



United States Department of the Interior

NATIONAL PARK SERVICE
Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525

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Memorandum

To: Sophia Fox, Aquatic Ecologist, Cape Cod National Seashore

From: Larry Martin, Hydrogeologist, NPS Water Resources Division
Kelly Medeiros, Hydrological Technician, Cape Cod National Seashore

Subject: Hydrologic monitoring in the vicinity of the Wellfleet municipal water-supply well

Summary:

During the course of 2011-12, it was observed that the water surface elevation at Duck Pond declined several feet. Recent high water levels at Duck Pond were 10½ feet MSL in May 2010 and 9¾ feet MSL in May 2011. The water level has steadily declined since then to about 6½ feet MSL in late-2012. There has been some speculation by the local citizenry about the possibility that groundwater pumping from the Wellfleet municipal water-supply well could cause the observed water level decline at Duck Pond.

We found no correlation between groundwater pumping from the Wellfleet municipal water-supply well and water levels at nearby monitoring wells and ponds. We did find that the water levels at monitoring wells and ponds correlate with the Palmer Hydrological Drought Index for the area. Thus it appears that the observed decline of the water level elevation at Duck Pond is a response to the dry conditions that have prevailed since early 2010. There is no evidence of differences in water level decline at the ponds or monitoring wells near the water-supply well compared to a pond and monitoring wells far from the pumped well.

Introduction:

The Town of Wellfleet operates a municipal water-supply well at a site south of Cahoon Hollow Road, approximately 1000 feet east of the Senior Center and 1500 feet east of Duck Pond (Figure 1). There is some concern that pumping groundwater from the municipal water-supply well will lower the water table and affect the water levels of nearby ponds, e.g. Duck and Dyer ponds. Groundwater pumping on a regular basis began in November 2010.

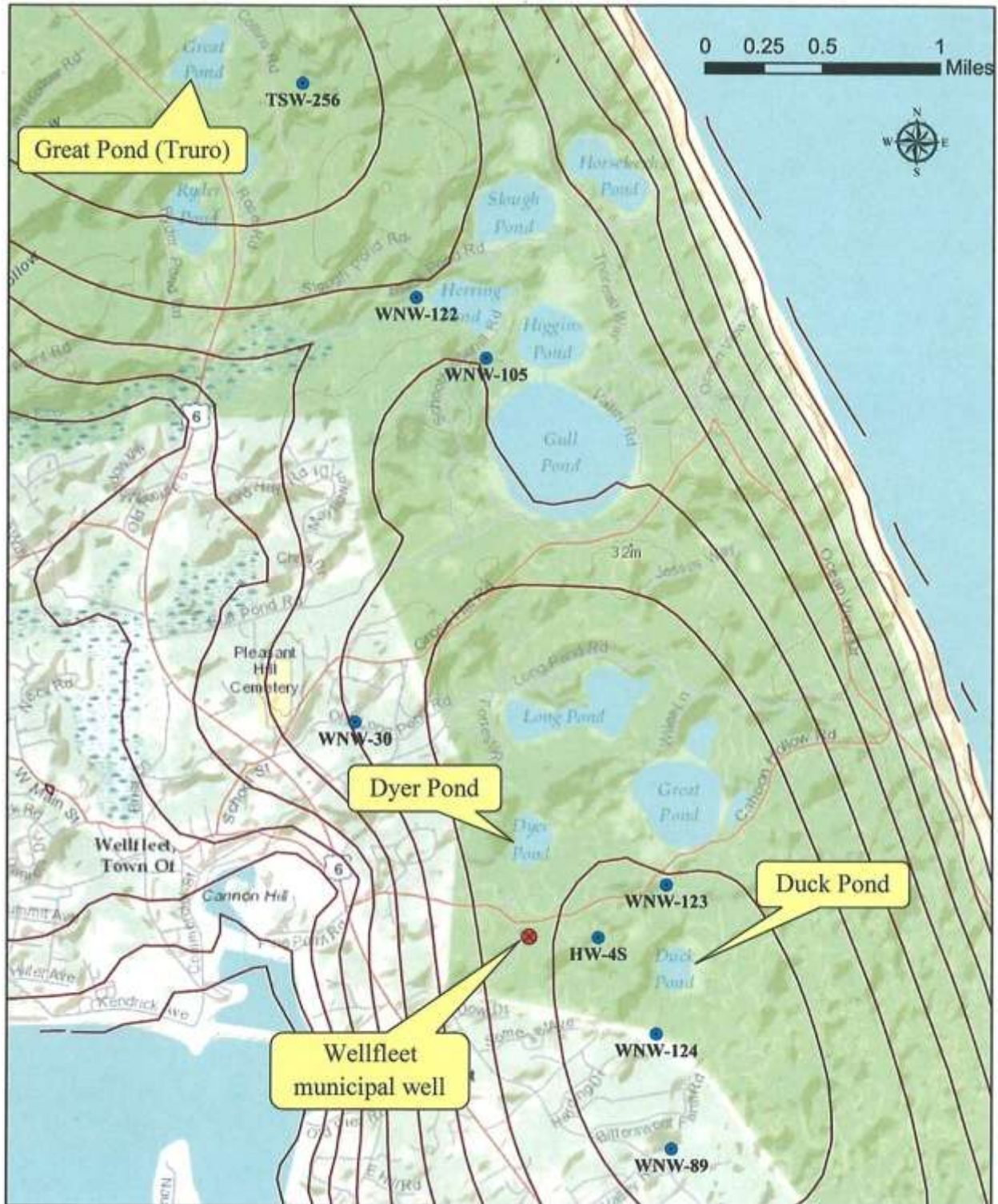


Figure 1. Locations of monitoring wells and ponds near the Wellfleet municipal water-supply well. Red lines are water table contours (2004), GIS shapefile obtained from Mark Adams, CCNS. Contour interval is 1 foot. The highest contour line surrounding Duck Pond is 9 feet above MSL.

We do not have a complete record of the quantity of water pumped from the Wellfleet municipal water-supply well, but so far the peak pumping in the summer months is 40-45,000 gallons per day. Pumping in the winter months averages 15-20,000 gallons per day (Figure 2).

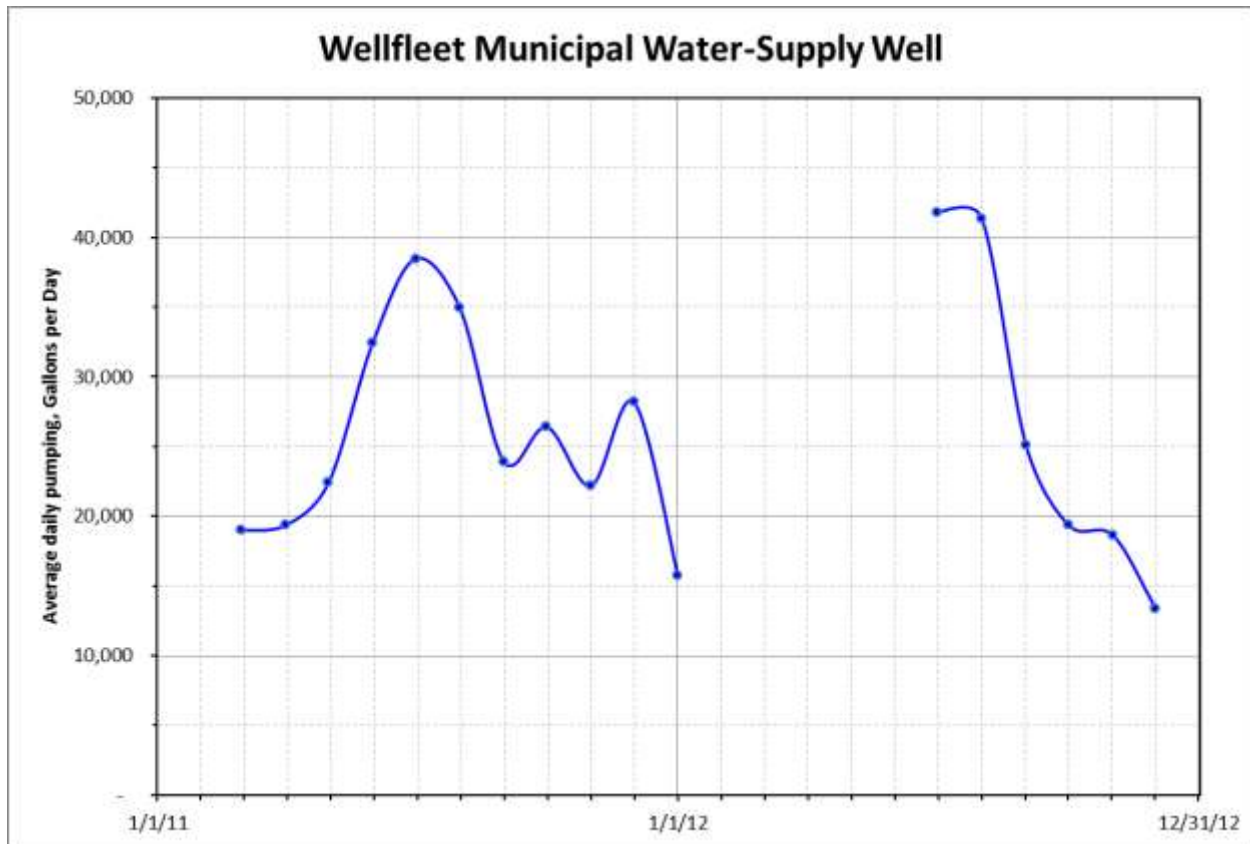


Figure 2. Average daily pumping from the Wellfleet municipal water-supply well.

Predicted drawdown from pumping at the Wellfleet municipal water-supply well

Current pumping rates from the Wellfleet municipal water-supply well are relatively small. Average daily pumping ranges from about 15-20,000 gallons per day in the winter to 40-42,000 gallons per day in the summer (Figure 2). For comparison, Provincetown pumps about 1,200,000 gallons per day in the summer from the Pamet aquifer in North Truro.

We would expect very little drawdown from the current pumping schedule for the Wellfleet well. We can estimate the amount of drawdown that would occur at any distance from the pumped well using the Theis equation. We use average values for hydrologic properties of the Cape Cod aquifer and specific data regarding pumping from the municipal well. The following properties were used in the analysis;

Transmissivity = 15,000 ft²/day

(assuming hydraulic conductivity of 200 ft/day and aquifer thickness of 75 feet)

Specific Yield = 0.15

Pumping Rate = 5,500 ft³/day = 41,000 gallons per day

Pumping time = 365 days

The resulting calculation shows that we would expect about 0.1 foot of drawdown (1¼”) at a distance of 1500 feet (the distance from the well to Duck or Dyer Pond) after one year of continuous pumping at a rate that is equal to the highest pumping rate in the summer. This analysis assumes that there is no recharge during this period, i.e., no infiltration from rainfall or snowmelt. The analysis also assumes that the aquifer is homogeneous and isotropic, disregarding any layering or stratification in the aquifer.

As a practical matter, such small, theoretical changes to the water table elevation from groundwater pumping at the municipal well are undetectable and within the range of the natural variability of the Cape Cod aquifer due to recharge from infiltration of rainfall and snowmelt. The pumping rate might increase in the future as additional customers begin to use water from the Wellfleet water system. NPS plans to continue the current groundwater monitoring as a part of the Cape Cod inventory and monitoring program; therefore we may be able to detect groundwater level changes and re-evaluate the effect of pumping in the future.

Analyses of water level data

To see whether there were any detectable differences in water levels that might be attributed to groundwater pumping from the municipal water-supply well, we made use of monthly measurements of the groundwater levels at several wells in the area and the surface water levels at several ponds measured by the National Park Service.

We examined surface water levels for Duck and Dyer Ponds, as they are both about 1500 feet from the well. We also compared these data to water levels for Great Pond (Truro) as a “control” pond. Great Pond (Truro) is far removed from any area with significant groundwater pumping, so it should be representative of natural conditions. If there is an impact from groundwater pumping from the Wellfleet municipal supply well, we would expect water levels at the nearby Duck and Dyer ponds to decline faster than at the control site; the more distant Great Pond (Truro). Similar patterns of water level change among the three ponds would suggest natural fluctuations and no impact of well pumping.

In addition to pond levels, we looked at groundwater elevation data from several monitoring wells near the Wellfleet municipal water-supply well and compared the data with a monitoring well (TSW-256) near Great Pond (Truro) as the “control” site. If groundwater pumping was lowering the water table, the effect should be more noticeable near the pumped well, e.g., the

drawdown should be greatest at HW-4s, less at WNW-123 and WNW-124, and even less at WNW-30. Data from six monitoring wells and three ponds were evaluated:

<u>Well #</u>	<u>Well Name</u>	<u>Distance from pumped well</u>
HW-4s	Dog Park	700 feet
WNW-123	Garrison	2,200 feet
WNW-124	Power Line	2,500 feet
WNW-89	Paines Campground	3,900 feet
WNW-30	Old Long Pond Road	5,100 feet
WNW-256	Mitre	15,000 feet

<u>Pond Name</u>	
Dyer Pond	1,400 feet
Duck Pond	1,600 feet
Great Pond (Truro)	15,000 feet

We expect the water table elevation and pond levels to fluctuate in response to weather and climate conditions, rising during wet periods and lowering during dry periods. The Palmer Hydrological drought index (PHDI) provides a standardized measure of wet and dry conditions and is a more accurate indicator of groundwater conditions and reservoir levels (i.e., ponds) than the standard drought indices or precipitation data. A positive number indicates wetter than normal conditions and negative numbers represent drier than normal conditions, with the size of the number indicating the severity of the drought. Figure 3a shows the PHDI for the coastal Massachusetts zone for 2000-2012. As an example, figure 3b shows the correlation of the drought index with water levels at Great Pond. Water levels at other ponds and monitoring wells show a similar correspondence with the PHDI.

During much of the period from 2000-2012, the area has been wetter than normal. The latter part of 2001 and most of 2002 was a drought period, as was the latter half of 2007. Starting in 2008, the area was wetter than normal for 4 years, until late 2011. Thus, most people's short-term memory of hydrologic conditions on the cape is for the wetter than normal conditions that have been prevalent since 2003. The index started a rapid decline in late 2011, indicating the onset of a dry period, which lasted through the summer of 2012. During these dry periods, we would expect to see a corresponding lowering of the water table and surface water elevations in ponds.

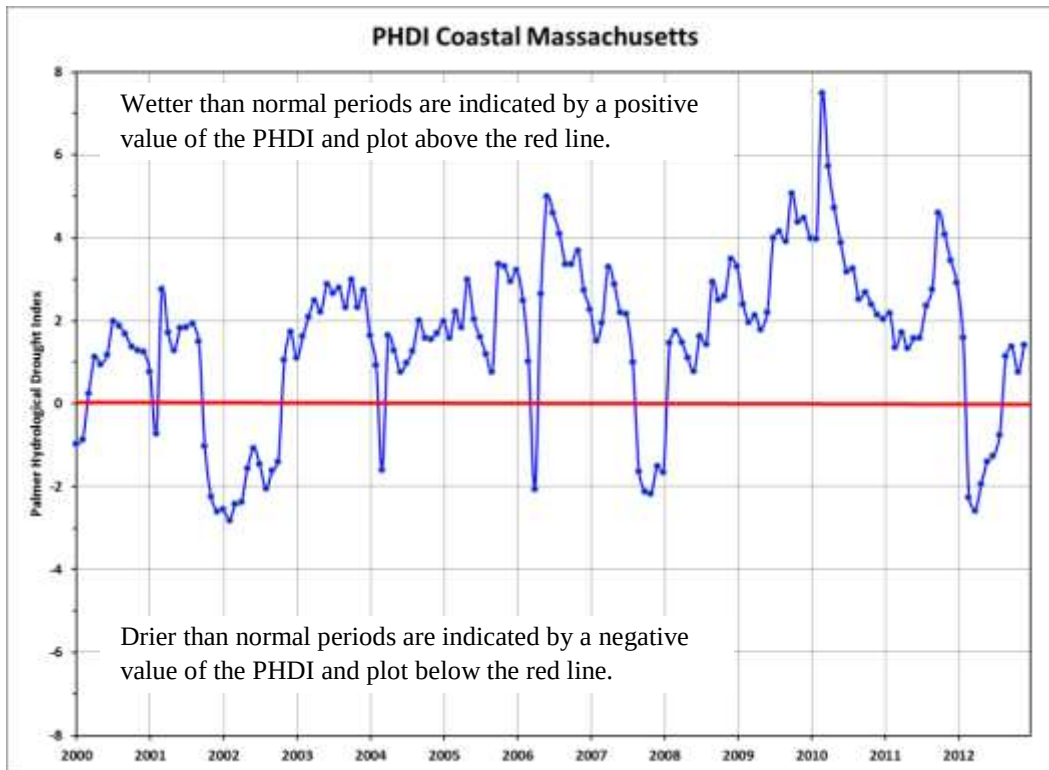


Figure 3a. Palmer hydrological drought index for the coastal Massachusetts zone, 2000-2012.

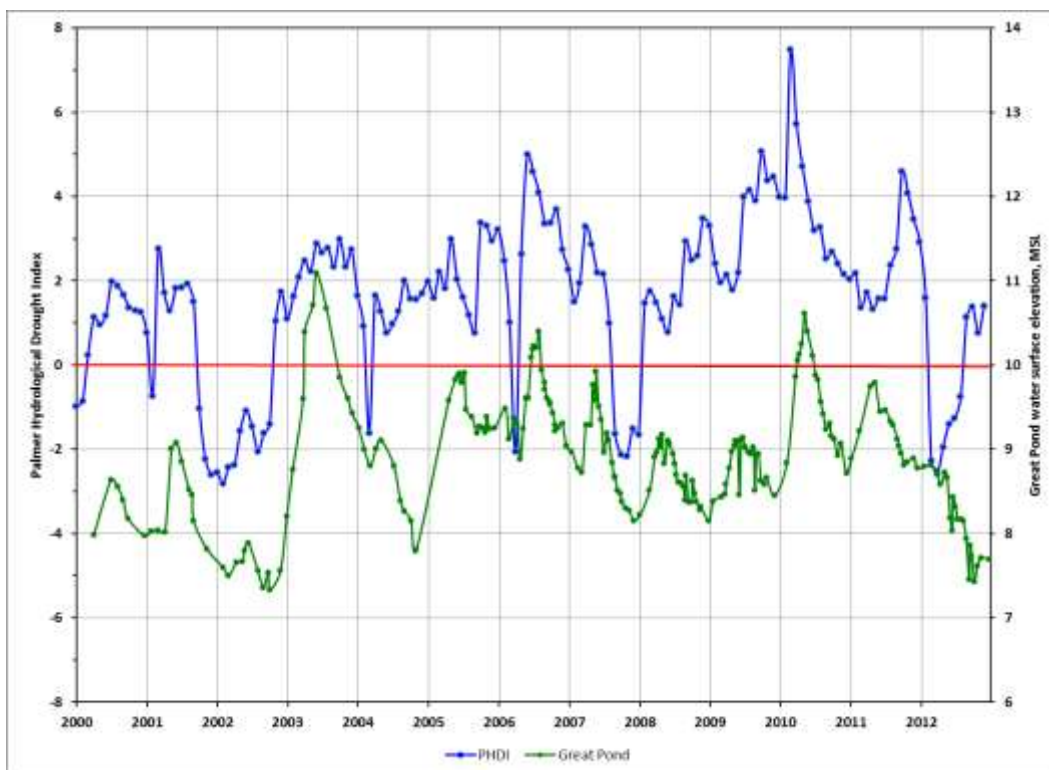


Figure 3b. Example of correlation between the Palmer hydrological drought index and the water surface elevation at Great Pond (Truro).

Data Analysis

Monthly water level monitoring was initiated at most of the wells and ponds in 1999 or 2000. The data for each site were arranged in a table in an Excel spreadsheet to facilitate calculation of the minimum, maximum, and mean water level for each month. In the following example, there are 14 water level measurements at well WNW-124 during the month of July (Table 1). The highest water level was 10.95 feet (2003). The lowest water level was 7.12 feet (2002). The average water level during the month of July was 9.17 feet.

Table 1. Monthly water level measurements at monitoring well WNW-124 (Power Line).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1999			8.31	8.44	8.38	8.17	7.91	7.60	7.32	7.25	7.29	7.23
2000	7.24		7.68	7.97	8.66	8.81	8.54	8.34	7.86		7.57	7.28
2001	7.30	7.42		7.95	8.83	9.01	8.81	8.32	7.96		7.49	
2002		6.73	6.61	6.83	7.00	7.22	7.12	6.82	6.72	6.67	6.57	7.32
2003	8.07		9.36		11.08	11.31	10.95			9.88	9.36	8.88
2004	8.77	8.53	8.37	8.41	8.89	9.10	8.82	8.45	8.17	7.89	7.51	
2005		8.16	8.65	9.17	10.11		10.28	9.85	9.27	9.09	9.04	9.03
2006		9.45	9.47	9.34	9.47	10.03	10.43	9.98	9.66	9.25	8.92	7.73
2007	8.54	8.46	8.47	9.07	9.67	9.74	9.48	8.90	8.52	8.07	7.76	7.64
2008	7.64	7.93	8.62	9.04		9.21	8.94	8.43		7.05	7.63	7.21
2009			7.93	8.42	8.81	9.03	8.89	8.57	8.32		8.09	8.01
2010	8.29	8.74	9.96	10.76	11.02	10.78	10.24	9.87	9.52	9.17	8.89	8.63
2011	8.72	9.26	9.52	9.85	10.11	10.07	9.82	9.54	9.16	8.93	8.77	8.71
2012	8.69	8.76	8.76	8.64	8.53	8.40	8.15	7.87	7.55	7.33	7.09	6.98
Min	7.24	6.73	6.61	6.83	7.00	7.22	7.12	6.82	6.72	6.67	6.57	6.98
Max	8.77	9.45	9.96	10.76	11.08	11.31	10.95	9.98	9.66	9.88	9.36	9.03
Mean	8.14	8.34	8.59	8.76	9.27	9.30	9.17	8.66	8.34	8.23	8.00	7.89
Count	9	10	13	13	13	13	14	13	12	11	14	12

We then prepared a data plot for each well and pond showing the minimum, maximum, and mean water level for each month and repeating that data for each year of the period of record. We then plot the actual (monthly) measurements as a time series so we can see how the water table or pond level at any particular time relates to the minimum, maximum, or mean value for that site. The graph for well WNW-124 is presented in Figure 4 as an example.

As would be expected, low water levels coincide with drought periods in 2002, 2008, and 2012. High water levels are associated with wetter than normal periods, although the correspondence is not as distinct. For example, the high water level in 2003 does not have an associated peak in the PHDI (see Figure 3).

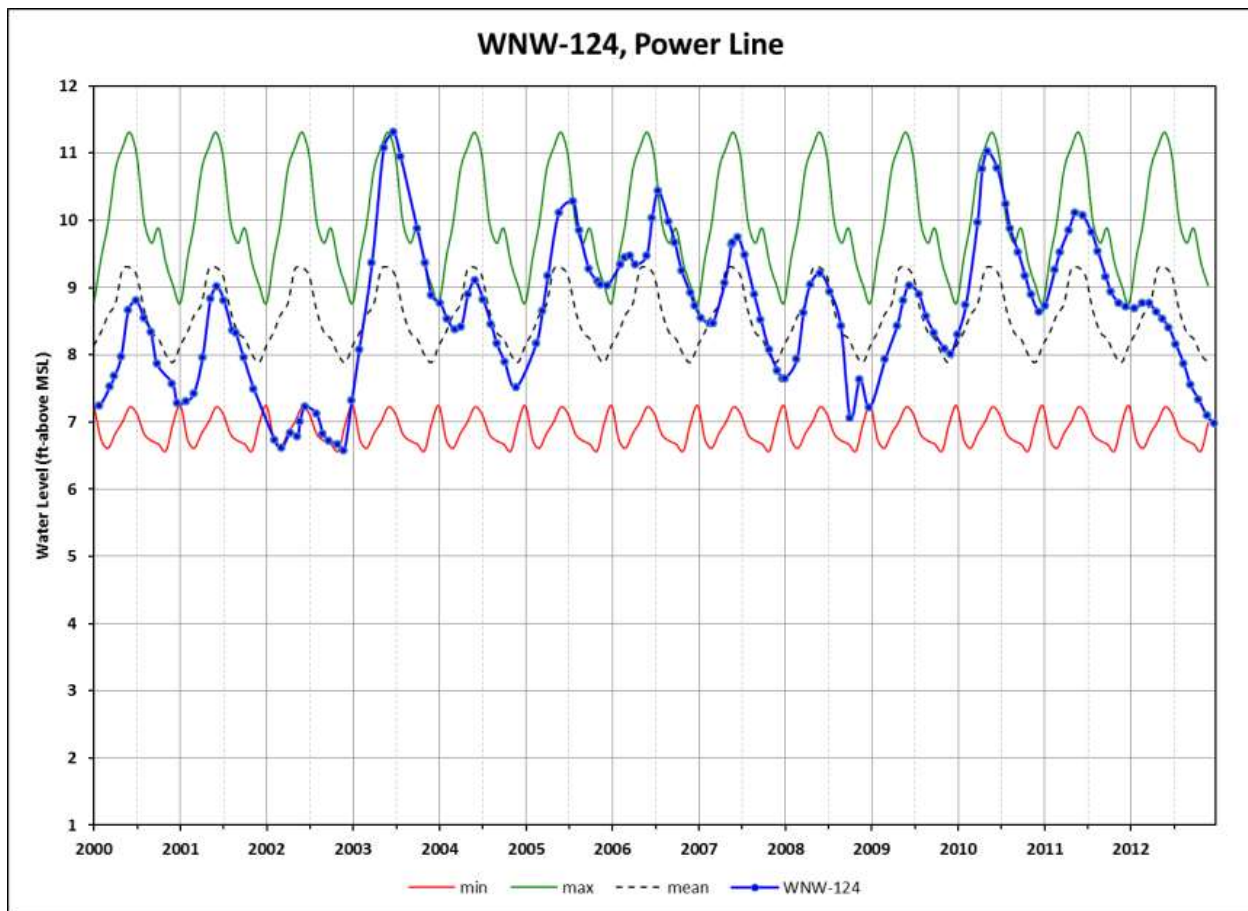


Figure 4. Approximately monthly measurements of the water level at Well WNW-124 compared to the minimum, maximum, and mean monthly values for the period of record, 2000-2012.

Full-page graphs are attached to this report for each of the monitoring wells and ponds that were included in the data analyses:

- Well WNW-123, Garrison
- Well WNW-124, Power Line
- Well WNW-30, Old Long Pond Rd.
- Well WNW-89, Paines Campground
- Well TSW-256, Mitre
- Well HW-4s, Dog Park
- Duck Pond
- Dyer Pond
- Great Pond (Truro)

Measurements at well HW-4s (Dog Park) were only started in 2011. Minimum, maximum, and mean values are not shown for that site because of the short period of record.

Comparison of pond surface data

Dyer and Duck Ponds are relatively close to the Wellfleet municipal water-supply well. Great Pond (Truro) is far from the Wellfleet municipal water-supply well (or any other well). If groundwater pumping is affecting the pond surface elevation at Duck or Dyer Pond, we should see a change in the relationship between the water-surface elevations at Duck and Dyer Ponds (near the pumped well) compared to the water-surface elevation at Great Pond (distant from the pumped well) after the Wellfleet municipal water-supply well went on-line in November 2010. If pumping was affecting the water levels at Duck and Dyer Ponds, then we would expect to see the water levels at those ponds decline faster and to a lower elevation, than at Great Pond, particularly in the summer when the pumping rate increases. Instead, we see that the relationship between water levels at Duck, Dyer, and Great Ponds remains about the same before and after pumping from the Wellfleet water-supply well was initiated in November 2010.

Figure 5 shows the surface elevation of Dyer Pond and Great Pond (Truro) from 2000-2013 and Duck Pond from 2006-2013. We see that the normal annual fluctuation of the water surface elevation is 1-2 feet. In extremely wet or dry years, the fluctuation can be 3-4 feet.

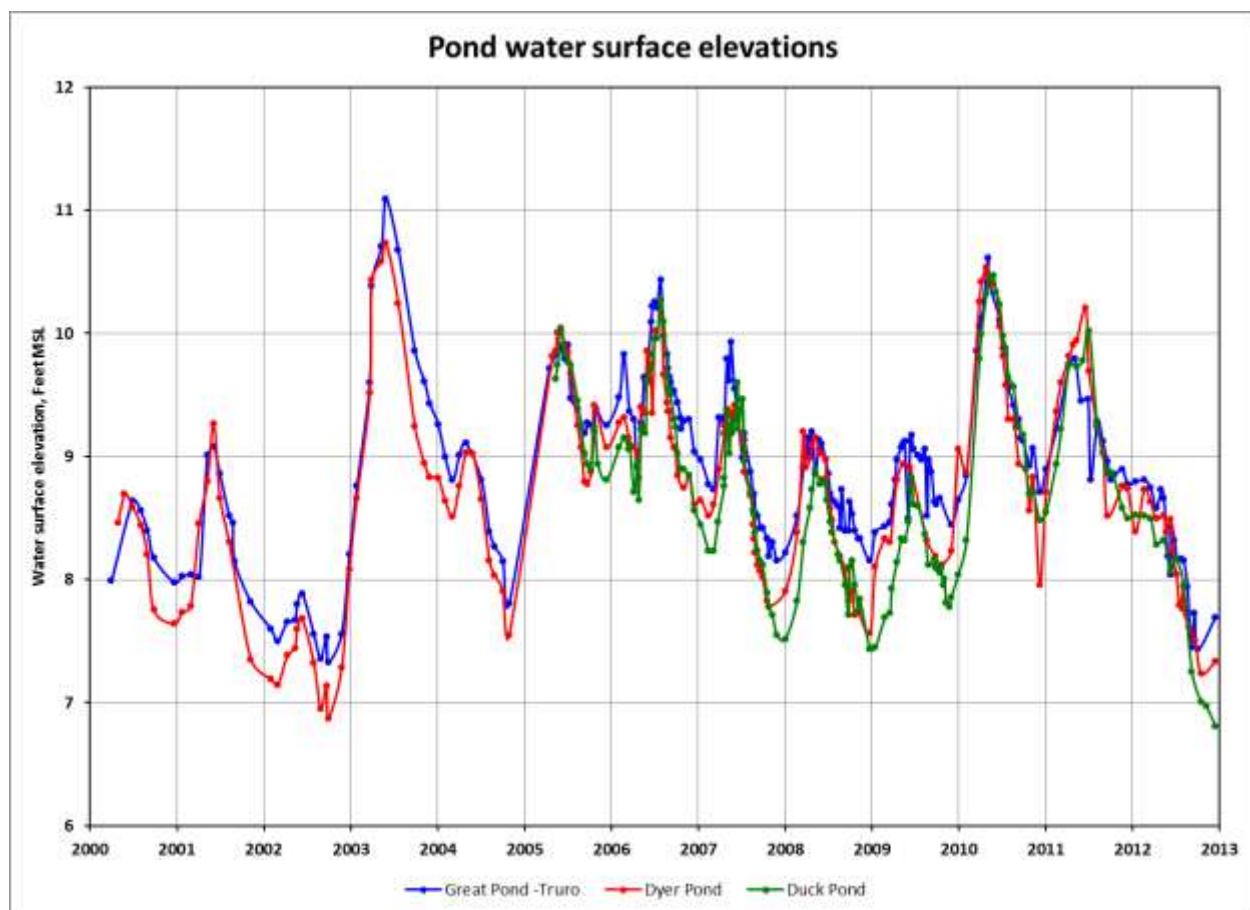


Figure 5. Surface elevations for Duck Pond, Dyer Pond, and Great Pond (Truro) since 2000.

There is good correspondence among the water levels at all three ponds (Figure 5), despite their different distances from the municipal well. The data show that the water surface elevation for Duck Pond was generally lower than the other ponds during the dry seasons from 2006 to 2013. While the water surface at Duck Pond in the latter part of 2012 is about a foot lower than during other dry years (2008 and 2009), the water levels at Dyer Pond and Great Pond (Truro) (although higher than Duck Pond) are also about a foot lower than in the dry periods in 2008 and 2009. Thus, the low water level at Duck Pond is consistent with other observed responses to drought conditions in 2012.

Referring back to Figure 5, we see that the water surface elevations in Dyer Pond and Great Pond (Truro) in late 2012 are about the same as was observed during the dry period of 2002. Great Pond (Truro) is far beyond the area of influence of groundwater pumping and can be assumed to be representative of natural conditions.

The data show that pond water surface elevations at Duck, Dyer, and Great ponds are currently being controlled by larger scale climatic factors rather than local drawdown of the water table by the municipal well.

Correlation of groundwater elevation and pond surface

Figure 6 shows the water table elevation at two monitoring wells near Duck Pond and the water surface elevation at Duck Pond from 2005-2012. We see that most of the time the water surface of Duck Pond is slightly lower than the adjacent water table. We observe no pattern that is attributable to drawdown from groundwater pumping. If pumping was causing a drawdown of the water table in the vicinity of the pumped well, we would expect the water levels in nearby monitoring wells to show a faster rate of decline in the summer after pumping started in 2010 when compared to the rate of decline prior to groundwater pumping.

We see a similar correspondence between the water table elevation and pond surface for well WNW-123 and Dyer Pond (Figure 7) and for well TSW-256 and Great Pond (Figure 8) for the period of record and no change in the relationship after municipal pumping started as shown in Figures 7 and 8.

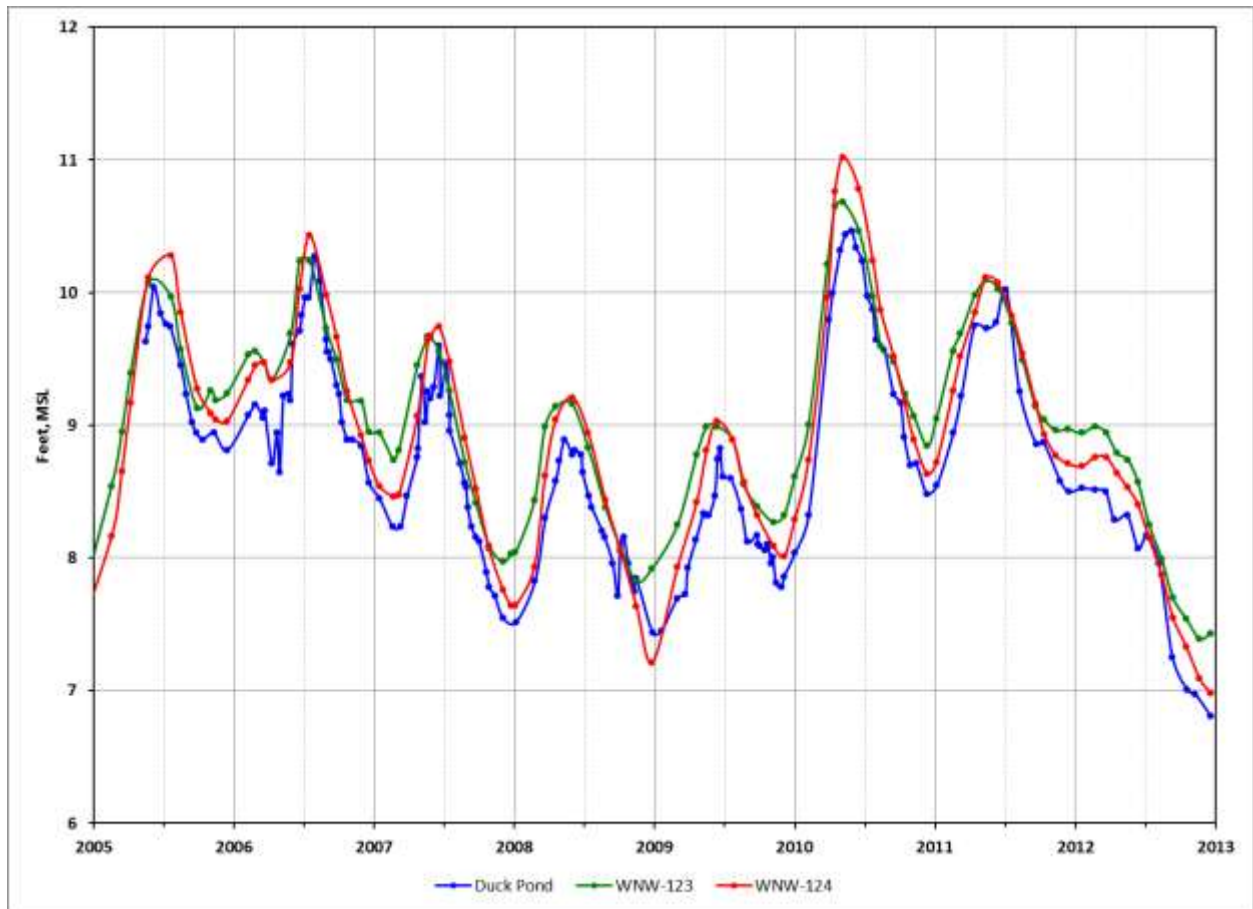


Figure 6. Water level elevation at Duck Pond and two nearby monitoring wells, 2005-2012.

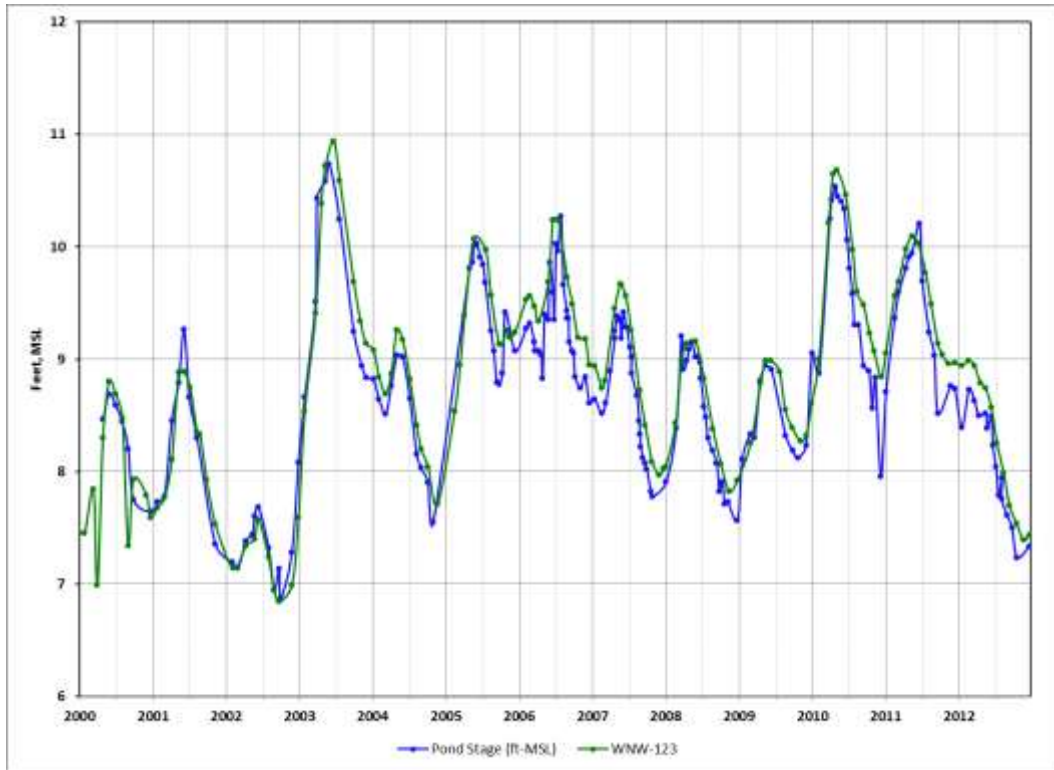


Figure 7. Water level elevation at Dyer Pond and well WNW-123, 2000-2012.

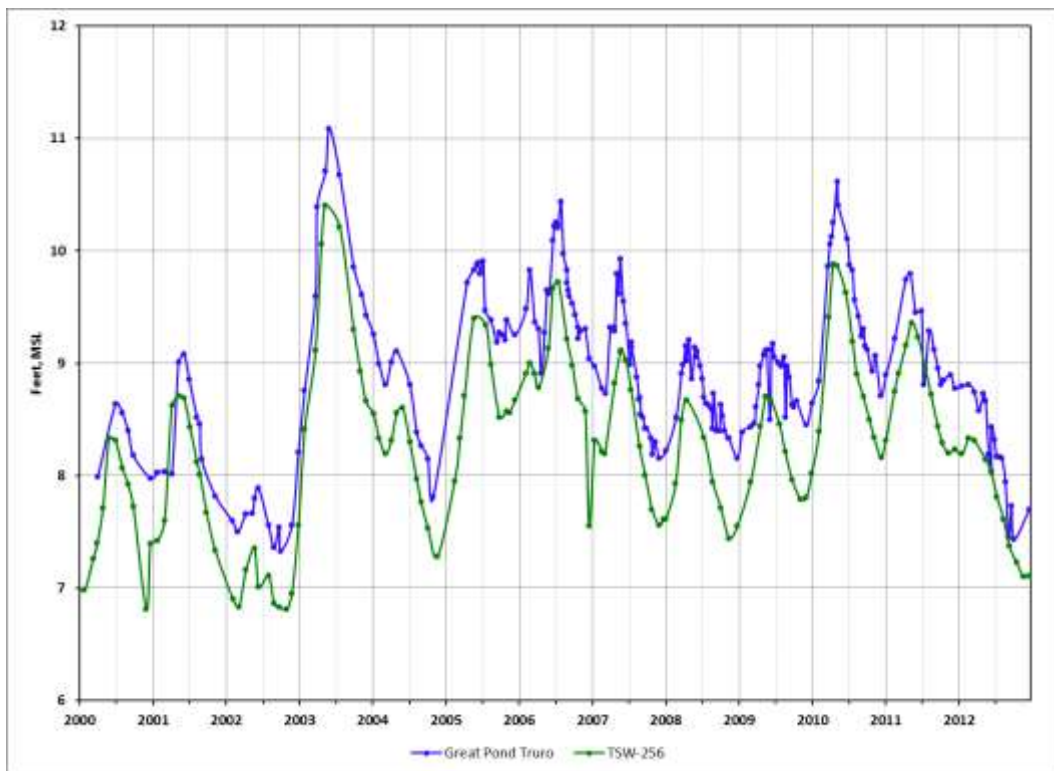


Figure 8. Water level elevation at Great Pond (Truro) and well TSW-256, 2000-2012.

Comparison of water table elevations at monitoring wells

If pumping groundwater from the Wellfleet municipal water-supply well was causing a localized drawdown of the water table, we would expect to see a larger decline in the water level at monitoring wells closer to the pumped well. Figure 9 shows a plot of all of the water table elevation data at the monitoring wells analyzed for this report. The three wells plotted on the upper part of the chart all have similar water table elevations (WNW-123, WNW-124, and TSW-256). Wells WNW-123 and WNW-124 are closest to the pumped well, and yet they exhibit about the same rate of decline and a close correlation with the water level in the more distant well TSW-256 before and after the municipal water-supply well was brought on line in March 2011.

We see the same correlation and rate of decline for water levels in all of the monitoring wells regardless of their distance from the pumping well. If groundwater pumping was having an effect on the water table elevation, we would expect to see a faster decline of the water table elevation in monitoring wells near the pumped well after the start of pumping November 2010. The decline should be greater in the summer months when the pumping rate is larger. Instead we see about the same pattern of fluctuation for all wells, regardless of distance from the pumped well, before and after the Wellfleet municipal water-supply well was brought on line.

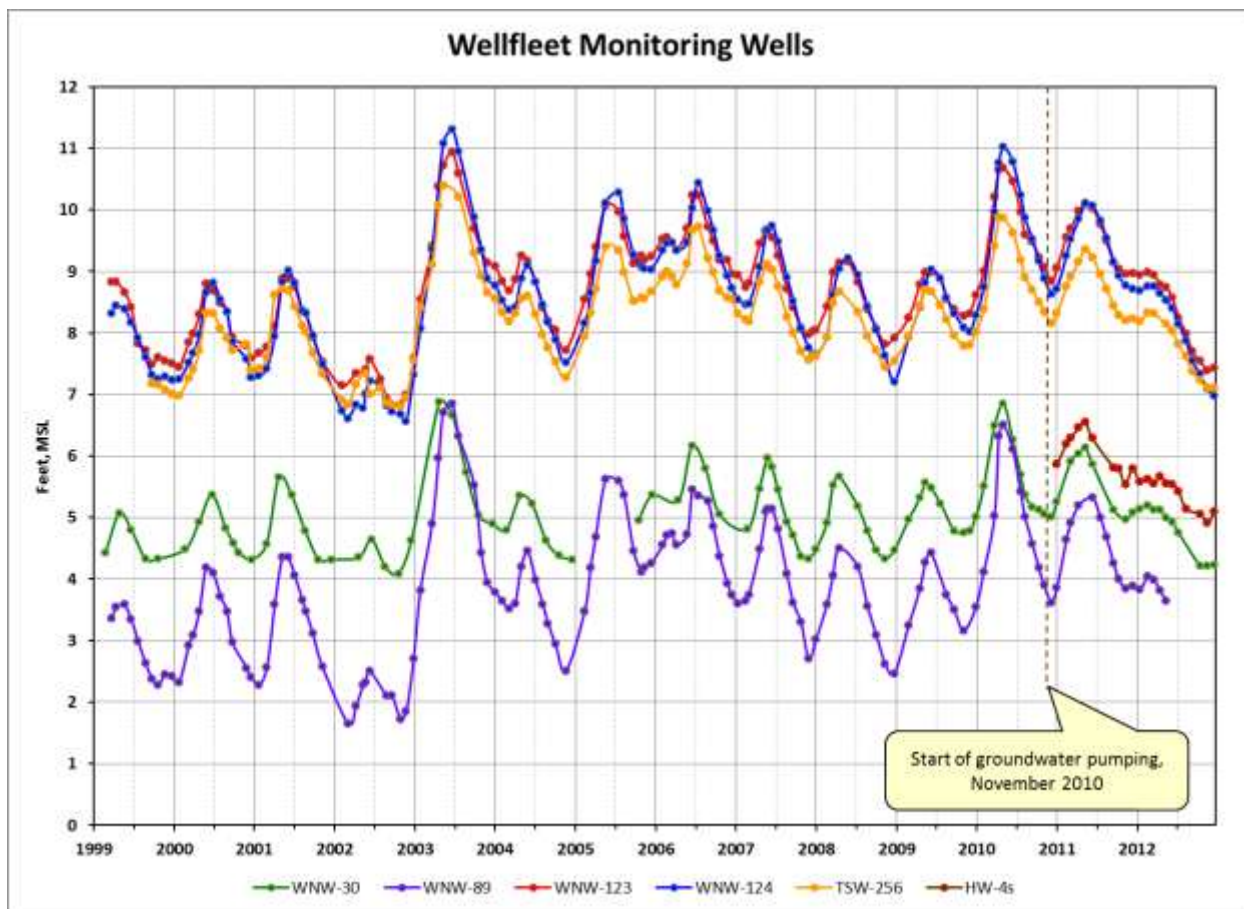


Figure 9. Water table elevation at six monitoring wells, 1999-2012.

Conclusions

1. Groundwater level monitoring and pond surface elevation monitoring provide no evidence of increased drawdown of the water table or pond surface elevation in proximity to the Wellfleet municipal water-supply well.
2. Current observed low water levels are similar to what has been observed in the past during similar dry periods, and are likely the result of climatic factors.
3. Predictions of groundwater level drawdown at Duck Pond due to pumping at the municipal well are minor to negligible at the current pumping rates.
4. Natural hydrologic variability masks the minor, if any, effects of groundwater pumping. Or stated another way, groundwater pumping would need to be much greater to cause an observable effect on water levels in Dyer or Duck Pond.

If there are any questions regarding this report, please call Larry Martin at (970)-225-3515.

