8 Summary and Conclusions

The purpose of the study was to quantify evapotranspiration of the poplar trees and assess the degree to which the phytoremediation system impacts groundwater direction and flow. Total evapotranspiration of the site was accomplished by means of a water budget and solving for ET as well as comparing total ET to other studies and the Thornthwaite Method. Poplar tree evapotranspiration was attained through the White Equation, Groundwater Recession Method, and the calibrated groundwater flow model. Phytoremediation effects on direction and groundwater flow were investigated by means of contour plots of the site based on data collected from the piezometers and monitoring wells. This data also showed how the aquifer behaves during different seasons of the year. In addition to the contour plots, the groundwater flow model provided insight into how the tree water consumption alters groundwater flow.

8.1 Comparison of Tree Consumption Methods

Three methods were used to determine the amount of water consumed by the trees: (1) White's Equation (2) the Groundwater Recession Method and (3) the groundwater flow model. MW6 is the only well in which all three methods could be employed. The volume per day per tree value for methods 1 and 2 is obtained by multiplying the rate of groundwater decline attributed to ET by the area of tree coverage (0.7 acres) and then dividing by the number of poplar trees (927). The value for the groundwater model is found by dividing the output of the wells (166.24 ft^3/day) by the number of trees (927).

1. White's Equation: During the period of August 27, 1999 to September 9, 1999, the trees consumed 0.030 in/day (0.62 gal/day/tree).
2. Groundwater Recession Method: The trees used 0.040 in/day (0.81 gal/day/tree) on August 28, 1999 and 0.030 in/day (0.62 gal/day/tree) on August 30, 1999.
3. Groundwater Flow Model: During the period of August 26, 1999 to September 15, 1999, the trees used 0.065 in/day (1.34 gal/day/tree).

Hinckley et. al. (1994) reported water consumption by 4 year old poplar trees to range from between 5.3 and 6.9 gal/day for a 36 ft tall tree to between 10.3 and 13.5 gal/day for a 50 ft tall tree based on sap flow measurements. Sap flow measurements account for all water used by the tree (water taken from saturated and unsaturated zones) whereas the methods used in this study only account for water taken from the saturated zone. There was no information given in the Hinckley study about site conditions. The Oneida poplar trees range from three to four years old. The tallest poplar tree at the Oneida site following the 1999 growing season is 27.5 ft (Lawrence, 2000).

All three methods yield similar results. The groundwater recession method is most restrictive because of the large difference in average groundwater levels between winter and summer months. White's Equation is easiest to use if detailed pressure transducer data is available. One must be careful when using White's Equation not to mistake barometric pressure fluctuations for fluctuations caused by phreatophytes. White's Equation becomes more difficult to use when the trees are first beginning to grow and when the trees are starting to enter dormancy. This is because negative values of tree consumption can result during these periods and in winter months due to the errors discussed in Chapter 5. The calibrated groundwater model can be a powerful tool when looking at tree consumption. Not only can it be used to check other tree consumption methods, but it can be used as a predictor for how the aquifer will respond as the trees consume more water.

Unfortunately, the data in this study does not reflect the peak transpiration rates that occur during the months of June and July. The 0.62 gal/day/tree to 1.34 gal/day/tree rates calculated would be significantly higher during these months and would perhaps come much closer to the transpiration rates reported by Hinckley et. al. (1994). It is also expected that transpiration rates will increase significantly in upcoming years as the poplar trees continue to grow.

8.2 Phytoremediation System Water Use

The lowest rate calculated (0.030 in/day) yields a volume of 76.25 ft^3/day (570 gal/day) of water transpired by the poplar trees. The highest rate calculated (0.079 in/day) yields a volume of 165.17 ft^3/day (1236 gal/day) of water transpired by the poplar trees.

Several assumptions were made to calculate water use for the entire 1999 growing season. The growing season (resulting in water use by poplar trees) is assumed to last from mid-April to mid-October (6 months). An evapotranspiration rate of 0.041 in/day (average of three methods) is assumed for the entire growing season. This value is based on the date above because the time at which the data was collected was during the transition from a peak transpiration period to a very small transpiration period. Using the 0.041 in/day rate over the 6 month growing season and multiplying by the 0.7 acres of tree coverage results in a 1999 transpiration total of 140,292 gallons (18,754 ft^3). The *total* ET calculated for the 10 month period in 1998 was 1,570,064 gallons (200,887 ft^3). The tree use in 1999 accounts for 8.94% of this total. This number would only be reduced slightly were the 1998 water budget for all 12 months used since very little evapotranspiration occurs during the months left out (January and December). The 8.94% total is considerably less than the 20 to 25% total that Sorensen et. al. (1999) found for the ratio of pecan tree transpiration to total ET. Possible reasons for this are a poor estimate of the average summer ET or that the trees are still a year or two too young to produce the rate of evapotranspiration seen in the literature. Geraghty & Miller estimate 0.2 million gallons (26,736 ft^3) were used by the poplar trees during the 1998 growing season (compared with 18,754 ft^3 calculated above).

8.3 Conclusions

Groundwater flow at the site is significantly affected by the phytoremediation system. Water contours show that water is at least to some degree directed towards the phytoremediation system during the growing season which helps contain the contamination plume. Figure 4.3 shows how the water levels are affected as a whole by the process of evapotranspiration. Water levels are lowered during the growing season due to increased evaporation rates and the transpiration of plants. The lower water levels and smaller hydraulic gradients reduce the amount of water that can potentially be contaminated by creosote still sitting on the bedrock. As the trees continue to grow and consume more water, it can be expected that the aquifer in the vicinity of the poplar trees will not have a saturated thickness (be dry) during many of the summer/fall months.

There are several other conclusions in this study that only relate indirectly to the objective but are nonetheless significant:

- Diurnal fluctuations of the water table were noticed all the way to the bottom of the well as the water table lowered. This indicates that the poplar trees' roots are well established all the way to bedrock and can transpire water from depths of 8 to 10 feet.
- The groundwater flow model is not well calibrated for data sets where water levels approach bedrock.

- Because evaporation rates from the land surface are so much higher during summer months than winter months, water levels in the aquifer would likely exhibit the same general trends as seen in Figure 4.3. This is due to reduced infiltration because of what is evaporated off of the land surface or used by grasses, even though, the trend in the data would not show the same extremes without the poplar trees. Only the poplar trees can reclaim groundwater and soil moisture and prevent it from being contaminated (or uptake contaminated groundwater).

8.4 Future Considerations

More monitoring of the site needs to be done in relation to evapotranspiration to truly learn its effect. The data in this study is not sufficient to draw accurate conclusions concerning peak transpiration rates or total transpiration over the entire growing season. Some ideas concerning future study of the site are:

- Examine transpiration rates of the poplar trees during the entire growing season to determine when transpiration begins and ends as well as peak rates.
- Application of White's Equation should get easier and be more accurate as amplitudes of the fluctuations increase as the trees grow.
- It would be beneficial to place pressure transducers at other locations on the site. There is no data at the western end of the site (near P1, P2, and P3) or the extreme eastern end of the site which might provide further information on how the interception trench controls the water (See Figure 8.1).
- Transducer may need to be moved away from the center (i.e. P4 and P6) of the phytoremediation system. The aquifer will likely be dry (resulting in no data collection) during many of the summer months as the trees continue to grow (See Figure 8.1.).
- It would also be beneficial to place a pressure transducer outside of influence of trees to act as a control (perhaps where the Temp well was located – see Figure 8.1). This will provide a way to compare tree use in the aquifer to non-tree use in an area with similar aquifer properties. It could also provide data on the extent to which poplar trees reduce recharge.

Figure 8.1: Oneida site drawing showing recommended placement of pressure transducers for future study of evapotranspiration and its effects on the site.