Memorandum

To: *Bill Prehoda, P.G.*

From: *Dan O'Rourke, P.G.*

Date: *March 22, 2016*

Subject: *Drought Simulations using the Newark Basin Groundwater Model: FINAL*

Introduction

Groundwater model simulations have been conducted to evaluate the change in head and stream baseflow within the Newark Basin associated with two drought scenarios. Simulations were conducted with the existing Newark Basin Groundwater Model developed by the USGS using SUTRA (herein referred to as the SUTRA Model; Yager and Ratcliffe, 2010; **Figure 1**). The primary objective of the drought scenarios was to evaluate the response of the Suez Water New York (SWNY) wells within the model domain to determine if any wells go dry during a drought. The scenarios were developed to mimic the drought of record in the northeast United States (early to mid-1960s).

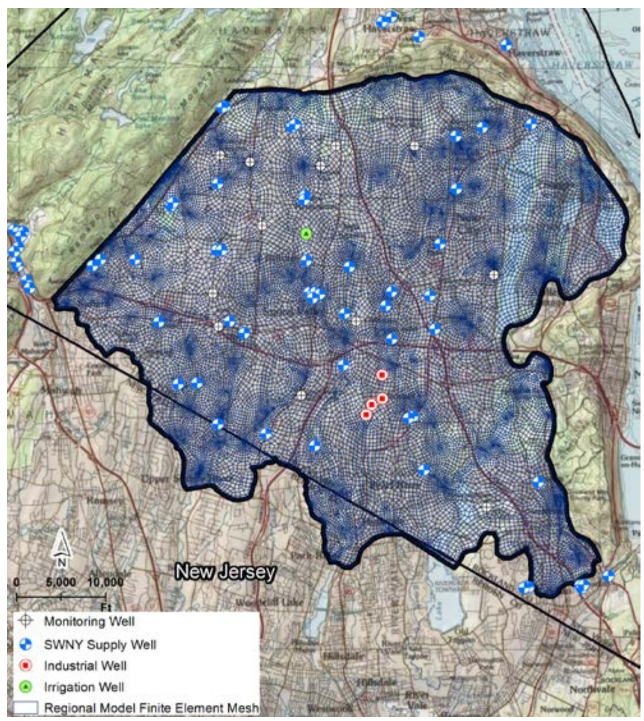


Figure 1 Finite element mesh for the Newark Basin Groundwater Model developed by the USGS

As part of the SUTRA Model development, the USGS conducted transient simulations to evaluate the aquifer response to changes in pumping and recharge over time. Two simulations were conducted:

1. A short term simulation was conducted representing a three year period between 2000 through 2003. That simulation used monthly time steps incorporating monthly groundwater withdrawals and recharge.

2. A long-term simulation was conducted simulating conditions from 1960 through 2006 using annual time steps of pumping and recharge.

These simulations provided the foundation of the drought evaluations.

Drought scenarios were developed in a collaborative effort between SWNY, Rockland County Department of Health and CDM Smith. The drought scenarios were developed to:

- Evaluate the impact of an extensive short-term drought;
- Evaluate recharge conditions from 1960 to 1970 and approved groundwater pumping capacity, and
- Evaluate conditions from 1960 to 1970 with approved groundwater pumping capacity AND changes to reservoir levels.

The third scenario was run as a test to determine how the boundary conditions at the reservoir influenced the rest of the model. In the existing SUTRA Model, the water surface elevation is set as a specified head.

The development of model simulations and model results are summarized below. It's important to note that this evaluation was conducted using the regional model. The results include simulated head at individual wells. Generally, this requires a much more refined grid, with discretization similar to the Spring Valley SUTRA Model (Yager and Ratcliffe, 2010). Therefore, it should be noted that head loss at individual supply wells are estimates only and are intended to evaluate which wells could be at risk during a significant drought. Development of a more refined grid is outside the scope of this project.

Drought Simulations

Simulation 1: Short Term Drought

The purpose of the short term drought simulation was to simulate the impact to the Newark Basin Aquifer due to a short-term drought condition while keeping pumping maximized. In order to fully capture seasonal impacts, monthly time steps were required.

The objective for this simulation is to simulate a two year drought based on the lowest recharge simulated in the 1960-2002 model simulation. This recharge is represented as 1966 (11.2 in/yr.; **Figure 2**). Because the recharge in the long-term simulation is annual, in order to simulate monthly conditions, the recharge had to be subdivided into monthly time steps. The monthly distribution of annual recharge as published by Heisig (2010; **Figure 3**) was utilized. The annual 1966 recharge

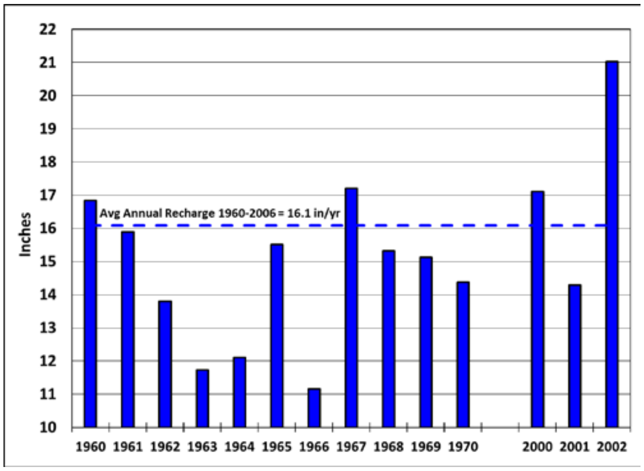


Figure 2 Annual recharge included in the SUTRA Model.

used in the long-term simulation in the SUTRA model was distributed into a monthly recharge based on the percentages in **Figure 3**.

Pumping conditions represented the actual 2000, 2001 and 2002 pumpage that is included in the SUTRA Model. For the drought period of 1966, the approved pumping capacity was utilized for SWNY wells (simulated approximately 16 million gallons per day (mgd)). The approved capacity is based on an annual average. Pumping was distributed by month based on monthly distributions in 2001 and 2005, which were dry years. For the New York Country Club, the SUTRA Model includes approximately 0.43 mgd from April through October and no pumping in other months. This was held through the drought period as well. Similarly, pumping that occurs at Pfizer (formerly Lederle), 2000 and 2001 conditions were used for the 2 year drought period.

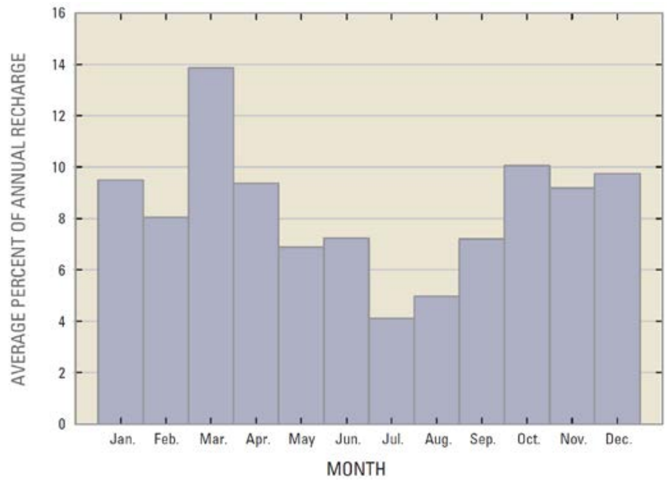


Figure 3 Monthly distribution of annual recharge (modified from Heisig, 2010).

In summary, the short term simulation utilized the USGS short term transient run through 2002 to represent starting conditions. At that point, the aquifer is "full" (**Figure 4**). For the "short-term" drought simulation, the following conditions were simulated:

- Years 1, 2 and 3: 2000, 2001, 2002 pumping and recharge conditions (duplicated from the SUTRA Model)
- Years 4 and 5: 1966 recharge and maximum pumping
- Years 6, 7 and 8: 2000, 2001, 2002 (same as 1-3).

Simulated pumping and recharge are shown on **Figure 5**.

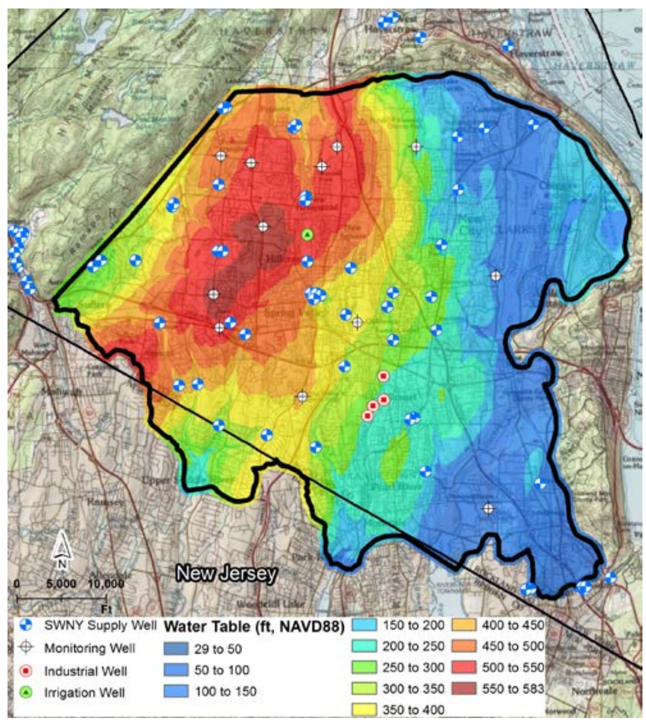


Figure 4 Starting conditions for Simulation 1 representing the end of December 2002.

Results of the short-term drought simulation are shown on **Figure 6**. Time periods are at the peak of the drought which represents September of

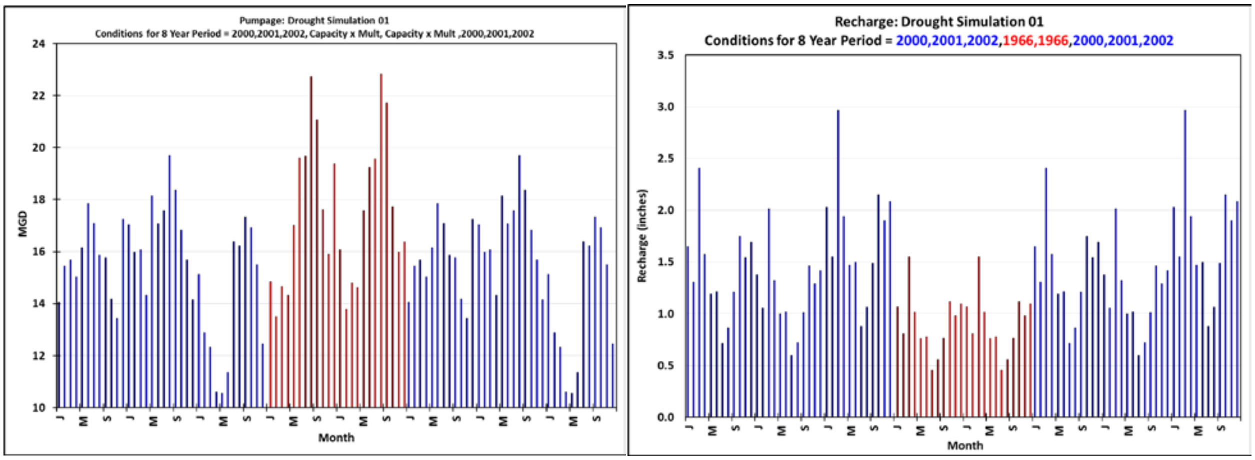


Figure 5 Simulated pumpage and recharge for drought simulation 1 (short-term).

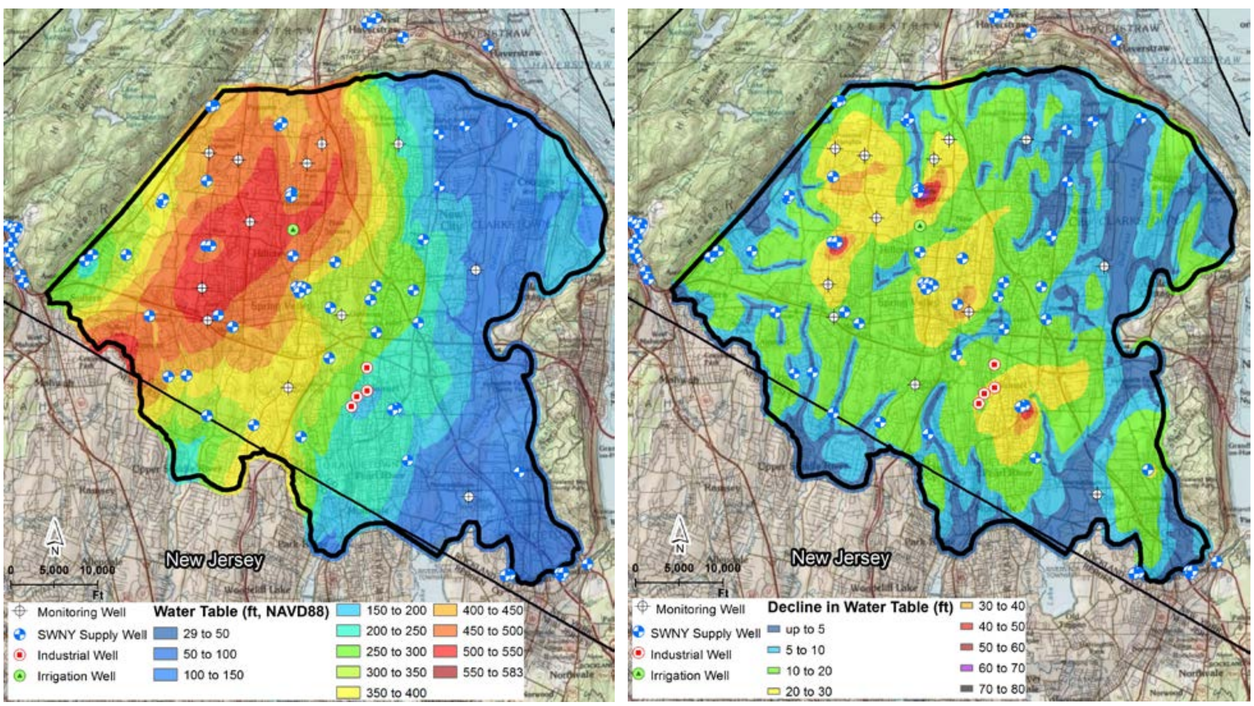


Figure 6 Simulated water table (left) and the decline in the water table (right) for the short-term drought condition.

the second drought year. For the decline in the water table, the difference represents the difference from September 2002 and September of the second drought year.

As shown on **Figure 6**, the water table declines more than 50 feet in some areas, particularly around the Nanuet, Viola and New Hempstead well fields. Simulated aquifer impacts are shown at various monitoring wells on **Figure 7**. As the objective of this modeling effort was to evaluate impacts to the SWNY system, water table declines at various SWNY wells are shown on **Figure 8**.

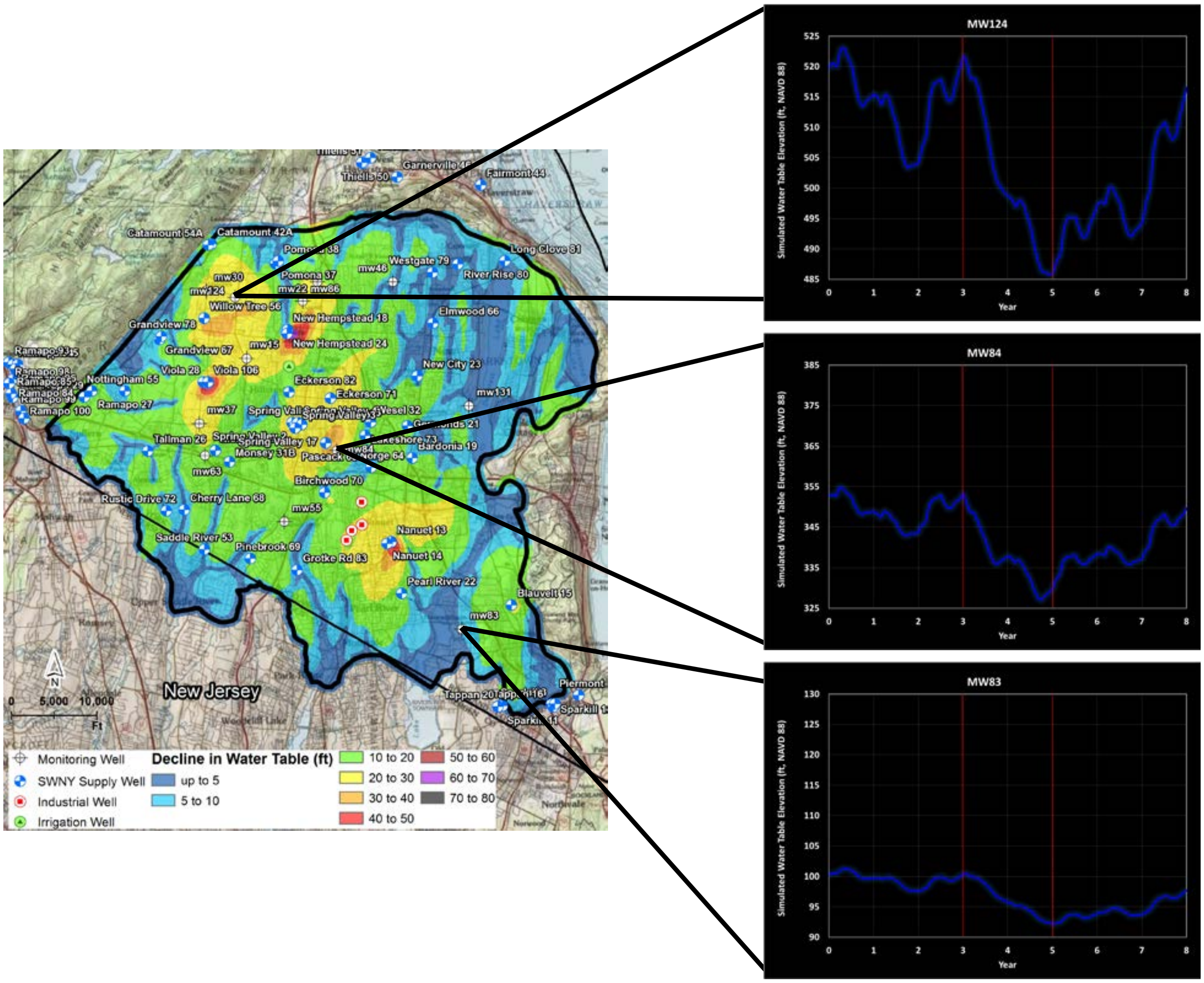


Figure 7 Simulated decline in head at three monitoring wells during the short-term drought simulation.

Note that the water level drops below the pump setting in the Viola (orange line) which indicates that the well would shut down during this period. The pump settings of most of the other supply wells are deep enough so that the short term drought does not result in a decline great enough at those wells to shut them down.

There may be issues at the Catamount, Germonds, Pearl River and Ramapo (Newark Basin) well fields as well. However, there is additional uncertainty with these well fields as the SUTRA Model indicates that they go dry during 2000 to 2003 conditions. One reason for this is that the model could be somewhat under simulating heads during normal conditions. Also, it is possible that the no flow boundary to the west is resulting in too much water being withdrawn locally, resulting in lower heads at the Catamount and Ramapo (Newark Basin) wells.

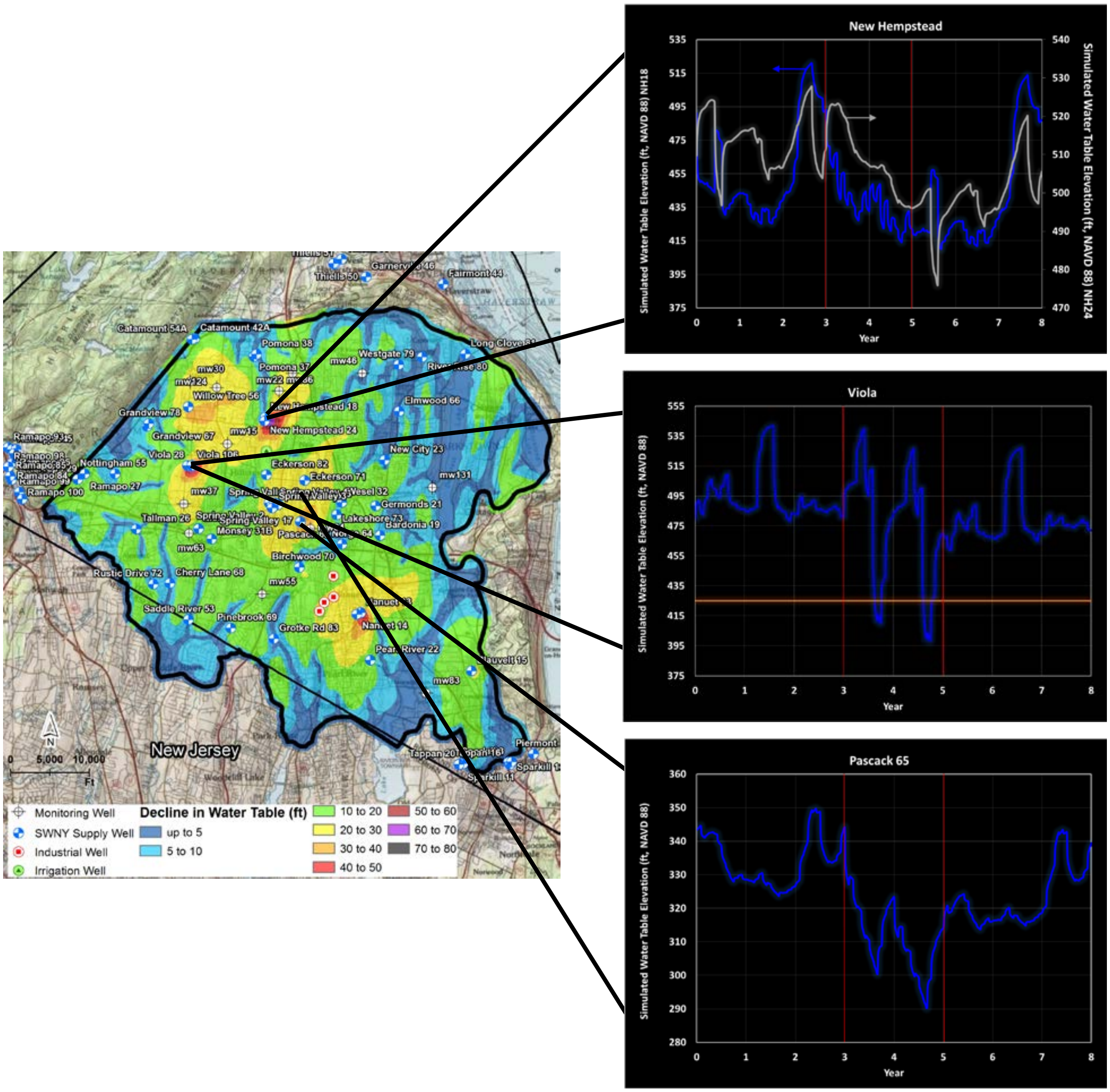
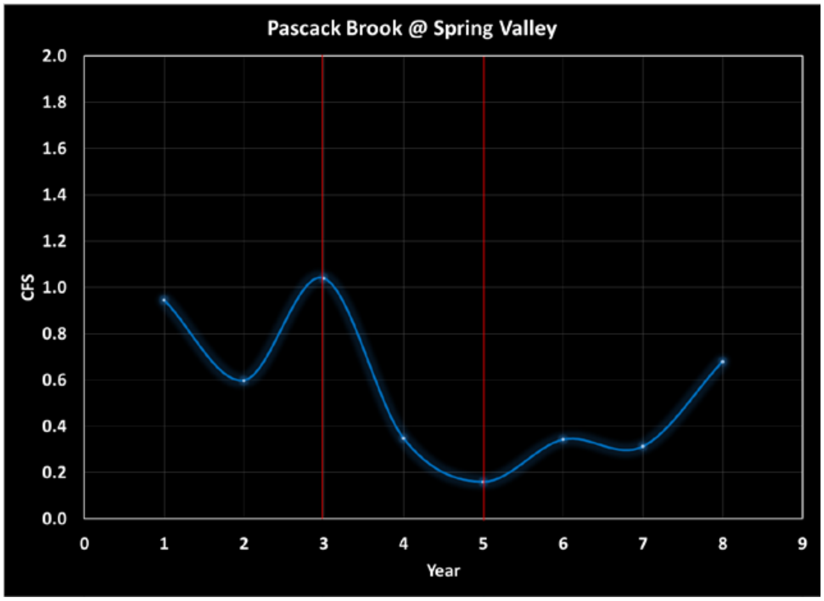


Figure 8 Simulated groundwater table at three water supply well stations. The orange line on the Viola plot represents the pump setting.

As the water table drops due to drought conditions, baseflow to streams will decline as well. The simulated baseflow to Pascack Brook at Spring Valley is shown on **Figure 9**. As shown on the figure, baseflow significantly decreases during the drought period. Although this stream was not gaged throughout the entire drought period of the 1960s, baseflow approaches zero during the early stages of the drought.



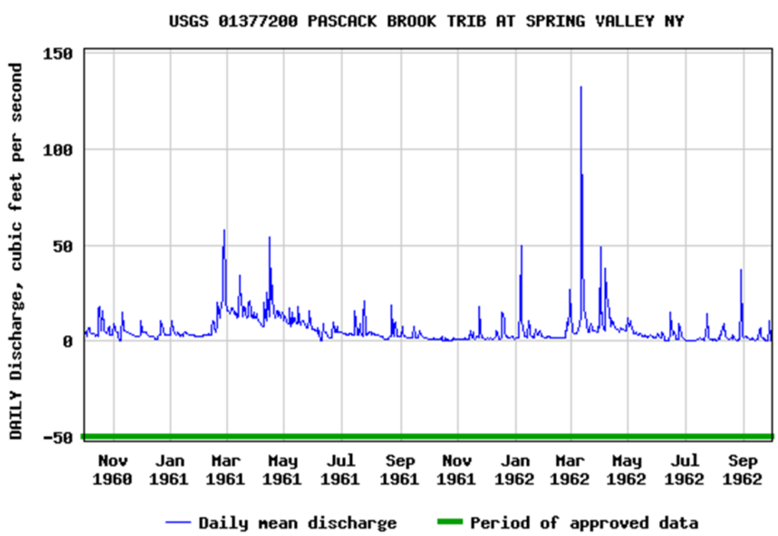


Figure 9 Simulated baseflow to Pascack Brook at Spring Valley during the short term drought simulation. Observed flow (bottom) from USGS.

It should be noted that the decline in the water table may be somewhat optimistic, particularly in areas near the southern model boundary or near the major lakes to the east (**Figure 10**). The SUTRA model utilizes a specified head at those areas and that head will remain fixed throughout the drought simulation. This is further evaluated in Simulation 3.

Simulation 2: Long Term Drought

The objective of the second simulation was to evaluate an actual drought period. For this simulation, recharge conditions from 1960 to 1970 were simulated. A total of 17 years was simulated in which the annual average recharge of the long term transient USGS simulation was used for three years prior and three years after the drought period. Annual recharge was distributed monthly based on the distribution in Heisig (2010; **Figure 4**). The pumping that was simulated for the drought period in Simulation 1 (approved capacity) was assigned throughout the entire 17 year period. Pumping and recharge for this simulation are shown on **Figure 11**.

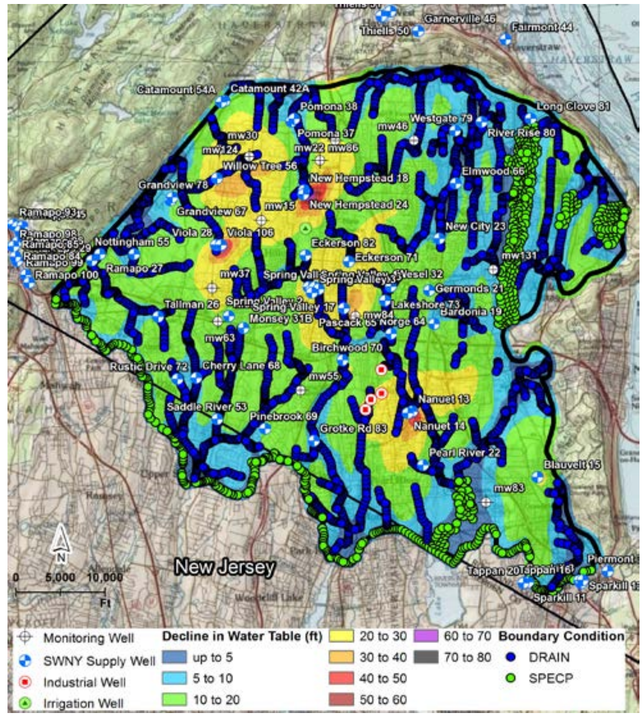


Figure 10 Boundary conditions for surface water bodies in the SUTRA Model. Streams are represented as drains and open water (lakes) as specified head.

Simulation results are shown on **Figure 12**. Note that the decline in the water table is not as drastic as Simulation 1, but that is due to a lower starting point. Simulation 1 compared the 2 year period to 2000 through 2002 conditions of pumping and recharge whereas this simulation compares the drought period to a period of average recharge but approved capacity pumping.

Simulated changes in water level at the monitoring wells on **Figure 7** are shown on **Figure 13**. As shown on the figure, the changes in water level during the drought period are not as drastic, but the absolute minimum is lower than Simulation 1. The change in water level at MW83 is dampened somewhat likely due to the fixed boundary condition at Lake Tappan. The simulated water table at Viola (**Figure 14**) clearly shows an impact to long term drought as the water level routinely falls below the pump setting (orange line). In addition to Viola, there may be issues at the Catamount, Germonds, Pearl River and Ramapo (Newark Basin) wells, as discussed above.

Simulated baseflow to Pascack Brook is shown on **Figure 15**. The trend is similar to the short term drought simulation, although the flows are lower due to the extended drought and increased pumping used throughout the simulation.

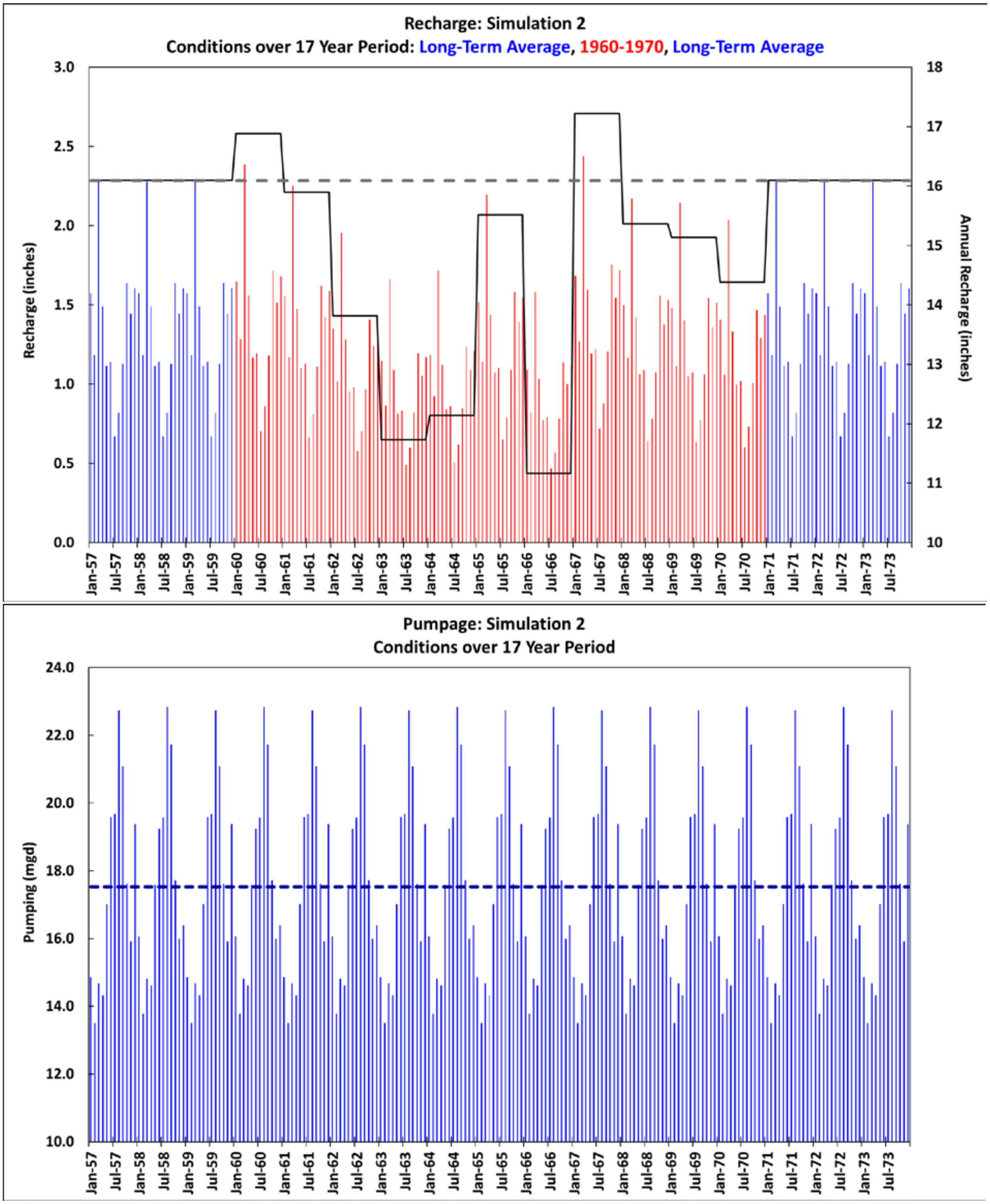


Figure 11 Recharge (top) and pumping (bottom) for long-term drought simulation. Average annual recharge is shown in the solid black line for each year as well as long-term average annual recharge (dotted line). Average annual pumping is shown by the dotted blue line.

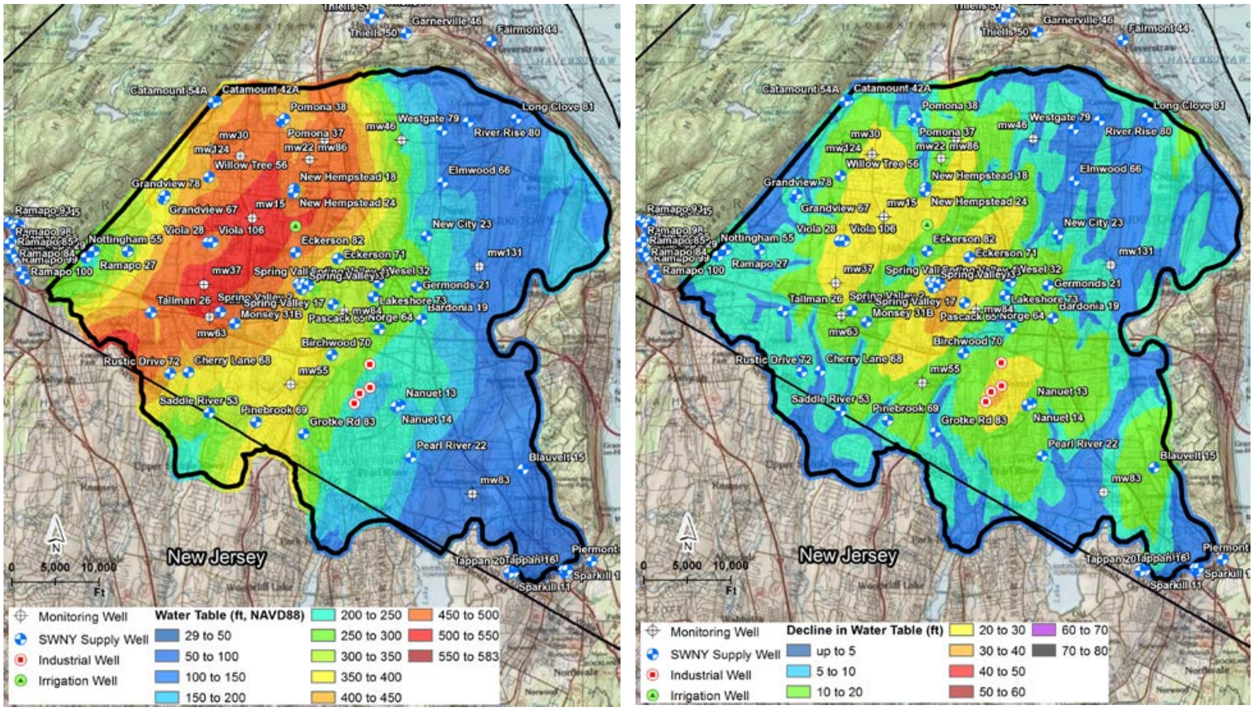


Figure 12 Simulated water table (left) and the decline in the water table (right) for the long-term drought condition.

Simulation 3: Long Term Drought / Sensitivity

The third simulation was developed to test the influence of the fixed heads on the head within the aquifer and ultimately at the SWNY supply wells. The simulation focused on evaluating Lake DeForest by changing the water level over time within the long-term drought simulation. For the drought period of 1960 to 1970, reservoir data were obtained from SWNY and average reservoir elevation data were calculated and incorporated into the model. Three year periods prior to the drought period and after the drought period were set at the water elevation specified in the SUTRA Model. Simulated water elevations at Lake DeForest are shown on **Figure 16**. The model was re-run and simulated water levels at SWNY wells were generated over time. The influence of the reservoir does not extend to SWNY system wells.

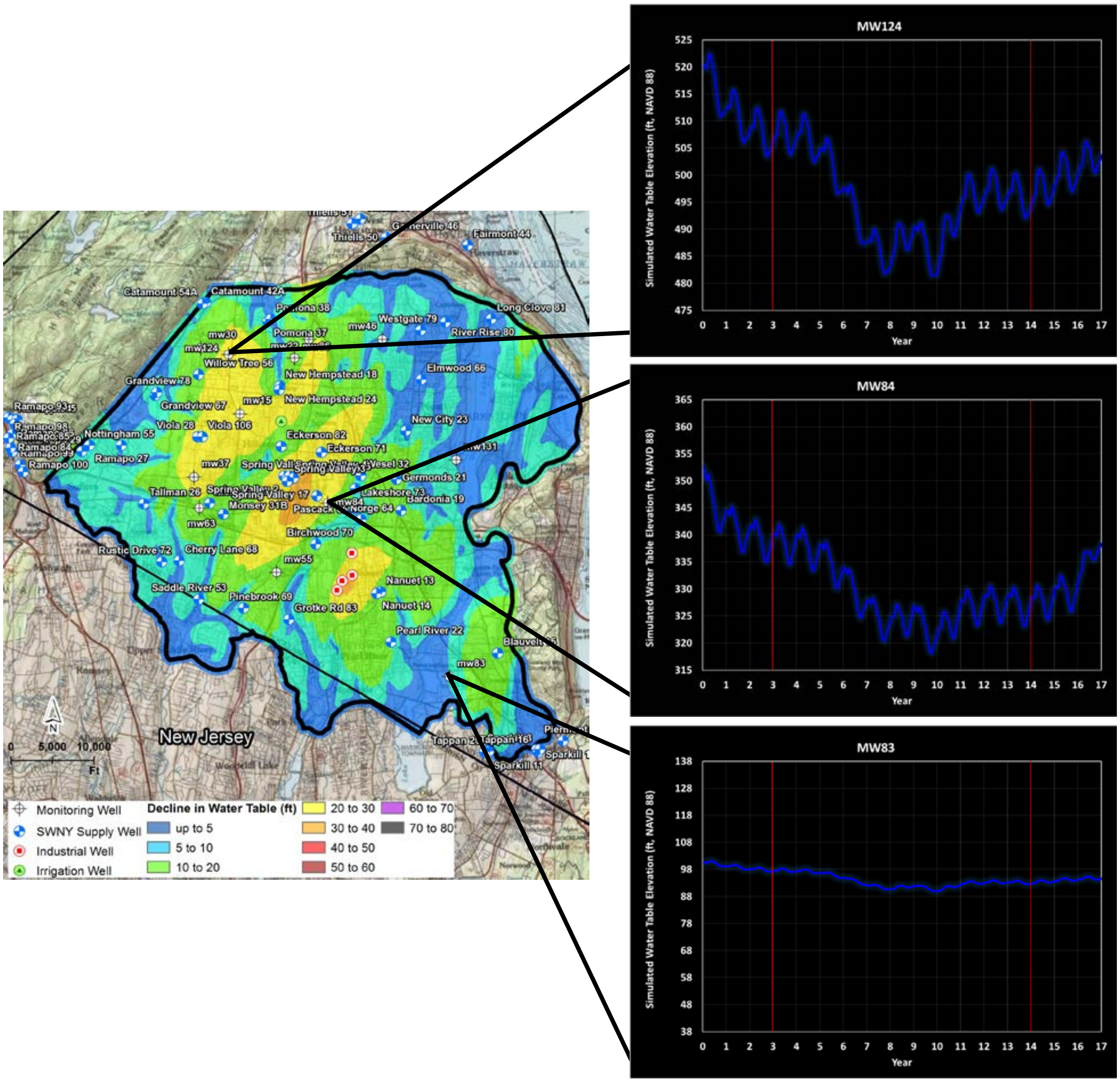


Figure 13 Simulated decline in head at three monitoring wells during the long-term drought simulation.

Figure 14 Simulated water table elevation at the Viola well field. The orange line represents the pump setting. Note the water level drops below the pump setting during the antecedent period (due to increased pumping used for pre drought conditions).

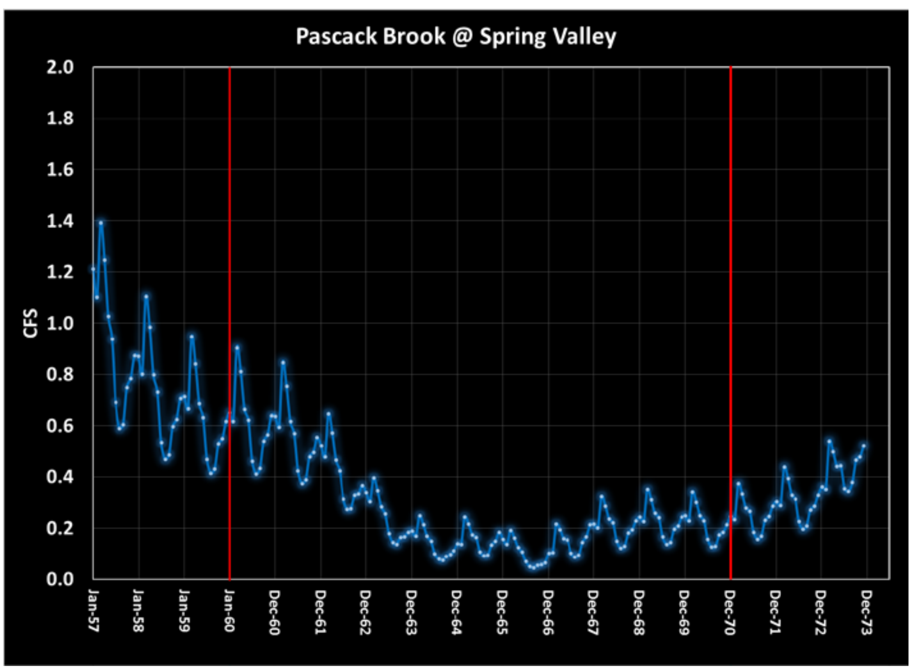


Figure 15 Simulated baseflow to Pascack Brook at Spring Valley during long-term drought simulation.

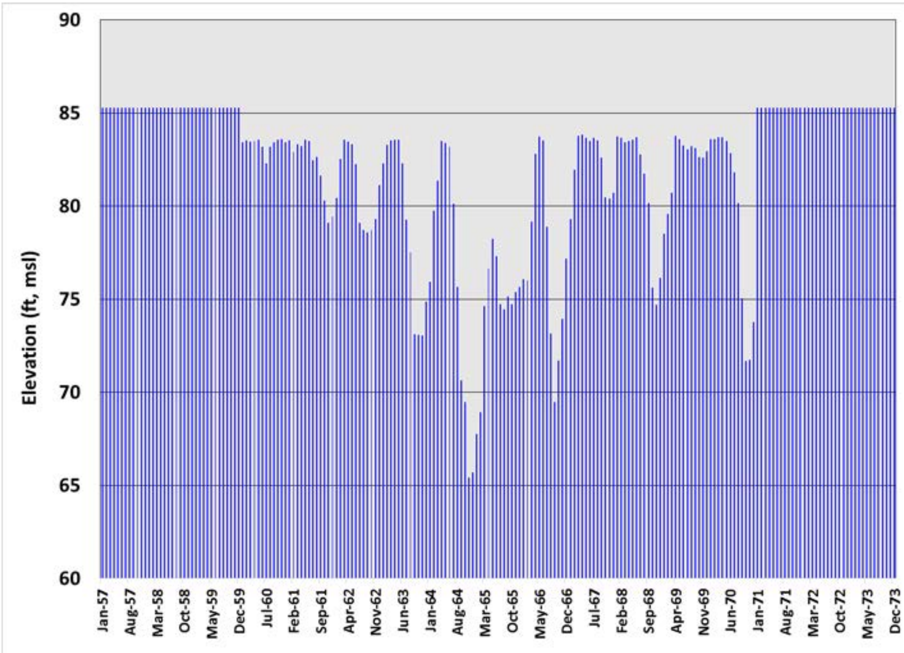


Figure 16 Simulated water level elevation at Lake DeForest for Simulation 3.

Summary & Conclusions

The existing SUTRA Model developed by the USGS was run under various drought scenarios to evaluate which SWNY wells were most vulnerable under drought conditions and to assess the reduction of pumpage that would be necessary to keep the wells pumping. It's important to note that the simulations conducted utilized a regional model and estimates of water level decline at the individual wells is therefore a simulated approximation. To accurately assess water levels within the wells, additional refinement is required.

Also, it should be noted that drought simulations are extreme, using the historic record drought in the northeast United States combined with maximum pumping from supply wells for up to 17 years. Although we have seen numerous droughts between 1970 and today, they have not been as intense as the 1960s drought.

The Viola wellfield is at risk due to the simulated water levels falling below the pump setting. In order for the Viola wells not to go dry within this simulation, the pumping rate needs to be reduced so that head is above the pump setting at all times. Model simulations suggest that a reduction of approximately 35% during August and September periods (and perhaps the entire summer) is required at Viola (**Figure 17**). However, this is a reduction from this extreme drought simulation, not actual conditions. Any loss in capacity at Viola can potentially be gained at other wells in the system, but additional evaluation is needed.

Additional reduction may also be needed at the Catamount, Germonds, Pearl River and Ramapo (Newark Basin) wells, although as mentioned above, it is not clear if the reduced heads are an artifact of the model.

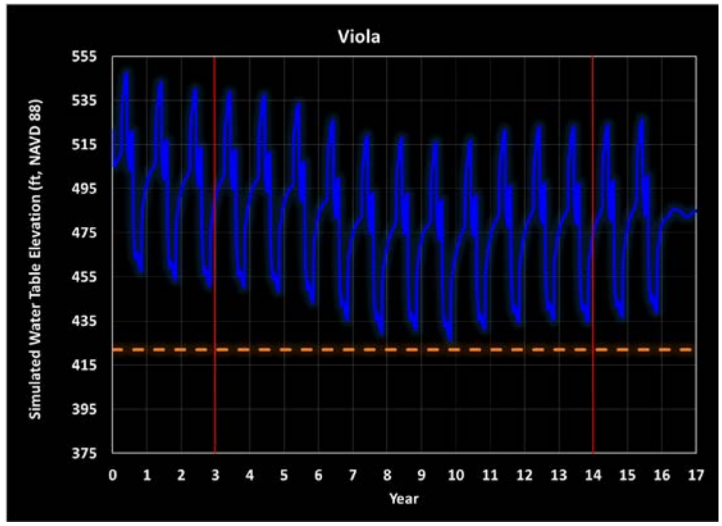


Figure 17 Simulated water level at the Viola wells following a 35% reduction in pumping during August and September drought periods.

Although this study has focused primarily on SWNY water supply wells, drought conditions could have a significant impact on domestic water supply wells. Domestic wells are generally shallower than community public supply wells and therefore are at a higher risk of going dry during a drought. A plot of known domestic wells over a map of depth to water during the Simulation 3 drought conditions is shown on **Figure 18**. As shown on the figure there are a significant number of domestic wells within the model domain that simulations suggest would result in a depth to water of more than 100 feet below grade during the drought scenario. In those areas, any wells that are shallower than 100 feet are simulated to go dry.

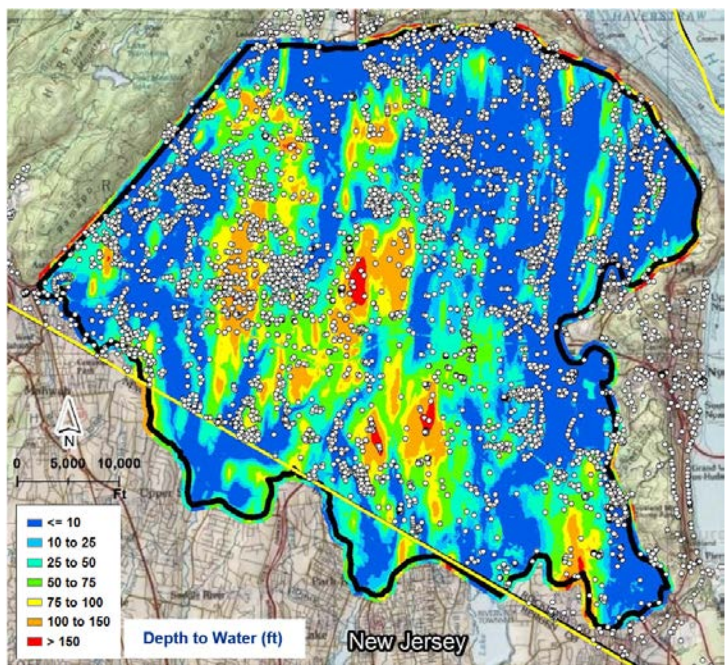


Figure 18 Simulated depth to the water table during the peak of the drought in Simulation 3.

Based on the model simulations conducted, the following conclusions can be made:

- Many areas throughout the SWNY system show more than a 20 foot head decline in significant drought scenarios;
- Problems are evident at Viola during significant drought and maximum pumping conditions;
- Other issues may occur at Catamount, Germonds, Pearl River and Ramapo (Newark Basin) well fields;

- Water table declines may have significant impact on private wells;
- The simulated water level declines should be compared with measured data, if available

References

Heisig, P.M., 2010, Water resources of Rockland County, New York, 2005–07, with emphasis on the Newark basin bedrock aquifer: U.S. Geological Survey Scientific Investigations Report 2010–5245, 130 p., at http://pubs.usgs.gov/sir/2010/5245.

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