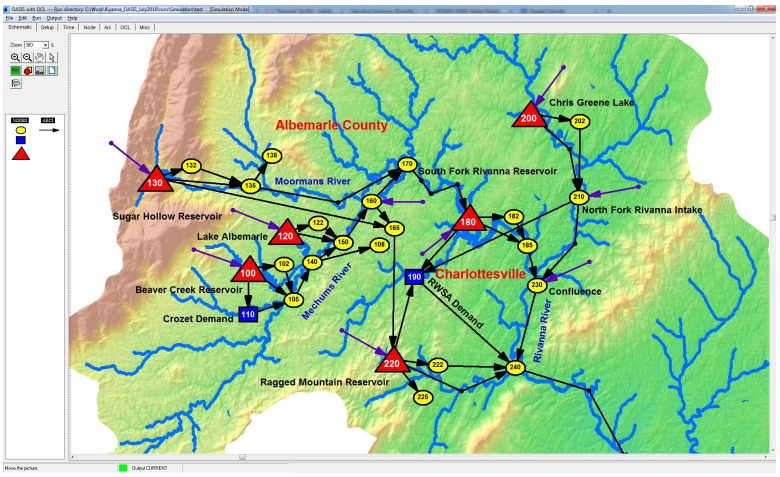
AT THE FOREFRONT OF DROUGHT MANAGEMENT:

USING FORECASTS TO IMPROVE RELIABILITY AND LOWER COST



Using its OASIS software, HydroLogics has spent 30 years finding more efficient ways to manage water in river basins that now supply about 20% of the U.S. population. With increasing competition for water, escalating costs of new supply, and growing climate variability, our clients — from small communities to the largest cities and water/power companies in the world— are embracing our unique forecast-based approach to system operations and drought management.

Key benefits of forecasts:

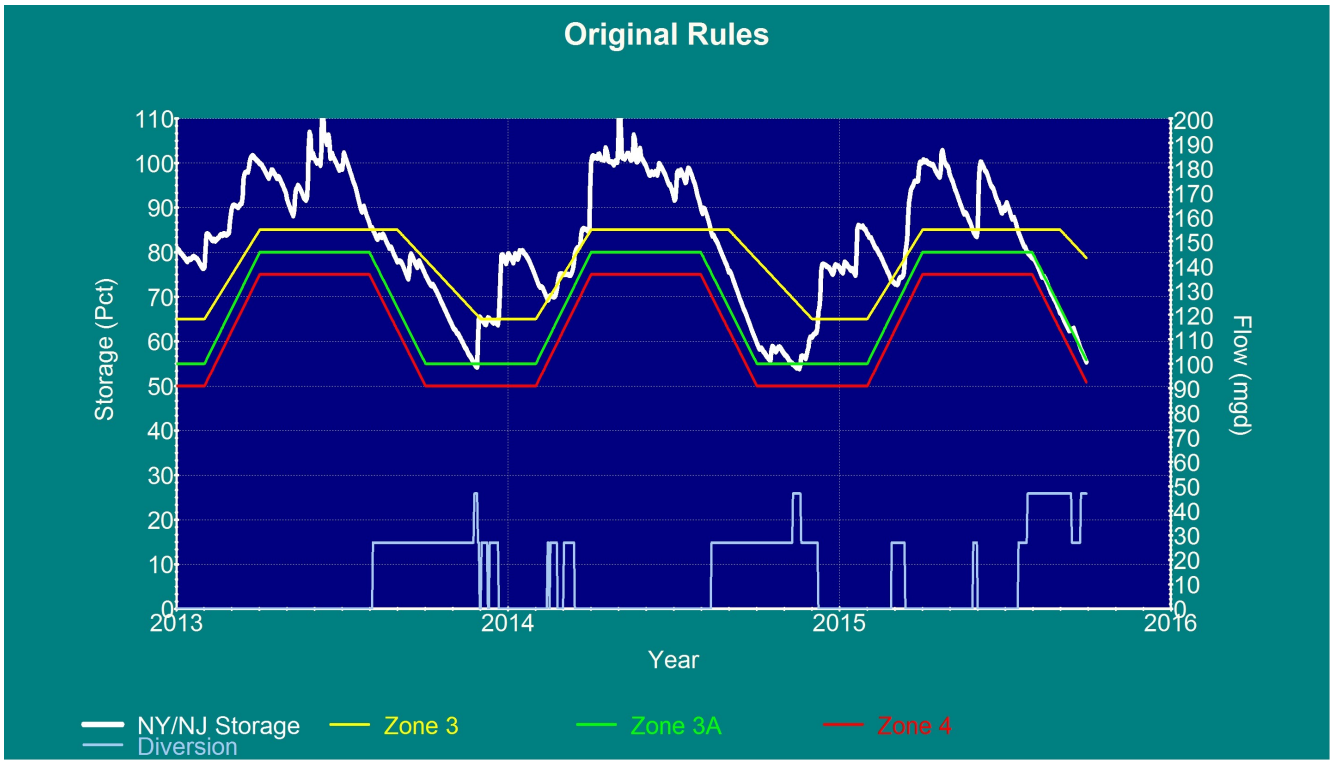
- Reduce guesswork inherent in drought management
- Improve timing of drought response, making systems more resilient and cost-effective

The Role of Forecasts

The water industry has long relied on the concept of safe yield – usually the maximum sustained demand that can be met in the worst drought on record-- for reliability assessment and capacity planning. But operators would never run their system to the safe yield for fear of running out of water, so rules are needed to reduce the risks. Reservoirs often rely on storage-or elevation-based rule curves that lead to corrective action – like demand restrictions, cutbacks to downstream releases, or backup supplies-- but rule curves fail to account for the specific nature of individual droughts. Hence the value of forecasts: conditioned to how wet or dry the river basin is at the time they are made, they provide insight on the potential severity of the current drought and thus give operators a complete understanding of the risks to the water supply. They can be thought of as dynamic rather than static (like rule curves or days of supply remaining) because they take into account a wide variety of factors that influence operations such as recent inflows, projected demands, and system outages.

Suez Water: A Case Study in the Evolution of Operating Rules

Below is an illustration of the power of forecasts using Suez Water New Jersey as a case study. A division of Suez, one of the largest water and wastewater providers in the world, this utility supplies drinking water to 800,000 people in northern New Jersey. The utility has relied on rule curves since the mid-1990s to guide the operations of its reservoirs in the Hackensack River Basin. Some of these curves are shown by the sloping lines in the OASIS plot below.



In this case, the pumps for a large and costly backup supply from an outside system are operated at varying flow rates when storage (white line) in the four reservoirs (one in New York, three in New Jersey) drops below the different rule curves (zones). For example, when storage (corresponding to the left y-axis) drops below zone 3, pumping (blue line, corresponding to the right y-axis) is set to 27 million gallons a day (mgd). This increases to 48 mgd when dropping below zone 3A. The plot shows how the system would perform using these rules in a repeat of the hydrology from 2013 through the fall of 2015.

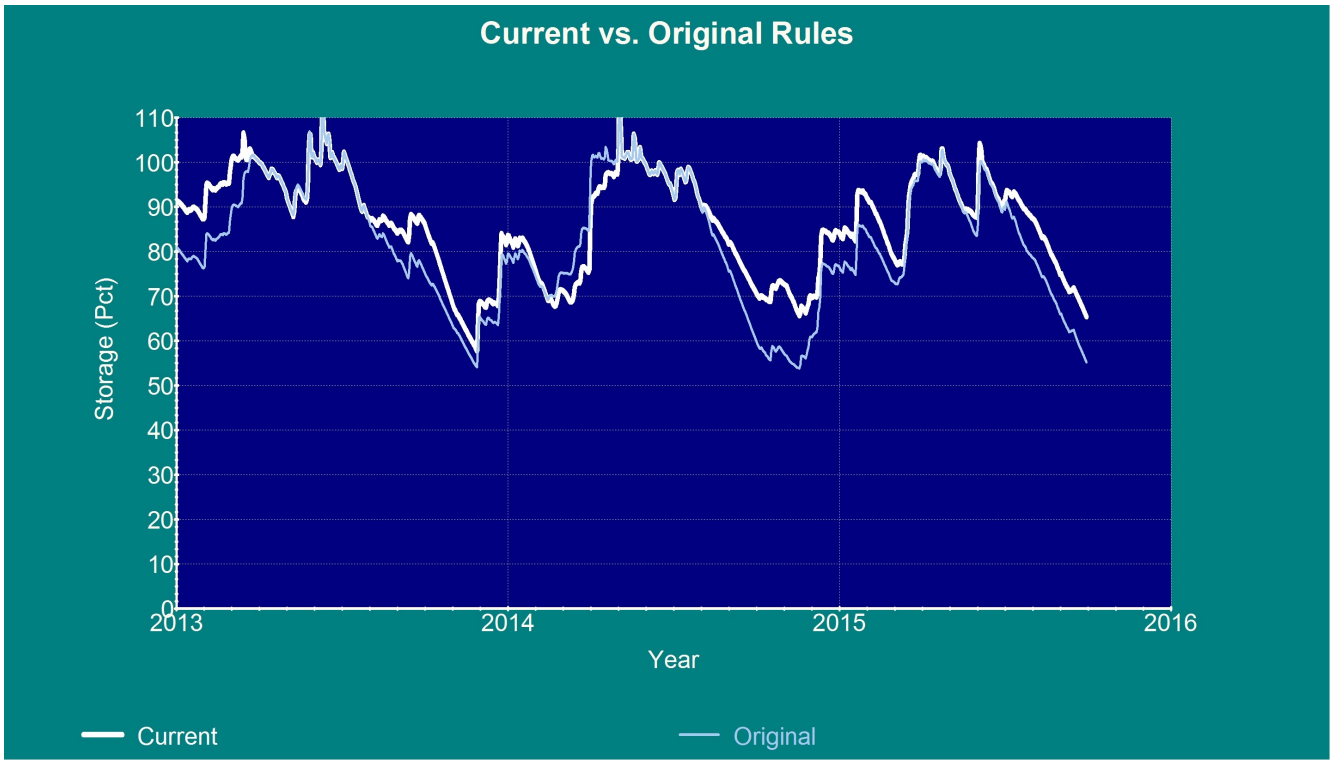
To improve reliability in operations, specifically the balancing of the reservoir supply in New York and New Jersey, Suez Water New Jersey hired HydroLogics to develop an OASIS model of the river basin and to refine the operating rules. Although many diversions are activated for backup supply, we focused on the most significant one as shown in the plot above, and identified a forecast-based policy for that diversion that could improve reliability and lower cost. In this case, we developed alternative rules that would trigger the backup supply if there was a 50% chance of dropping below zone 4 in the next 10 weeks. Because of the client's familiarity of rule curves and the novelty of forecasts, we decided to insert an over-ride so that even if the forecast-based trigger was not invoked, the diversion would turn on if storage ultimately dropped below zone 3A.

The simulation of these alternative rules is shown below, simplified to show just the storage and diversion. Note in the spring of 2015 (outlined in red), the diversion is for a much shorter period of time than under the original rules as shown above. In this situation, the forecast indicated that the diversion was not needed at all, but eventually was activated because of the zone 3A over-ride.

Later in 2015, Suez Water New Jersey decided that additional room for improvement could be made by adopting forecasts for all of the rules, meaning that forecast-based rules would replace the rule curves that had been in place for 20 years. This demonstrated the utility's commitment to innovative and sustainable water management and has gained recognition by its global parent company and state regulator alike. As part of this process, HydroLogics convened a drought exercise with the operations staff to better understand their decision-making process and their risk tolerance. In this exercise, we used OASIS in its unique "gaming" mode to sequentially lead the operators through a "virtual" drought — one that was not made known to them in advance but was based on actual hydrology— and modifying the rules based on how they reacted as the drought intensified. The result of this collaboration is the current set of forecast-based rules (current rules) that lead to activation/termination of different diversions during drawdown/refill of the reservoirs.

A simulation of the current rules over the same recent period is shown below. When contrasted with the original and alternative rules in the previous plots, it striking to see that the diversions that occur in the spring of 2014 and 2015 under the previous rules are eliminated under the current rules. This is because the current rules are driven by the forecasts, not the rule curves, and the forecasts often indicate that because of spring refill, low storage in the early part of the year is not necessarily cause for concern.

The plot below shows the overall improvement in reliability by virtue of the current, forecast-based rules. The drought exercise indicated a greater desire by operators to pump more water in the summer months to preserve storage during the drought season and a preference to pump less water in the winter months when the cost of pumping relative to water sales is higher.

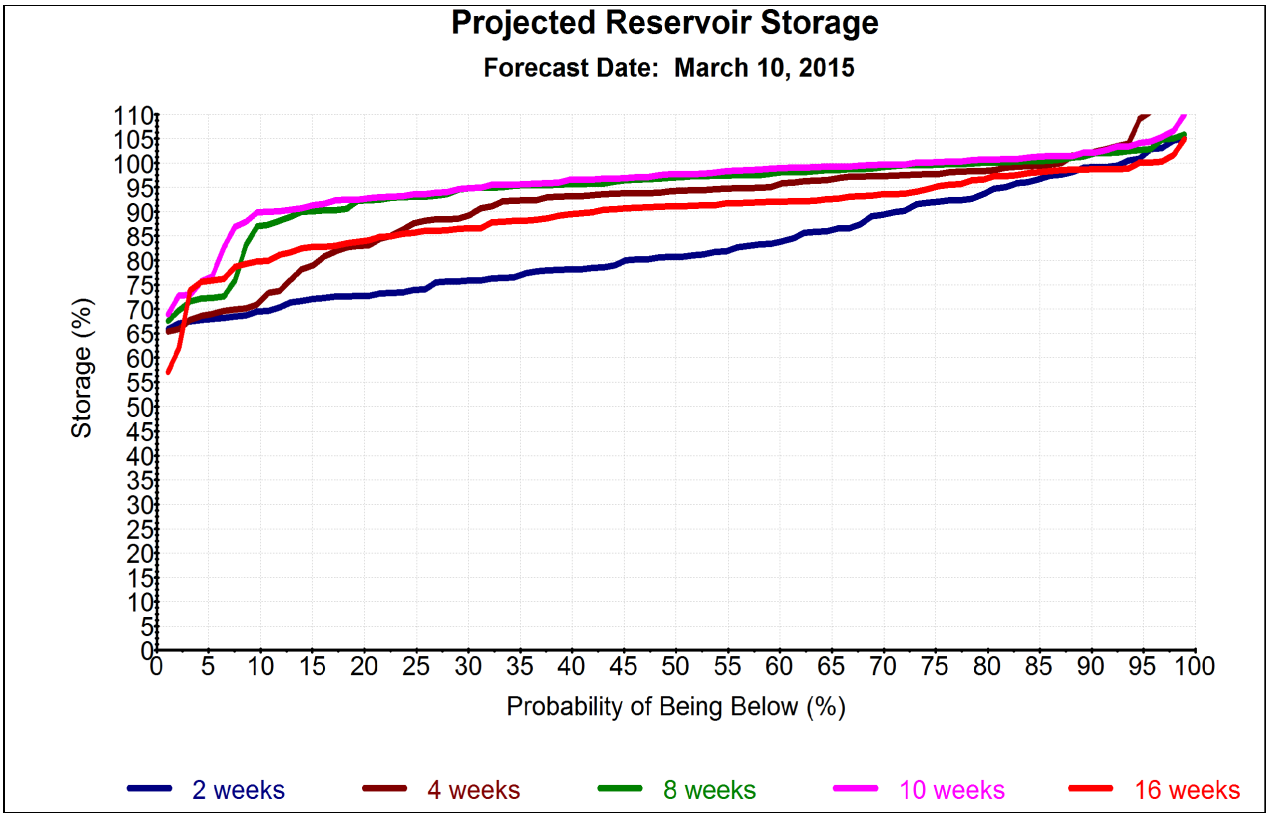


The plot shows improved storage levels under the current rules in the drought season (usually June through October) and similar levels of storage in the spring months. In the drought months, the forecasts are used to detect the drought early and lead to a proactive response, in this case pumping. The result is significantly fewer times that Suez Water would have to invoke additional drought response measures, like water use reductions, that can impose a financial burden on the utility through lost sales and cause disruption to the community.

In the spring months, reliability is not impacted — storage levels remain similar during these periods under the different rules— but the cost of the using the major diversion (usually over multiple weeks) is eliminated under the current rules. At approximately $60,000 every two weeks, or about 15% of the annual average spending, this results in substantial cost savings.

Using OASIS to Develop and Implement the Forecast-Based Rules

As emphasized in our *Taking the Doubt Out of Drought*™ campaign, forecasts reduce the uncertainty inherent in managing water because operators have a full range of risk. This is shown in the figure below based on a spring forecast of storage in Suez Water New Jersey's system.



Utilities generate these forecasts at the touch of a button using the real-time operations mode of our OASIS software – by inputting starting reservoir storage and recent inflow data to "condition" the forecasts to determine how wet or dry the period is relative to previous years. OASIS predicts the level of future storage -- all equally likely-- based on operating the system using a repeat of the conditioned inflows from previous years.

Deciding on when to take action (i.e, when there is a x% chance of reaching y% storage in z weeks) is determined by the risk tolerance of the operators, so we use OASIS in its planning mode to test probability-based triggers over the historic inflow record and ensure that they meet the client's criteria for minimum acceptable storage levels, frequency of using backup supplies and demand restrictions, pumping cost, etc. In this case, the current rules for Suez Water as described earlier are in the form of multiple probability-based triggers, each leading to a specific drought response. No other software has the flexibility or power to help develop such rules and seamlessly implement them for real-time operations. And by having confidence in managing the next drought, our clients often revisit their capacity planning and in the process save tens of millions of dollars by scaling back on excess capacity without compromising reliability.

For more information, visit us at www.hydrologics.net and click on the *Overview* presentation on our products and services and the companion *Forecasts* presentation on the role of forecasting.