The Recent Long Island Drought

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Abstract
Drought is a qualitatively defined and determined phenomenon. Some local indications in the Town of Brookhaven suggest Long Island is in the midst of a prolonged and now serious drought. However, comparisons of the elements of typical drought considerations show that if there is a drought in Suffolk County, it appears to have started in 2015, and is not as long or deep as some other dry periods, especially the one that occurred in the mid-to-late 1960s.

Introduction
Drought is a qualitatively defined condition. The National Weather Service (NWS) (2008) defines it as "a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people." This broad definition allows drought to be determined to occur in a variety of settings, such as the southwest of the US where conditions are normally very dry, the southeast of the US where conditions are normally very wet, Mediterranean climates such as California where there are usually wet and dry seasons over extended time periods, or the northeast of the US where moderate amounts of precipitation are usually evenly distributed across a year. Drought is a deviation from standard conditions, where some sort of noticeably impact to hydrological conditions occurs.

The NWS has three categories of drought. One is "meteorological drought." This is the first drought condition to be identified, usually. Meteorological drought is extended dryness in comparison to a standard amount of precipitation over a specified time. "Agricultural drought" is a second form of drought that is defined in terms of soil moisture deficits, losses in water sources (ground water, reservoirs) needed for irrigation, and of course reduced precipitation. "Hydrological drought" is the product of reduced precipitation that leads to impacted water supply (river and stream flow, reservoir levels, ground water levels), and can result in societal impacts. Although precipitation changes and resulting effects are defined for specific areas, the impacts of a regional drought may extend beyond those boundaries, due to obvious hydrological linkages (rivers flowing from one area to another) and more subtle effects (such as New York City or California reservoirs being remotely located from the points of water usage) (NWS 2008).

Overall determination of drought conditions is the result of combining a number of distinct measures of droughtiness. The University of Nebraska (Lincoln) uses a panel of 350 experts to assess conditions across the country on a regional basis. Five indicators are combined to produce a score from -4 (severe drought) to +4 (excessively wet); the weighting of these indicators varies depending on the expert judgement of their past reliability as a measure of drought in a particular setting. Supplemental data are also applied to the standard five indicators, with snow pack in the Sierra Nevada being used in California assessments, for instance (US Drought Monitor undated).

The five indicators that are typically combined are: 1) the Palmer Drought Severity Index; 2) the CPC Soil Moisture Model; 3) USGS Streamflow Weekly Data; 4) the Standardized Precipitation Index; and, 5) the Palmer Z Index (or Moisture Anomaly Index). The NWS is also using two newer products, an Experimental Long Term Blend Model, and an Experimental Short Term Blend Product (US Drought Monitor undated).

The Palmer Drought Severity Index is an agriculturally-focussed drought measure (Palmer 1965). It is an indirect soil moisture measure, where the water-holding characteristics of a region's soils are used in conjunction with precipitation data (soil water inputs) and temperature (a proxy for evaporation from soils). It requires a "complete" precipitation and temperature record to be computed, and does not recognize lags associated with frozen precipitation, nor does it address frozen soils. It incorporates the history of weather over a period of months to compute its values (US Drought Monitor undated), using a recursive formula that diminishes the impact of months farther from the current time period (Guttman 1998). It predicts impacts on crops well (US Drought Monitor undated). The Palmer Index values are set so that they will have similar meaning across different areas of the country, and range from -5 to +5 (Guttman 1998). Alley (1984) thought many aspects of the index were not justified conceptually, but also realized that many users had accommodated their judgements to its faults, and so found it to have great utility.

The NWS Climate Prediction Center (CPC) Soil Moisture Model is a "Leaky Bucket" model. Like the Palmer Drought Severity Index, it computes soil moisture by using precipitation, soil quality data, and temperature to determine soil moisture; a difference is that the CPC Soil Moisture Model also incorporates a calculation of run-off with evaporation to create its water balance (NWS CPC undated [1]; van den Dool et al. 2001).

USGS streamflow weekly data are measured levels of flow at monitored sites; the NWS (US Drought Monitor undated) does not specify how streamflows are aggregated across geographical regions, nor it is it made clear how drought is determined based upon the collected data.

The Standardized Precipitation Index is a probability measure for precipitation over a set time scale (user defined, ranging from 1-48 months, although 1 month is typically used) compared to historical records (as short as 20 years) (US Drought Monitor undated). It was developed by McKee in the mid-1990s at several conference proceedings (Guttman 1998). Guttman found it to be more consistent in its determinations across multiple locations (comparing spectral values of time series), and it has now been adopted by the World Meteorological Organization as the standard measure of drought (US Drought Monitor undated). The longer the historical database used to create the comparison, the more robust its results (Guttman 1998).

The Palmer Z index is created from the original Palmer Index, but uses the statistical distribution of the Palmer Index values to set its own values. The Palmer Z Index is more responsive to short-term changes in conditions than the original index (US Drought Monitor undated).

The experimental indices are set combinations of various common measures; unlike the current official US drought determinations, they are not subjective. The Long-Term Blend Model is 25% Palmer Index, 20% 24-month precipitation (as measured by percent of periods with more precipitation in the historical record), 20% 12-month precipitation, 15% 6-month precipitation, 10% 60-month precipitation, and 10% CPC Soil Moisture Model. The Short-Term Blend Model is 35% Palmer Z Index, 25% 3-month precipitation, 20% 1-month precipitation, 13% CPC Soil Moisture Model, and 7% Palmer Index (NWS CPC undated [2]).

In February 2016 most of these measures found Long Island was in moderate drought (it is difficult to find archived records more recent than a year ago, although the current assessment of Long Island is still "moderate drought"). The official February 21, 2016 classification was "moderate drought" (http://droughtmonitor.unl.edu/Home/RegionalDroughtMonitor.aspx?northeast); the Palmer Index for February 17 was <-2.0 and >-3.0 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif); the CPC Soil Moisture Model reported a "current" value of 10-20% (http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#). However, although the NWS does not archive recent results, a calculation of the global Standardized Precipitation

Index for February 2016 showed Long Island was in an area rated as +1.0 - +1.5 (slightly moist) (http://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/SPI.html?T=Feb%202016), and similarly, the Palmer Z Index for February 2016 was "moderately moist" (+1.0 - +2.5) (https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/zin/201602-201602).

Long-term data for a ground water well monitored since the 1940s showed that water levels near the Brookhaven landfill in Suffolk County were near historical lows, and had been consistently depressed compared to median values for a 67 year data base (1942-2009) since 2011 (Figures 1 and 2), and Beaverdam Creek, near to this well, is also drying over much of its historical flow(it has not flowed north of Montauk Highway for nearly a year). The issue I would like to address: is Long Island in a drought, and if so, how long has the drought been?

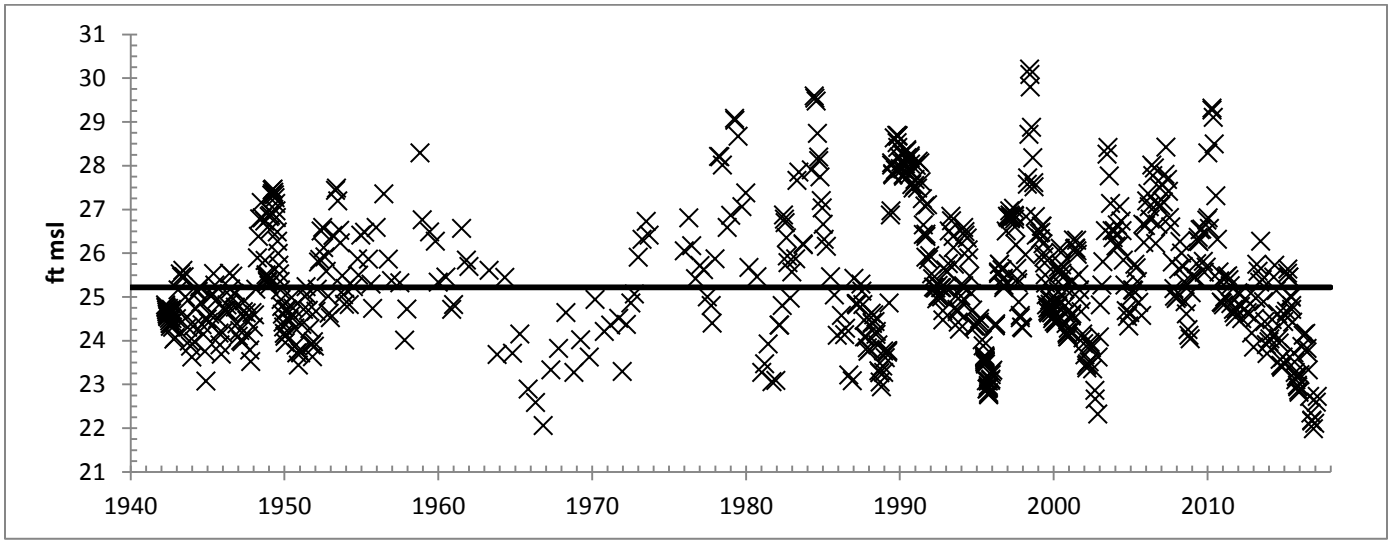

Figure 1. Long-term data for well #-3529 (solid line indicates median value 1942-2009, 25.22 ft msl)

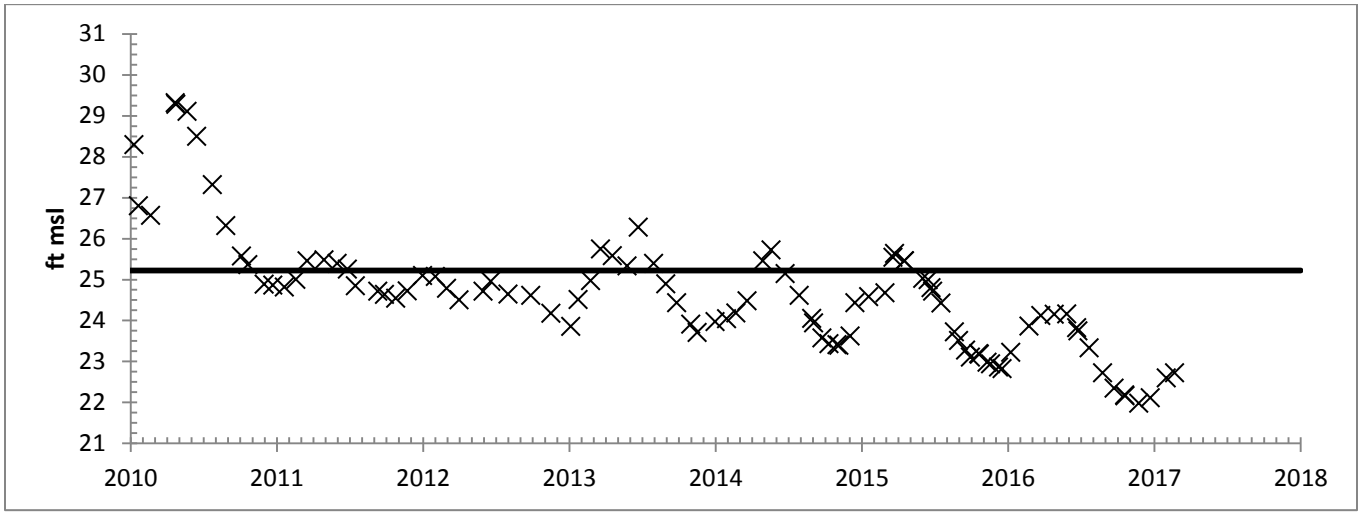

Figure 2. Data for well S-3529 2010-February 2017 (solid line indicates median value 1942-2009, 25.22 ft msl)

Materials and Methods

Mapped monthly Palmer Index values from the weekly NWS data set for 2010-2016 were translated into a graphical format. 1-month, 3-month, and 6-month Standard Precipitation Index (SPI) values for 1948-

2009 were calculated as training sets, and were used to determine the SPI values for 2010-2016, using the Brookhaven National Laboratory NWS data base, and 5% ("Very dry") and 20% ("Dry") threshold values. Monthly stream flows for Carmans River, Connetquot River, Nissequogue River and Peconic River were collected from the USGS New York Water Science Center; training sets from initial values (in 1942 and 1943) to 2009 were developed, and then were graphed for 2010-2016 using 5% and 20% threshold values. Head values for S-3526, collected by USGS, Suffolk County Department of Health Services, and various groups working for and with the Town of Brookhaven, and collated into a Town data base, with pre-1975 USGS data translated to the newer well location by subtracting one foot from the values to approximate the difference between the well locations (based on cross-comparisons to well S-47747 over the 1974-1976 period), were used to develop a 1942-2009 training set. Data for 2010-2017 were classified using 5% and 20% threshold values.

Results

The Palmer Index (Figure 3) shows that drought conditions (index values of -2 or less) occurred in the late fall of 2010, in the late fall of 2013, and from mid-2015 into 2016.

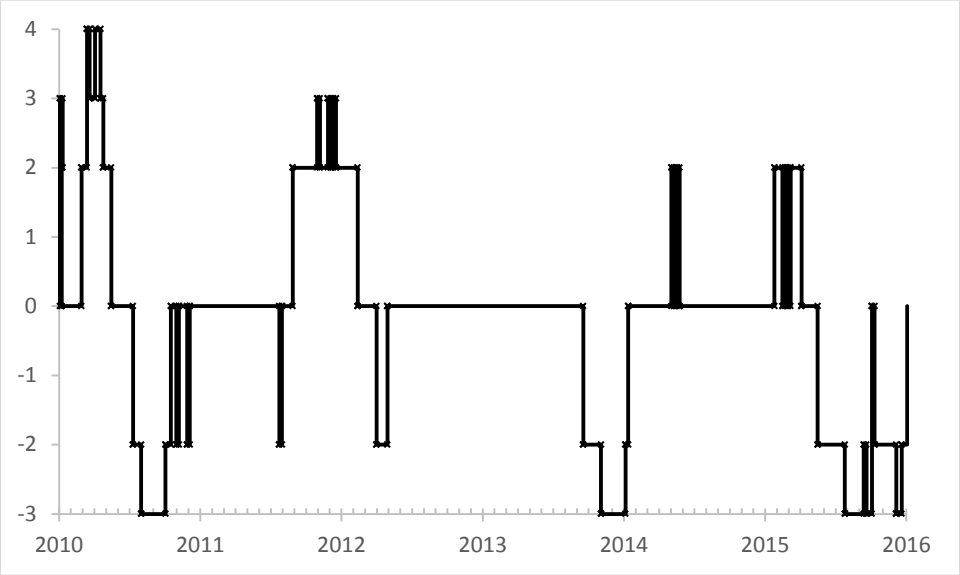

Figure 3. 2010-2016 Long Island Palmer Index

The 1-month SPI (Figure 4) does not show much indication of drought at all – lower rainfall values are fairly well balanced by higher rainfall values, although no "wet" or "very wet" months occurred in 2015-2016. The 3-month SPI (Figure 5) shows drier conditions beginning in 2015, although it is not clear if this constitutes a true drought. The 6-month SPI (Figure 6) shows a very similar pattern to the 3-month SPI.

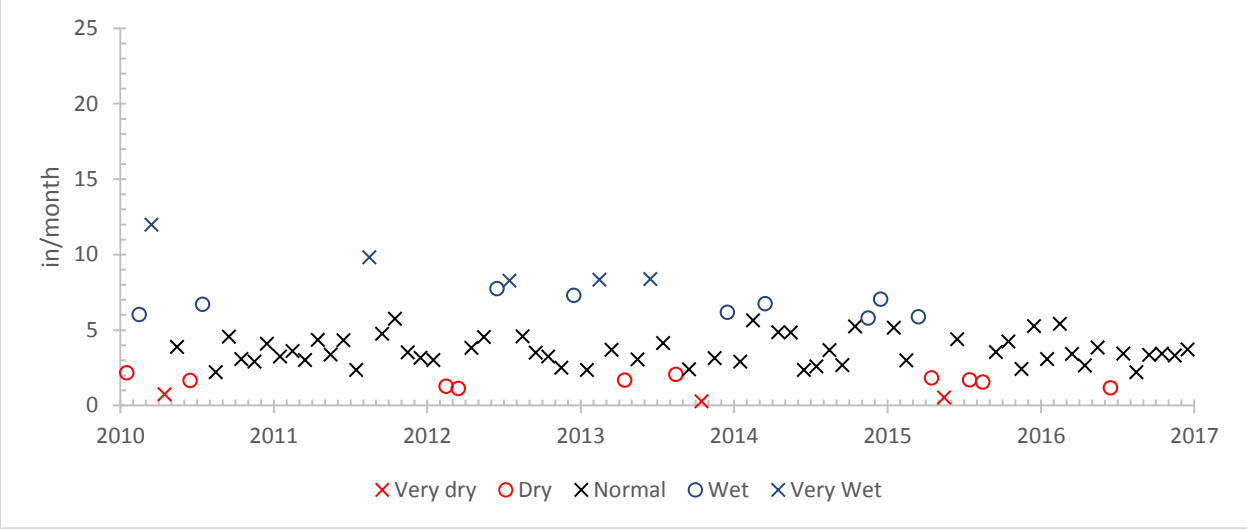

Figure 4. 1-month SPI (Brookhaven National Laboratory, Upton) 2010-2016 (5% and 20% thresholds)

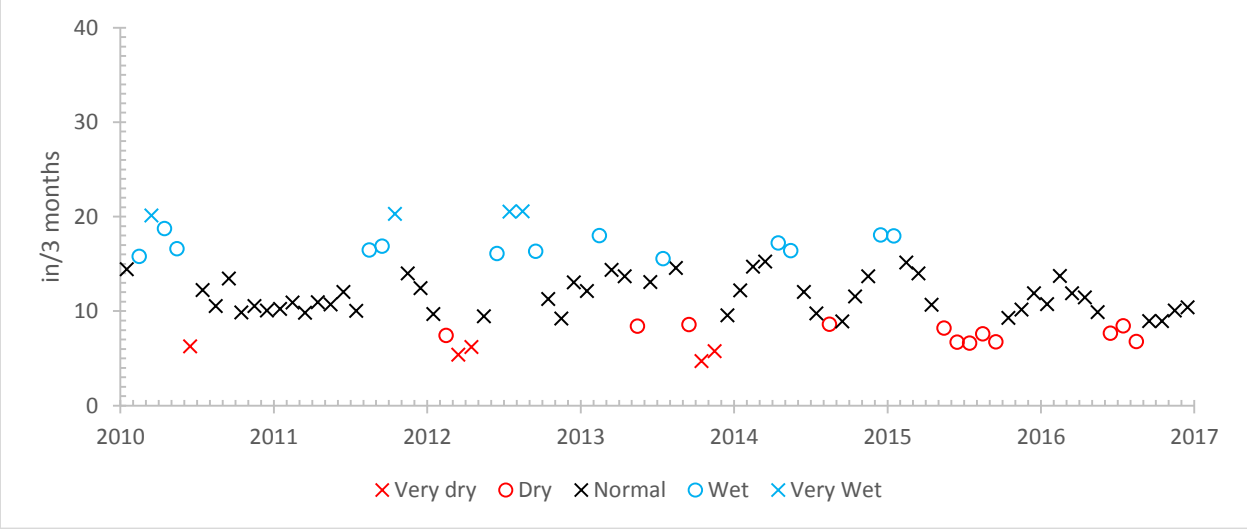

Figure 5. 3-month SPI (Brookhaven National Laboratory, Upton) 2010-2016 (5% and 20% thresholds)

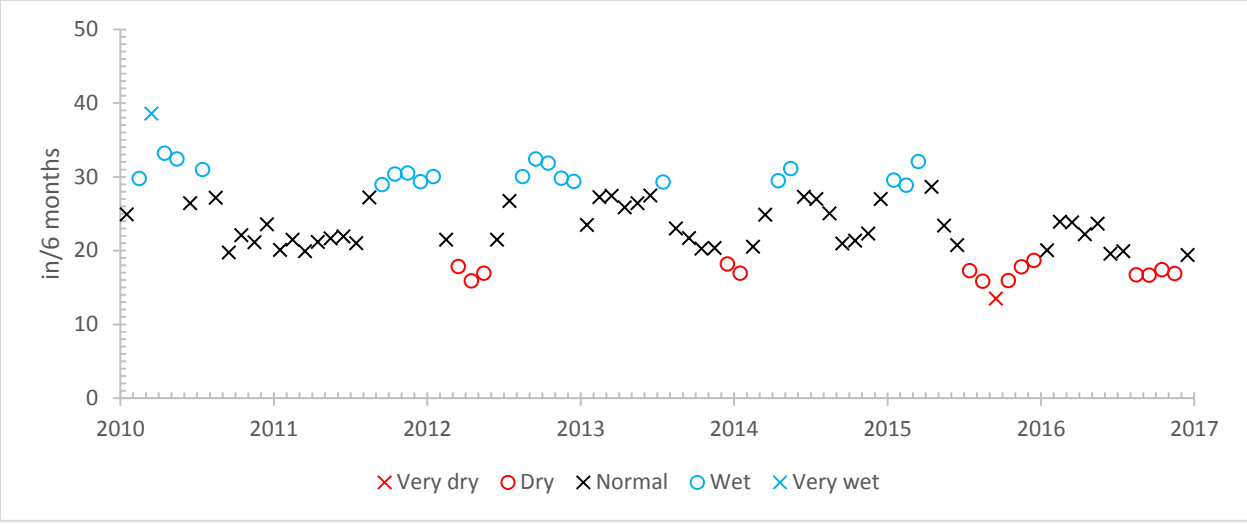

Figure 6. 6-month SPI (Brookhaven National Laboratory, Upton) 2010-2016 (5% and 20% thresholds)

Stream flows for Carmans River (Figure 7) suggest that there has been drier conditions from 2012-2017, with no "wet" conditions reported. Connetquot River data (Figure 8) show no indications of unusually dry conditions. Flows in Nissequogue River (Figure 9) were much drier for each fall 2013-2016, although there were much higher flows in the spring of 2013 and 2015. Peconic River (Figure 10) shows lower flows from 2011-2016, with some very low flow rates in 2015 and 2016.

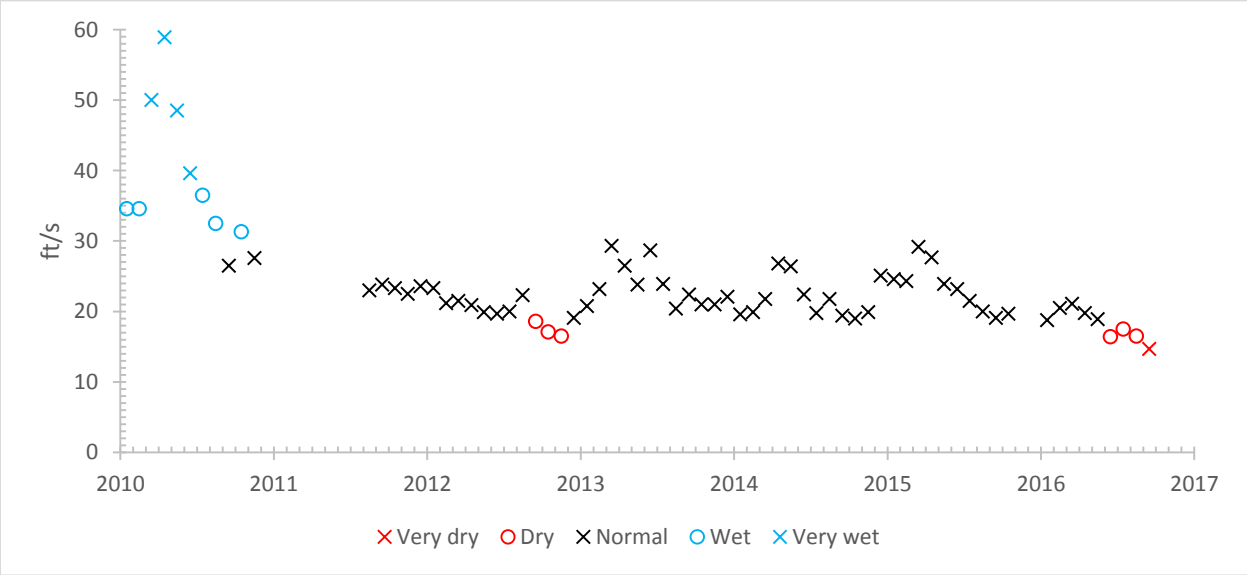

Figure 7. Carmans River monthly average flows (2010-2016) (5% and 20% thresholds)

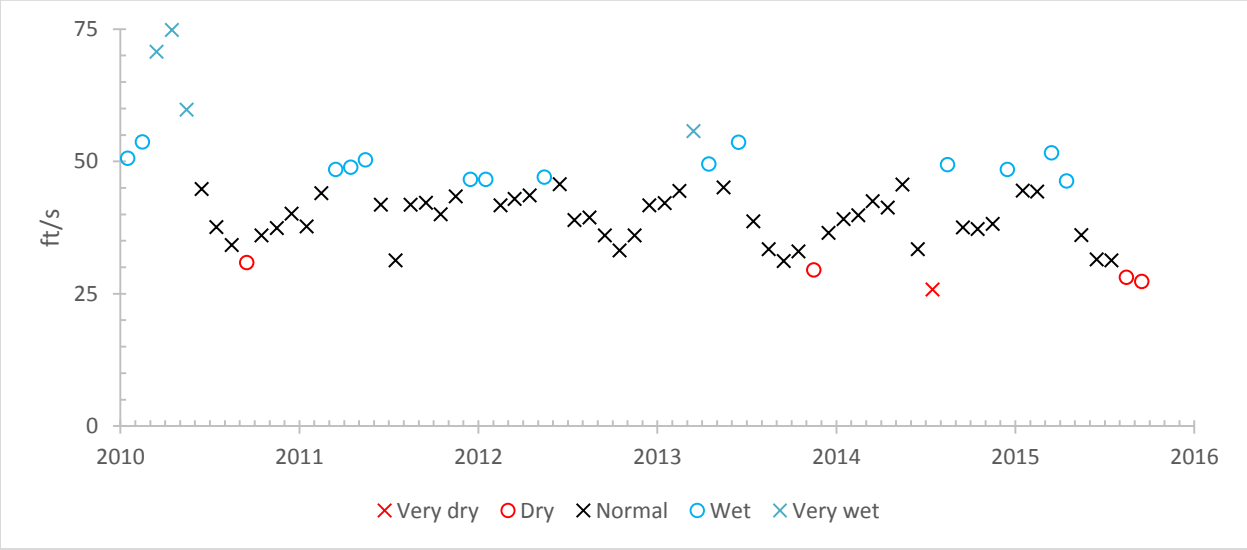

Figure 8. Connetquot River monthly average flows (2010-2016) (5% and 20% thresholds)

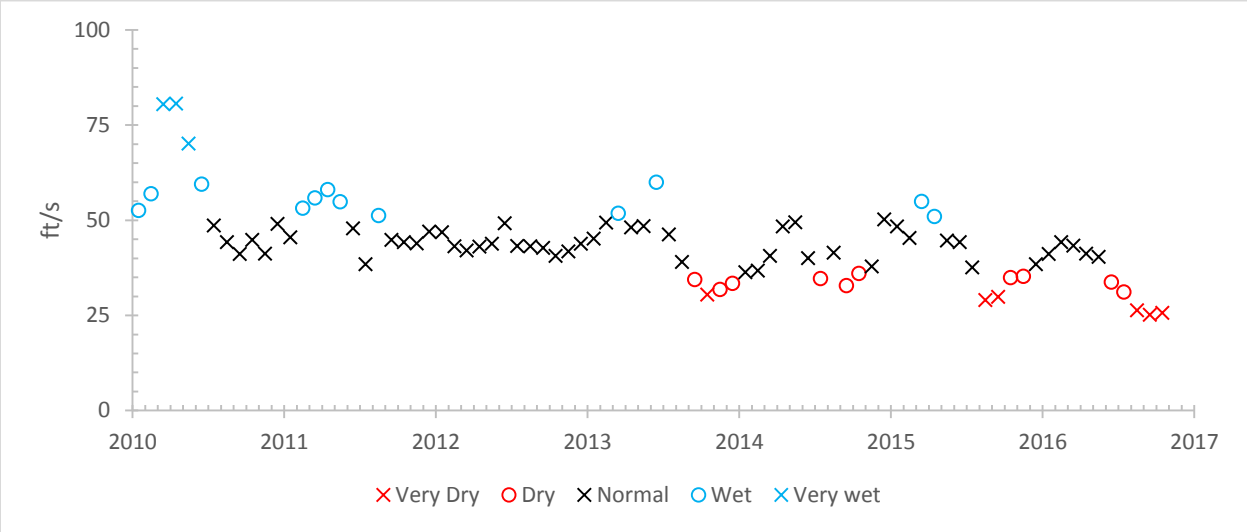

Figure 9. Nissequogue River monthly average flows (2010-2016) (5% and 20% thresholds)

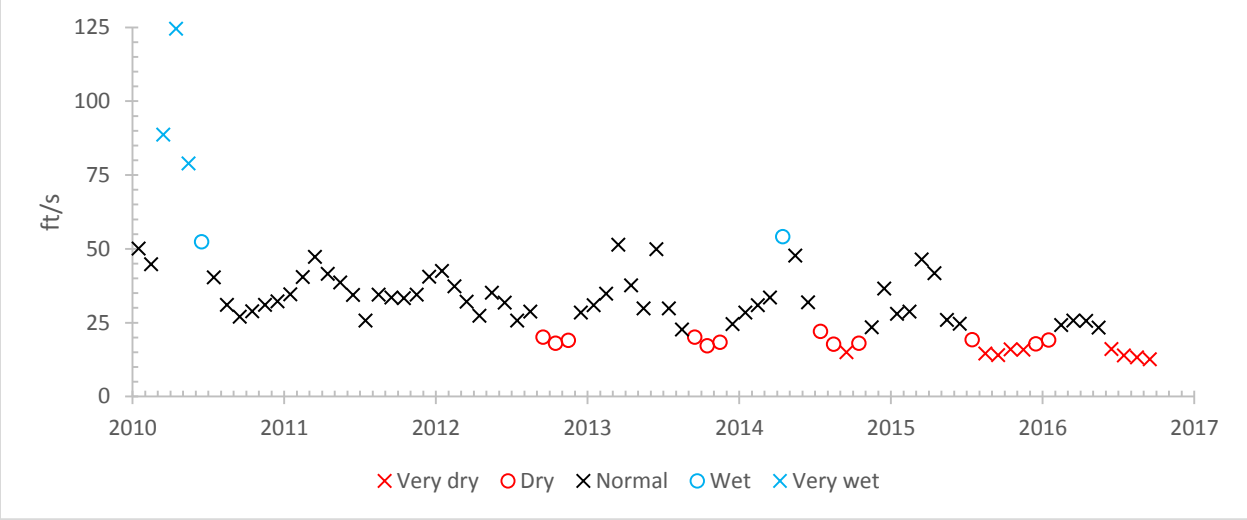

Figure 10. Peconic River monthly average flows (2010-2016) (5% and 20% thresholds)

Head data for S-3529 (Figure 11) show lower ground water levels from 2011-2016, with some very low levels measured in 2015 and 2016.

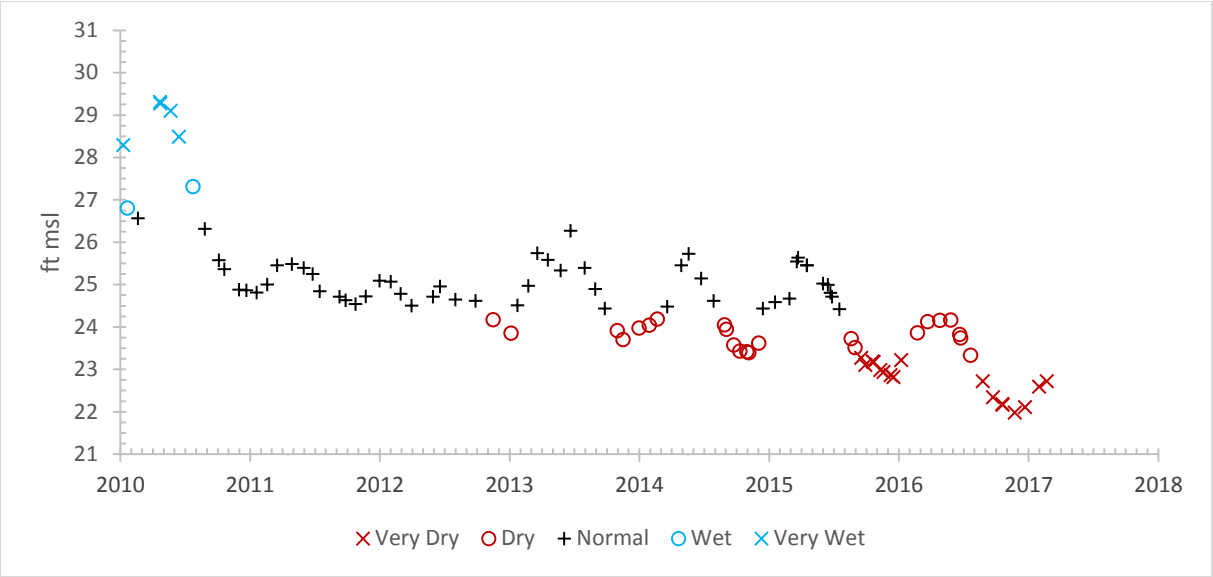

Figure 11. Head data for S-3529 (2010-2017) (5% and 20% thresholds)

Discussion

Ground water is responsible for stream flow on Long Island, although stream flow represents a more regional understanding of ground water conditions than one single well does, since a stream flow measurement represents discharge from the aquifer over the entire upstream basin. Precipitation is moderated by small amounts of run-off, and large amounts of evapo-transpiration, such that the most authoritative estimate by USGS is about 48% of Long Island precipitation reaches groundwater as recharge, a value that varies based on soil types and plant cover (Peterson 1987). This suggests there should be a reasonable correlation between the Long Island-wide Palmer Index, SPI measurements, variations in stream flows (assuming the stream flows are correlated), and ground water heads.

The data presented here do not agree very much over the 2010-2016 time period, however. Correlations for an extensive, expansive dry period from 2011 are lacking, although most measures point towards dry conditions from 2015 through 2016.

There are other time periods where there is better agreement that a drought was occurring. In the middle 1960s, even to the end of the decade and for a few years in the 1970s, some of the measures gathered here show strong indications of drought, such as all four river flow records (Figure 12, Connetquot River as an exemplar) and the ground water head data (although the data points were sparse then) (Figure 13). The SPI measurements are not as consistent; Long Island is such a moist climate that even in the driest conditions there are extended periods of much higher than normal rainfalls (see Figure 14, 6-month SPI).

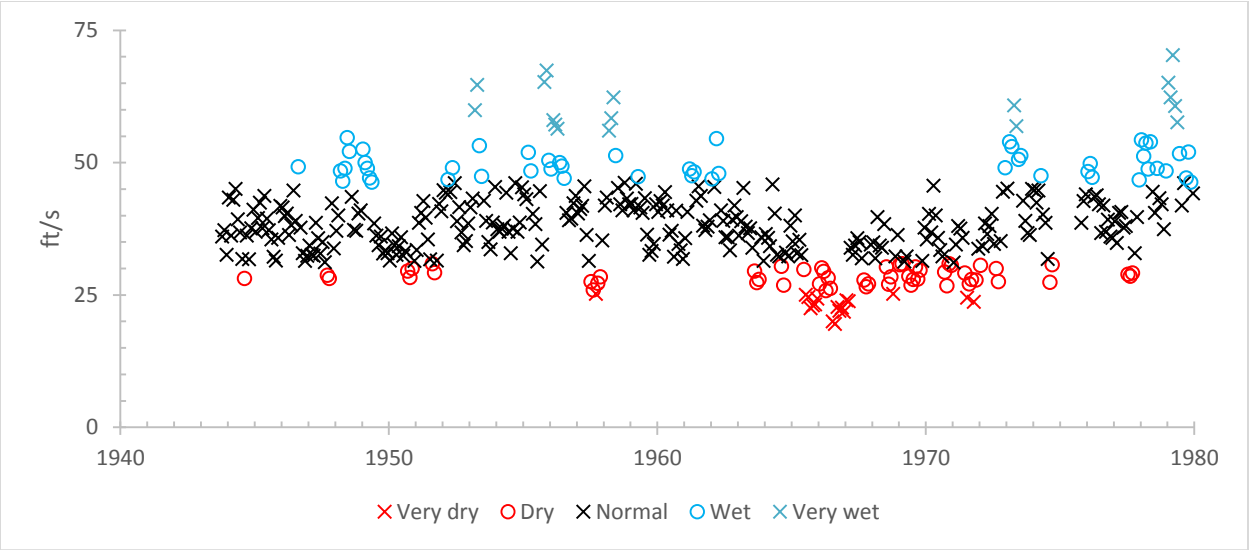

Figure 12. Connetquot River monthly average flows (1943-1979) (5% and 20% thresholds)

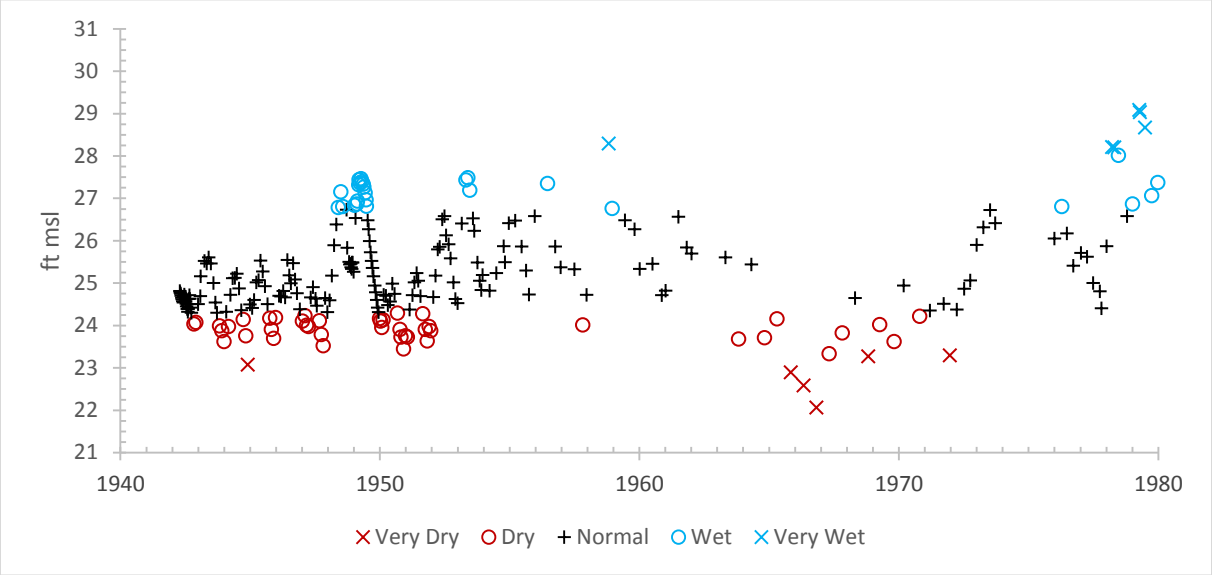

Figure 13. Head data for S-3529 (1942-1979) (5% and 20% thresholds)

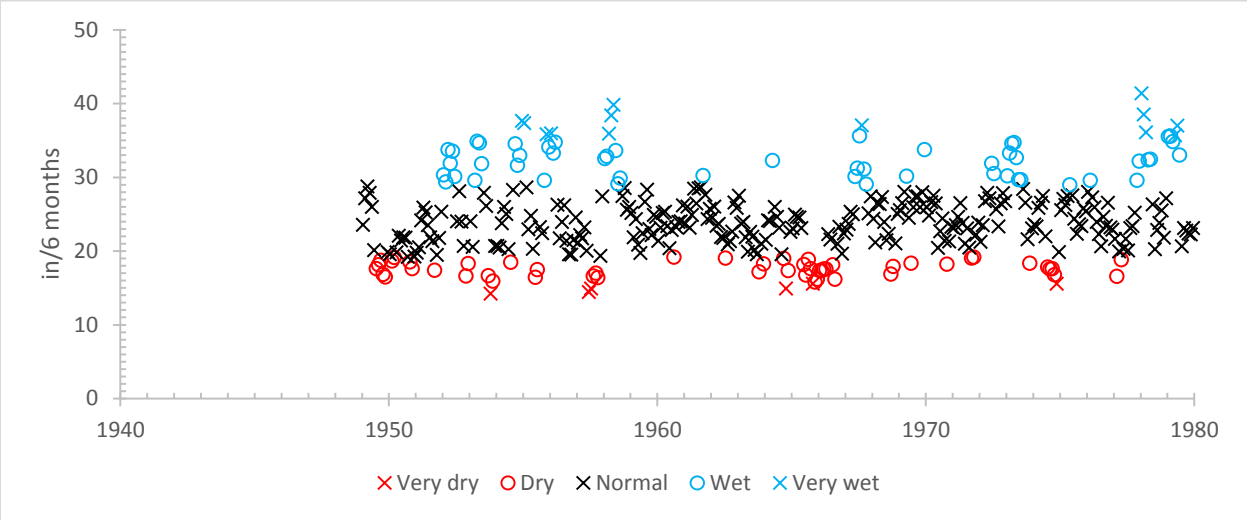

Figure 14. 6-month SPI (Brookhaven National Laboratory, Upton) 1949-1979 (5% and 20% thresholds)

Therefore, although some important measures (such as groundwater heads) have reached historical lows recently, this is not yet a historic drought for Long Island.

Conclusion

Long Island (Suffolk County) appears to be experiencing a two-year period of much drier than normal conditions. This is not as long nor does it appear to be as great a dry period as was measured in the period of 1965-early 1970s. River flows, which express an aggregated ground water head value for the upstream drainage area, may be a more generalized measure of droughty conditions than individual well records or rainfall data. The major rivers for Suffolk County do not always agree on whether conditions are droughty or not, however.

Acknowledgements

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