

Safe Yield of the NYC Water Supply System – A Look into the Unpredictable Future

by Robert Wasp

Endless deserts, flooded cities and devastating storms – all of these popular images are used in depictions of a future destroyed ecosystem. Over the last decade, the words “climate change” have become a household phrase as public and political interests have brought its subject to center stage.

Looking over the past 60 years of climate data, it is hard to dispute the trend observed in average temperatures. While annual average temperatures have risen with time, the effect that “climate change” has had on precipitation rates is far less understood. With the alarming prospects of climates becoming hotter, it is reasonable to assume that rainfall patterns will also change. How this change will look is not understood. For the thousands of public water supply systems nationwide whose customers critically depend on their service, this suggestion is very frightening. The result has left government and private entities alike scrambling trying to predict what effect future climate change may place on public water supply systems.

Among the largest drinking water supply networks in the world, the New York City system supplies a perfect example to examine the potential effects of changing precipitation. Providing over one billion gallons per day to its consumers from its three vast upstate watersheds, the New York City system relies directly on the water balance of its surrounding resources. A recent student project conducted at Manhattan College sought a better understanding of this uncertain future by exploring the impact of various precipitation scenarios on the New York City system.

The prediction of long term rainfall is realistically beyond current capabilities. Since weather is generally described as a random phenomenon, it is a major undertaking to create a model that reflects both the random and seasonal aspects of precipitation events. In addition, the duration and varying intensity throughout a storm are also difficult to represent. Rather than attempt to create new weather data, the project uses historical rainfall data as the foundation for all its scenarios. Historical precipitation data ranging between 1948 and 2008 were used as the basis.

NYC Drinking Water System

Featuring a storage capacity of almost six hundred billion gallons, the New York City water supply system provides a prime example of early urban planning. Originally conceptualized in the 1880s, the gravity fed city system consists of four primary upstate New York watersheds contained within three systems as depicted in Figure 1. Together the Croton, Catskill and Delaware Systems unite 19 reservoirs and three controlled lakes. The larger two systems, the Delaware and the Catskill, shuttle 90 percent of the city's daily supply, combining the flows within the Kensico Reservoir. From the Kensico, the water supply travels south via aqueducts to the Hillview Reservoir in Yonkers before being split among completed City

Water Tunnels 1 and 2. Currently, still under construction, City Water Tunnel 3 seeks to expand supply capacity while allowing system redundancy. With an estimated price tag of \$6 billion, City Water Tunnel 3 is phased for final completion by the year 2020.

The Croton System follows a slightly different path to the city. Originating from upstate New York counties Putnam and Westchester, the Croton System combines several small reservoirs into the Croton Aqueduct. The Croton Aqueduct travels 24 miles south to the Jerome Park reservoir located in the Bronx borough before servicing the city distribution system and its six thousand miles of pipe.

Project Approach

The New York City drinking water supply system was modeled using the EPA SWMM – Storm Water Management Model software. Using average statistics of regional soil conditions and impervious surfaces, the model generates watershed inflows primarily from

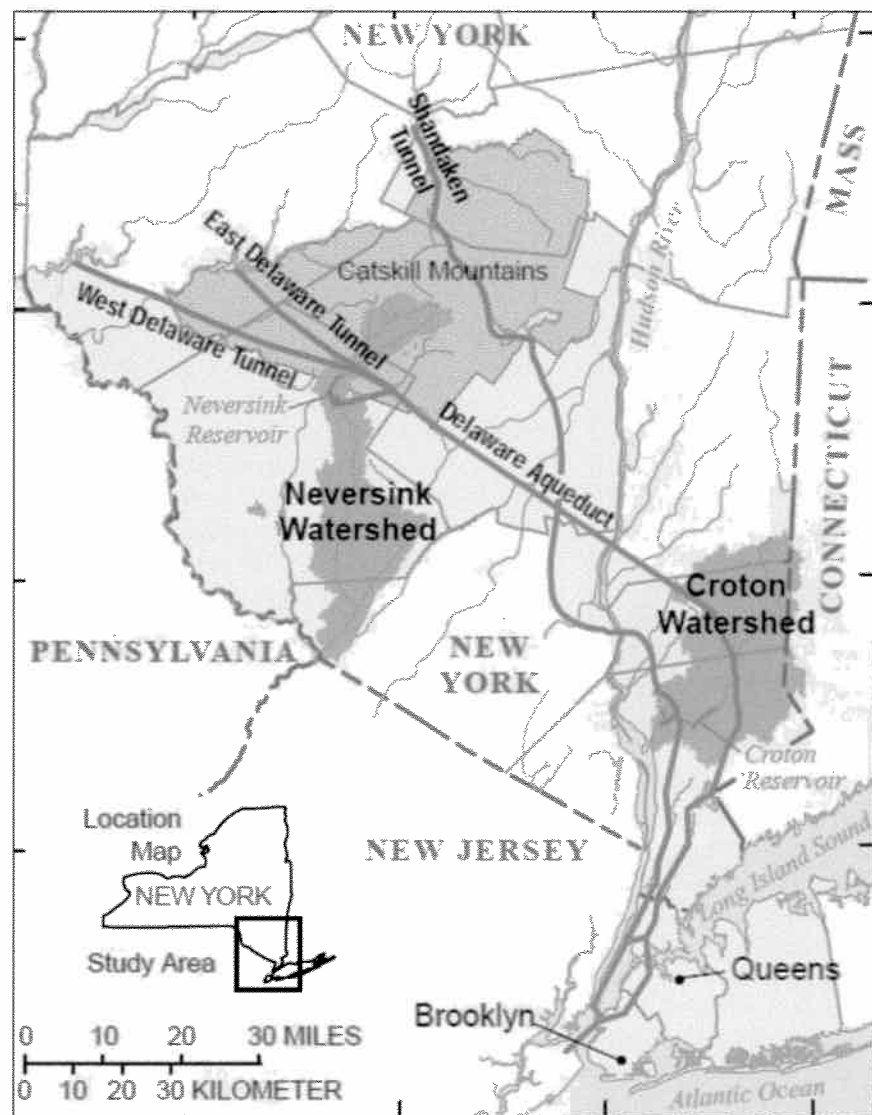


Figure 1. The NYC water supply

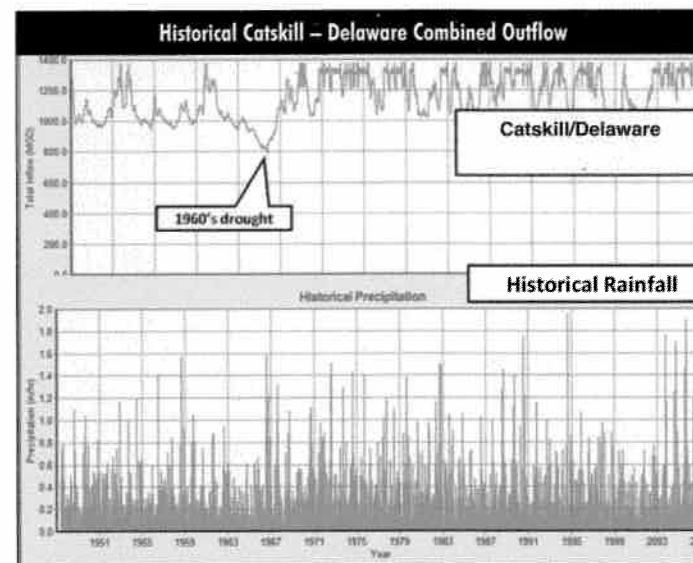


Figure 2. Historical precipitation and modeled output for the Catskill/Delaware systems

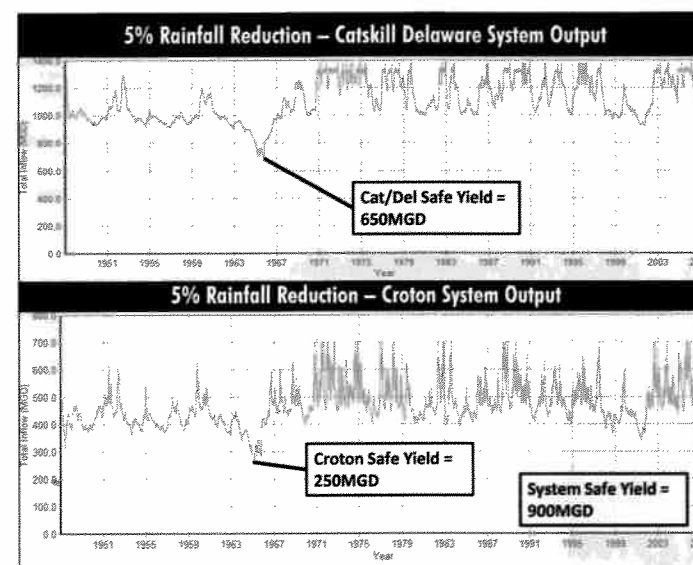


Figure 3. NYC system output for 5 percent rainfall reduction scenario

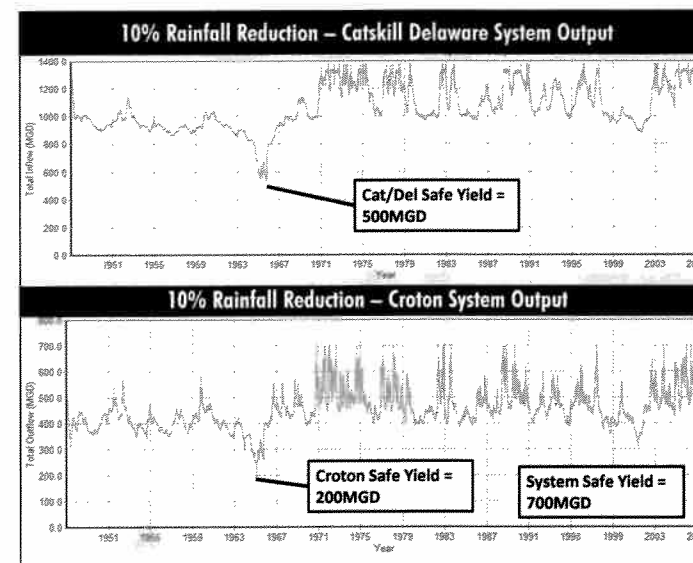


Figure 4. New York City system output for 10 percent rainfall reduction scenario

runoff during storm events. To account for the portion of inflow produced by groundwater infiltration, additional groundwater contributed flow was added to the system balance. Together these input conditions, with programmed water release rating curves for individual reservoirs, were used to model the historical city drinking water consumption.

Once the model was completed, it was run using the historical rain data from the years 1948 to 2008. Reservoir levels were graphed throughout the 60-year span and water release control curves were developed using this information. An example of the historical rainfall and resulting flow from the Catskill and Delaware systems is shown in Figure 2.

Once the base system model was developed, a series of four alternative rainfall scenarios were created. These are described below:

Scenario 1: Five Percent Reduction

A five percent reduction factor was applied to all historical precipitation. The reduction was applied only to the quantity of rainfall observed on a given day and did not reduce the longevity of the rain event.

Scenario 2: 10 Percent Reduction

Similar to the previous scenario, a 10 percent reduction factor was applied to all historical precipitation. The reduction was applied only to the quantity of rainfall observed on a given day and did not reduce the longevity of the rain event.

Scenario 3: Winters at 10 Percent Wetter and Summers at 10 Percent Drier

There has been much speculation that future rainfall patterns will include wetter winters and drier summers, or vice versa. This scenario was investigated by adjusting the winter and summer rainfall by 10 percent. Recorded precipitation was reduced or increased by 10 percent during select months of the year. For the months of December, January, February and March, daily precipitation was multiplied by a factor of 1.10 to produce a 10 percent increase. During the months of June, July, August and September, rainfall data was multiplied by 0.90, resulting in a 10 percent reduction in precipitation.

Scenario 4: Rainfall Randomized by Month

Under this scenario, “new” 60-year precipitation data sets were created by randomizing historical data on a monthly basis. Under this logic, a newly created year could feature rainfall from January of 1967 to be followed by data from February 2004 and then March 1973 and so on. Ten different “new” 60-year precipitation data sets were created and run using the SWMM model.

Safe Yield Results

Based upon the historical rainfall data, the safe yield of the New York City system was determined to be 1,100 million gallons per day (mgd). This figure was observed during the historical drought of record that plagued the tri-state area during the 1960s. This was then used as the benchmark by which the results of the various modified rainfall scenarios could be compared.

Scenarios 1 and 2: Five and 10 percent rainfall reductions: When factored reductions were applied to historical precipitation, the system responses resulted in safe yield reductions that were greater than the percentage applied. The results are shown in Figures 3 and 4, for the five percent and 10 percent cases respectively. For a five percent reduction in rainfall, a safe yield of 900 mgd was determined, a difference of 18 percent from historical. Similar results were observed for a 10 percent reduction in rainfall under which system safe yield was reduced by 36 percent. These results clearly underscore

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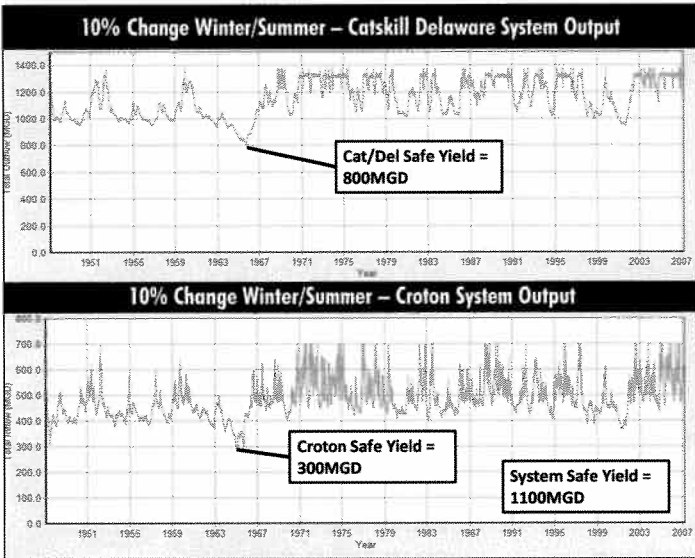


Figure 5. NYC system output for Winter – 10 percent wetter, Summers – 10 percent drier

the non-linear nature of such a complex system.

Scenario 3 – wetter winters and drier summers: The results of other scenarios were not found to be as drastic as those from fixed percentage decreases. When 10 percent wetter winters with 10 percent drier summers were examined, no significant reduction from historical safe yield was observed. As shown by the graphic in *Figure 5*, the extremes of system outflow merely appear dampened when compared to the historical model. This is most likely because the overall amount of rainfall was similar to historic levels, and the detention times in the combination of system reservoirs were long enough to effectively buffer the effect.

Scenario 4: monthly randomized rainfall: Ten experimental trials of the probabilistic investigation were carried out with historical data randomized differently each time. As shown in *Figure 6*, the results indicated that none of the trials yielded safe yields as low as the historical. It was observed that none of the randomized data sets yielded a drought period as long as the historical drought of the 1960s. By failing to recreate a drought of such duration, reservoir levels were never allowed to drop to the critical levels of the past. It is interesting to ponder just how many attempts would be needed to create a similar drought. This leads to the question of just how unusual was this drought – a one in 100 year event; a one in 200 year event?

A summary of the safe yield values for all the experimental scenarios compared to historical is shown in *Figure 7*.

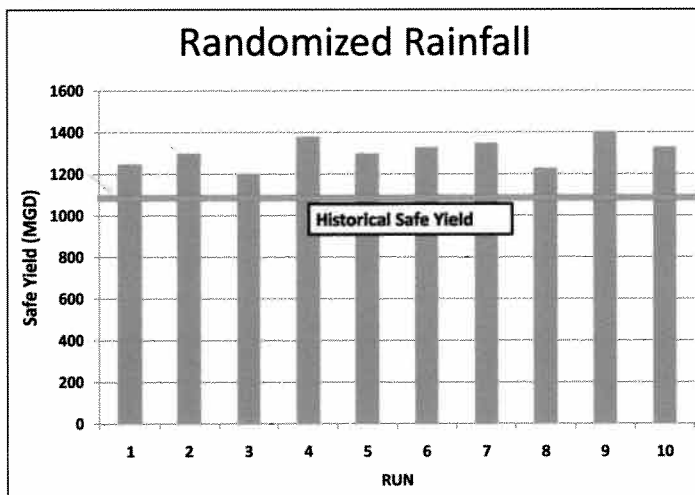


Figure 6. Safe yield for 10 randomized rainfall results

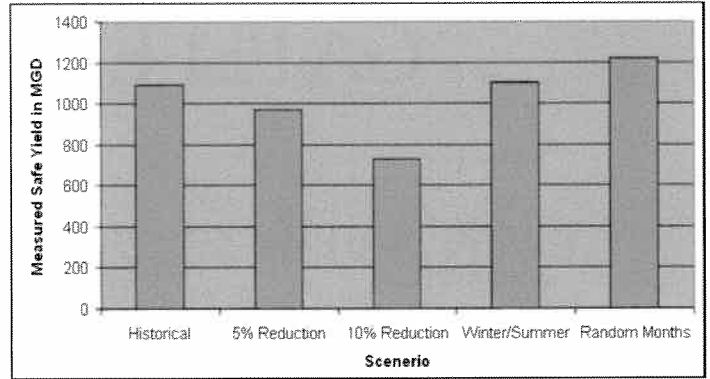





Figure 7. Summary of computed safe yield for all scenarios


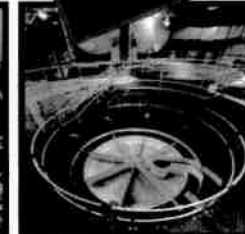
The results indicate that small long term decreases in precipitation can have seemingly greater impacts on system safe yield. This generates a need for careful examination of precipitation trends as reductions can have severe consequences for a water supply network. The wetter winter and drier summer phenomenon was absorbed by the system residence time and did not impact the safe yield. The 10 randomized time series actually predicted higher safe yields as the record drought of the 1960s was broken up. From a student project viewpoint, it is clear that water system modeling possesses tremendous potential for research and study. While it is certain that modeling cannot reverse the effects of climate change, the prospects of effective planning may provide the solution to future constraints.

Robert Wasp graduated this May from Manhattan College with a BS degree from the Civil and Environmental Engineering Department, and Dr. Scott Lowe, PE was his faculty advisor.



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