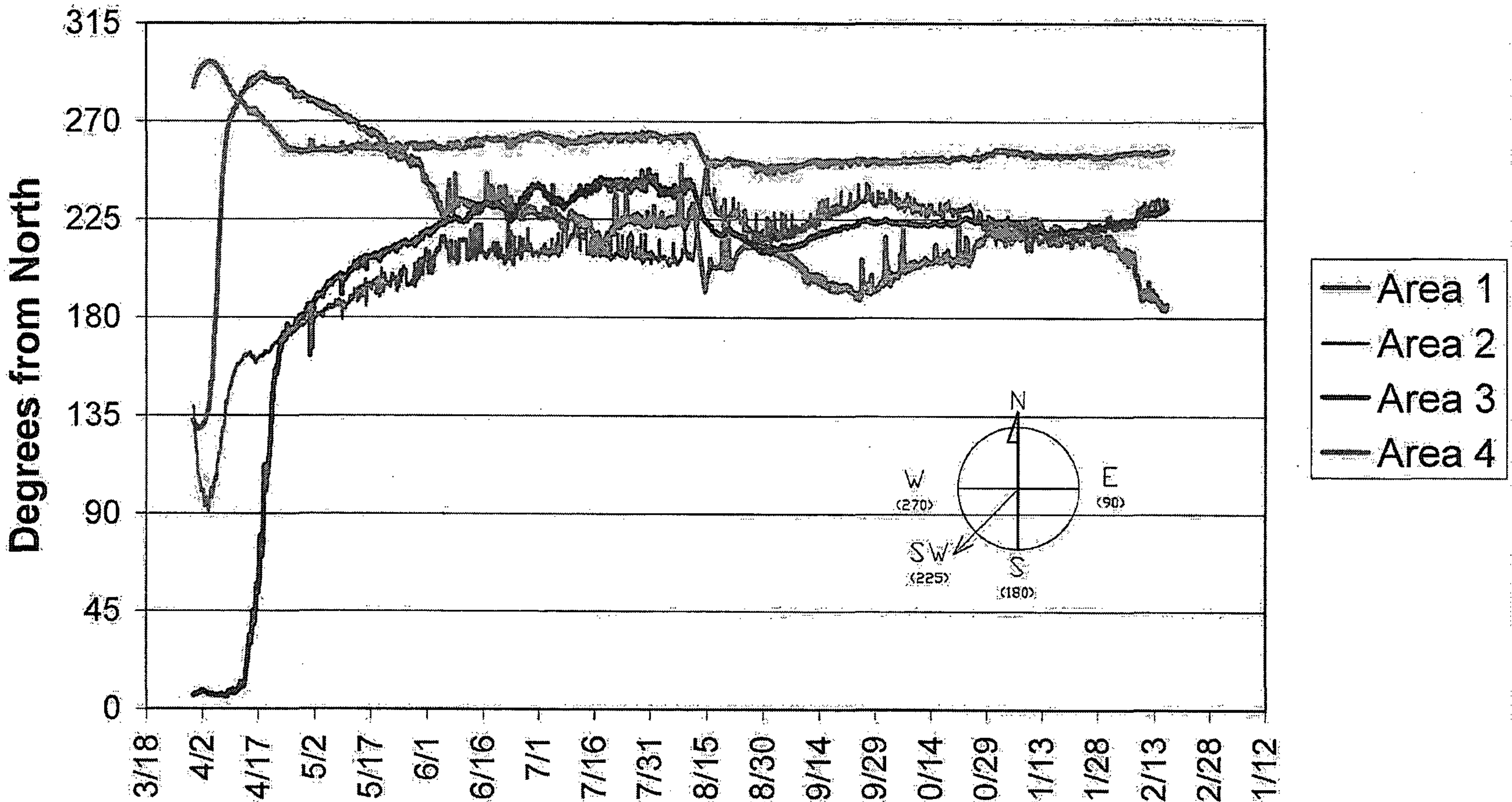

Figure 9. Composite of PINGP No-Flow Boundary Conditions.