Groundwater Head Monitoring in the Vicinity of the Brookhaven Landfill, 2015

David J. Tonjes
Department of Technology and Society
Stony Brook University
david.tonjes@stonybrook.edu

Abstract
Water levels were measured at 155 sampling points (80 distinct locations) near the Town of Brookhaven landfill on a near-monthly basis in 2015. Water levels were lower than historical means throughout 2015, because of an extended period of below-average precipitation. Flow to the southeast in the Upper Glacial aquifer is similar to that observed and reported on in 2014, and to what has been previously described. Some dynamics of head change across the recent 2014-2015 sampling period are described: there are no differences in the patterns of response to recharge at different sampling points in a well cluster that are screened at different depths of the Upper Glacial aquifer, and only small changes when comparing sampling points at the same location that are screened either in the Upper Glacial aquifer and the Magothy aquifer, or in the Upper Glacial aquifer and the confining layer. A systematic comparison across different locations found differences in response to recharge, however. There was small degree of correlation between the size of the vadose zone and response to recharge; however, although there is autocorrelation between the factors, geographical location seemed to be more important in determining how different locations compared in their changes in head over time. Notably, wells south of the LI Railroad tracks in Brookhaven hamlet (an area that is also between the estuarine portions of Beaverdam Creek and Carmans River) appears to respond very differently than the aquifer regions that discharge into the fresh water portions of Beaverdam Creek and the fresher portions of the Carmans River estuary.

Introduction
Water level measurements can be used to develop the head pressure relationships between different monitoring points of a groundwater system. These measurements can be used to develop equipotential head maps, which, if constant hydraulic conductivity is assumed, also describe flow patterns for groundwater. It is a relatively simple task to collect these measurements from an existing monitoring network, although taking a large number of readings in a single time period can be a daunting task. Measurements like these are key for model construction; repeated measures allow for either construction of dynamical models, or testing for model consistency under different head conditions. Establishing long-term data sets for an aquifer system also helps to better understand the groundwater as a resource -- for environmental purposes, or for human use. -- and also helps us to understand complicated processes that occur in such systems.

Materials and Methods
The Town of Brookhaven has a monitoring well network, consisting of groundwater monitoring wells constructed by the Town, its contractors, and the US Geological Survey (USGS), together with a set of fire wells constructed by the local fire department, a gaged stream station, a surveyed stream station, and a number of unsurveyed stream monitoring points in the near vicinity of its landfill. Suffolk County Department of Health Services also has a set of monitoring wells it constructed to monitor the Long Island Compost facility just north of the landfill. Some of the wells are located within Wertheim National Wildlife Refuge, and a permit to monitor these sites was obtained (although permission to monitor the wells was not always given by Refuge managers in 2015). Ten surveys of the monitoring network were made in 2015, on a near monthly basis (Table 1). The number of locations varied across the survey dates; one fire well broke in 2015, a number of well caps could not be untightened at times, and several locations were buried under snow or ice in winter.

Date	Points monitored
1/17/15	141
3/23/15	142
4/17/15	151
6/5/15	154
6/26/15	154
8/30/15	152
9/28/15	152
10/19/15	153
11/9/15	153
12/8/15	152

Table 1. Sampling effort, 2015

Field data (depth to water measurements) recorded in a notebook were transferred to a spreadsheet and the potentiometric height of the sampling points was determined by subtracting the surveyed height of the common measuring point on the well casing. The SCDHS wells have not yet been surveyed and so data for these wells were restricted to depth to water measures. A comparison of relative changes of these data over time was made by comparing the measured heights in the network beginning with data collected in September 2014 through January 2016 to the June 26, 2015 data (this date was chosen as one of the dates with more measurements than others). Although plans include construction of maps of the potentiometric height of the water table, these maps have not yet been drawn. Precipitation data were /collected from the National Weather Service station at Brookhaven National Laboratory (Upton, NY).

Results

Table 2 presents the data from 2015, showing potentiometric head data (number of measurements, maximum and minimum data for 2015, along with the number of readings ever made and historical maximum and minimum data) for the monitored locations (except for the SCDHS wells, where depth to water data are presented). Figure 1 shows a map of the water table (from December 2014).

	2015			Historical		
Cluster	**Samples**	**Max.**	**Min.**	**Max.**	**Min**	**Records**
MW5-S	10	28.06	25.86	33.53	25.50	160
MW5-I	10	28.05	25.84	33.53	25.47	133
MW5-D	10	28.04	25.82	33.49	25.47	147
MW6-S	10	26.66	24.17	32.14	24.16	142
MW6-D	10	26.62	24.18	32.10	24.15	130
72816-67	10	27.78	25.55	31.85	24.96	119
MW12-IR	10	27.77	25.56	31.84	25.11	54
Meth 18	10	26.43	23.72	28.46	**23.72**	60
3529-45	10	25.63	22.86	30.20	22.32	516
72812M-198	10	25.57	22.97	29.81	21.95	250
MRF-4	10	24.83	22.05	29.22	**22.05**	74
PZ-1	10	25.95	23.33	30.18	23.28	121
MW1-S	10	24.31	21.98	29.31	**21.98**	127
MW2-S	10	24.27	22.01	29.15	**22.01**	161
MW2-D	10	24.33	22.04	29.16	**22.04**	159
MW11-M	10	24.14	21.87	27.97	21.66	131
MW3-S	10	23.60	21.31	28.26	21.30	154
MW10-SR	10	23.99	21.70	26.12	**21.70**	37
MW10-IR	10	24.01	21.76	26.11	**21.76**	35
MW4-S	10	23.33	21.05	27.26	20.98	167
MW4-D	10	23.35	21.05	27.25	21.00	153
103140-120	10	22.85	20.50	26.53	20.46	80
73767-58	10	23.47	21.17	27.63	21.09	133
73768-79	10	23.49	21.16	27.64	21.09	105
103141-121	7	23.23	21.06	27.47	20.95	103
73764-58	10	23.14	20.82	26.91	20.76	127
73765-78	10	23.15	20.83	26.91	20.76	93
73766-108	10	23.13	20.80	26.89	20.79	96
73760-65	10	22.85	20.45	26.53	20.41	163
73761-85	10	22.84	20.46	26.54	20.41	119
73761R-85	8	22.39	20.23	26.31	20.20	118
73763-140	10	22.85	20.46	26.57	20.37	131
72813M-219	10	22.96	20.66	26.49	20.51	255
73758-53	10	22.60	20.20	26.65	20.14	142
73757-73	10	22.62	20.20	26.65	20.14	103
73756-103	10	22.61	20.19	26.65	20.16	122
73759-123	10	22.61	20.18	26.64	20.12	118
MW13-SR	10	24.15	21.48	**24.15**	**21.48**	21
44581-22	10	23.95	20.66	28.43	**20.66**	61
Meth-5	10	24.12	21.15	28.40	**21.15**	58
73750-34	10	23.94	21.00	28.41	**21.00**	132
73751-55	10	23.43	20.91	27.53	20.70	107
73752-85	10	23.45	20.89	27.53	20.72	123
73753-34	10	22.90	20.43	27.71	20.41	110
73754-55	10	22.89	20.43	27.62	20.41	113
73755-85	10	22.86	20.42	27.54	20.39	110
MRF-1	10	23.11	20.40	26.47	**20.40**	81
MRF-3	10	23.36	20.66	26.82	20.63	82
73943-45	10	22.88	20.26	25.45	**20.26**	84
72818-8	8	21.67	19.25	23.38	**19.25**	86
72819-23	10	21.86	19.25	23.48	**19.25**	74
72820-43	10	21.83	19.22	23.61	**19.22**	77
SCNYap2-S	10	13.93	16.96	**13.93**	**16.96**	15
SCNYap2-M	10	13.97	16.98	**13.97**	**16.98**	15
SCHB9A	4	15.28	15.31	**15.28**	**15.31**	4
SCHB9B	7	13.98	16.11	**13.98**	**16.11**	8
SCNYap1-S	8	12.39	15.14	**12.39**	**15.14**	12
SCNYap1-M	10	12.11	15.04	**12.11**	**15.04**	14
SCH-S	8	11.64	14.33	**11.64**	**14.33**	9
SCH-S2	10	11.46	14.40	**11.46**	**14.40**	15
SCH-M	9	11.57	14.51	**11.57**	**14.51**	14

SCSYap-S SCSYap-M	10 10	12.19 12.06	15.08 15.03	**12.19** **12.06**	**15.08** **15.03**	15 15
72159-45	10	19.56	16.61	21.60	**16.61**	27
95319-75 95320-145	10 10	22.88 22.87	20.53 20.52	26.38 26.37	20.37 20.40	88 75
95307-80 95308-143	10 10	22.36 22.35	19.96 19.97	25.01 25.83	**19.96** 19.91	33 85
72836-54 72837-73 95303-105 95304-141	10 10 10 10	22.21 22.26 22.23 22.22	19.77 19.84 19.80 19.79	25.34 25.35 25.39 25.33	19.68 19.68 19.68 19.67	94 95 89 89
95305-107 85306-143	10 10	21.87 21.97	19.38 19.51	25.31 25.11	**19.38** 19.50	86 85
72834-34 73945-50 76400-69 76401-89	10 10 10 10	21.55 21.58 21.55 21.56	19.10 19.13 19.09 19.10	24.67 24.69 24.65 24.65	19.09 19.11 **19.09** 19.08	100 77 81 81
73946-42 73947-60	10 10	21.19 21.19	18.67 18.64	23.62 23.58	**18.67** **18.64**	94 79
72821-21 72822-43 72136-63	10 10 10	20.68 20.67 20.68	18.03 18.02 18.03	23.35 23.18 23.34	**18.02** **18.02** **18.03**	93 83 84
47747-34	10	18.80	15.91	21.17	14.94	213
72154-45	10	13.27	10.85	14.23	**10.85**	27
72155-47	10	13.90	11.35	15.25	**11.35**	30
72147-38	10	10.74	8.49	11.98	**8.49**	28
72131-55 72833-72	9 10	20.12 20.08	17.73 17.68	22.51 23.81	17.69 17.64	94 82
72823-6 72824-20	10 10	21.21 21.08	18.81 18.69	21.96 21.49	**18.81** **18.69**	20 18
73953-44 73954-64	10 10	19.07 19.11	16.52 16.59	21.47 21.51	**16.52** 16.58	91 79
72827-14 72828-28 73955-63 95310-142	10 10 10 10	17.24 17.27 17.29 17.37	15.00 15.00 15.05 15.11	18.64 18.67 18.71 18.80	**15.00** **15.00** 15.03 **15.11**	97 93 88 89
95312-75	10	17.94	15.68	20.16	15.59	85
95314-76	10	16.17	14.24	18.03	14.17	88
72127-54	10	16.29	14.10	19.28	13.99	98
72149-46	10	13.38	11.84	14.51	**11.84**	35
BD-3	5	12.10	11.86	14.40	11.10	53
76380-24 76381-44 76382-64 76383-82 76384-102 76385-120	10 9 10 9 10 10	15.01 15.02 14.97 14.96 14.97 15.02	13.11 13.21 13.12 13.11 13.17 13.23	15.40 15.42 15.54 15.26 15.43 15.50	**13.11** **13.21** **13.12** **13.11** **13.17** **13.23**	24 21 22 21 22 22
72150-47	10	15.14	13.23	15.89	**13.23**	28
72152-45 98442-50 98441-85	10 10 10	13.68 13.68 13.69	11.59 11.58 11.59	**13.68** 15.18 15.19	**11.59** **11.58** **11.58**	14 82 69
98438-44 72151-46 98440-84 98439-121	10 10 10 10	12.97 13.10 13.00 13.08	11.25 11.30 11.30 11.33	14.59 **13.10** 14.64 14.19	**11.25** **11.30** 11.26 **11.33**	82 14 69 69
95323-35 98436-44 98437-85 72151M-164	10 10 10 10	11.75 11.71 11.75 15.19	10.30 10.26 10.26 13.93	13.26 13.21 13.28 17.23	10.23 10.21 10.23 13.52	86 80 80 88
MW101-S 98434-44 96201-75 96202-148	10 10 10 10	9.05 8.99 9.08 13.72	7.41 7.41 7.40 11.83	**9.05** 9.86 8.82 15.41	**7.41** **7.41** **7.40** **11.83**	14 82 84 84

BD-2	10	8.49	8.22	8.94	7.83	78
98435-121	10	8.89	7.29	10.00	**7.29**	70
MW102-S	9	6.27	5.55	6.24	**5.55**	15
72160-45	10	6.48	5.42	7.52	**5.42**	35
MW102-I	8	6.15	5.56	6.36	**5.56**	13
MW102-D	8	6.11	5.56	6.48	**5.56**	14
72170-33	10	3.86	2.74	7.03	2.65	28
MW105-S	9	3.63	2.53	4.46	**2.53**	15
MW105-I	9	3.62	2.55	4.44	2.53	15
MW105-D	9	3.60	2.53	4.46	**2.53**	15
72161-42	9	6.70	5.06	7.73	**5.06**	20
72162-40	10	4.69	3.56	5.25	**3.56**	36
MW103-S	10	4.38	3.38	**4.38**	**3.38**	14
MW103-I	10	4.41	3.39	**4.41**	**3.39**	14
MW103-D	10	4.52	3.49	**4.52**	**3.49**	14
MW104-S	9	2.79	2.23	3.32	**2.23**	13
MW104-I	9	2.77	2.22	3.30	**2.22**	13
MW104-D	10	3.22	2.21	3.26	**2.21**	14
72163-42	10	3.07	1.97	3.73	1.82	27
72167-45	10	4.56	2.57	5.65	2.51	27
72165-45	5	3.14	1.74	3.98	1.40	20
72164-48	10	2.98	1.82	3.52	1.67	28
MW106-S	10	2.98	2.14	3.28	**2.14**	15
MW106-I	10	2.97	2.17	3.29	**2.17**	15
MW106-D	10	2.96	2.13	3.25	**2.13**	15
/72171-46	10	3.22	1.98	3.70	1.65	27
72169-46	9	4.84	3.18	5.82	3.11	23
72168-45	10	3.60	2.00	4.33	1.72	27
72173-41	10	2.56	1.82	3.06	1.48	27
72172-42	10	2.32	1.74	2.74	1.49	27
72175-44	10	5.06	4.08	5.71	3.98	27

red = historical high or low in 2015
purple = depth of water value

Table 1. Summary of sampling data

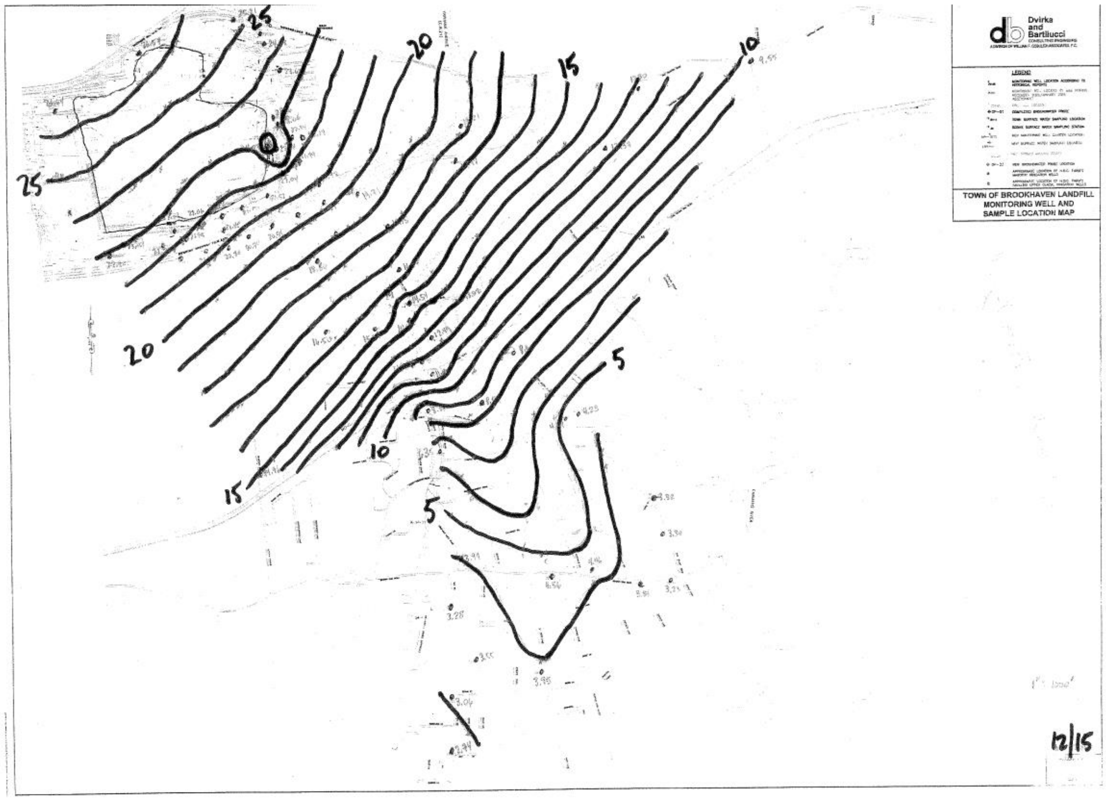

Figure 1. December 2014 water table map (equipotential contours)

Discussion

The area has been experiencing a persistent, but low-key, drought, according to data from the long-record well, 3529-45 (Figure 2; Figure 3 shows data since 2010). The first S-3529 was installed over 100 years ago although records before 1942 are sparse; it was re-installed at a different location in 1975 (previous data have been translated to the new location, coarsely, by subtracting 1 ft from the first data set, based on overlapping data from well 47477-34, another long record well in the Town data base).

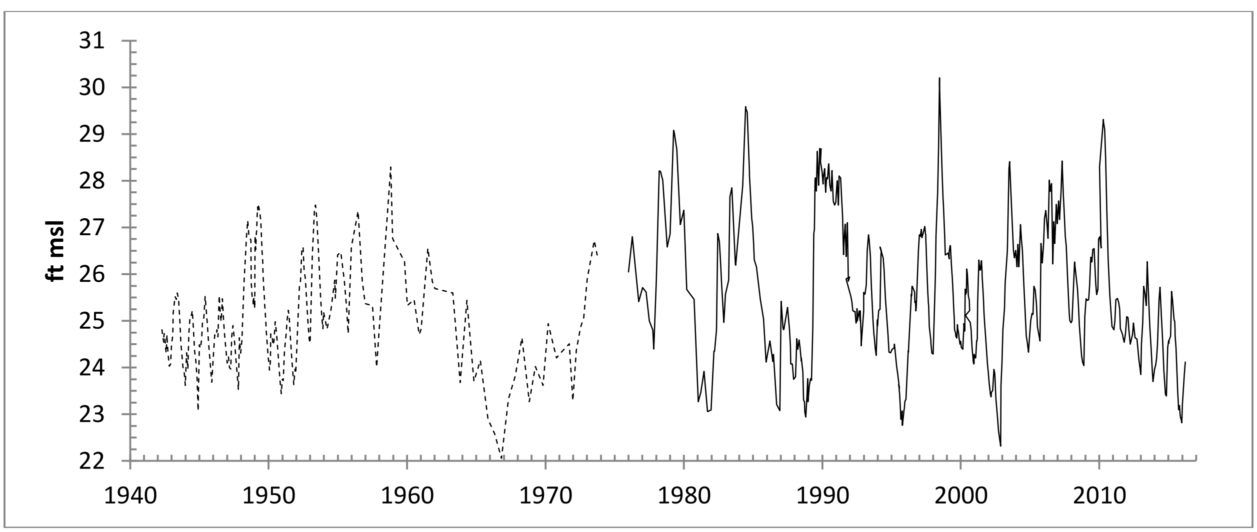

Figure 2. Head values, well 3529 (dashed lines are estimates from previous location)

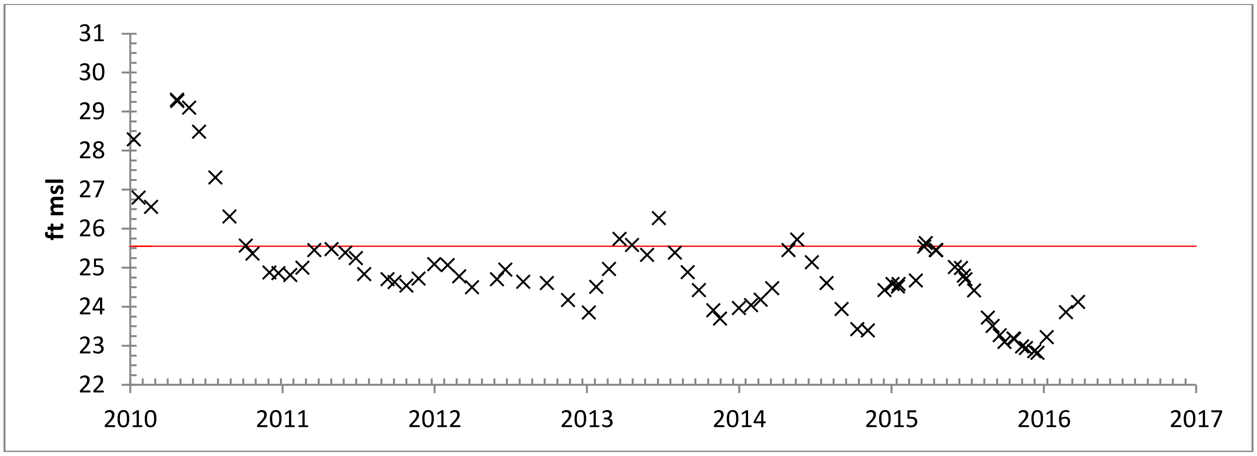

Figure 3. Water level data for 3529 since 2010 (red line indicates mean measurement since 1975, n = 528)

However, rainfall records from BNL (annual totals since 1948 in Figure 4) do not reflect any long trend towards dryness (extended reduced rainfall times in the record include 1962-1966, 1985-1988, and 1990-1995). 81 monitoring locations reached historical low values in 2015, but 41 of these were at relatively short or sparse record locations (less than 30 total measurements). It may be notable that minimum head values for 3529-45 have been at least 0.5 ft above the historical low measurement (the low was reached in November 2002), suggesting this has not been a vigorous drought.

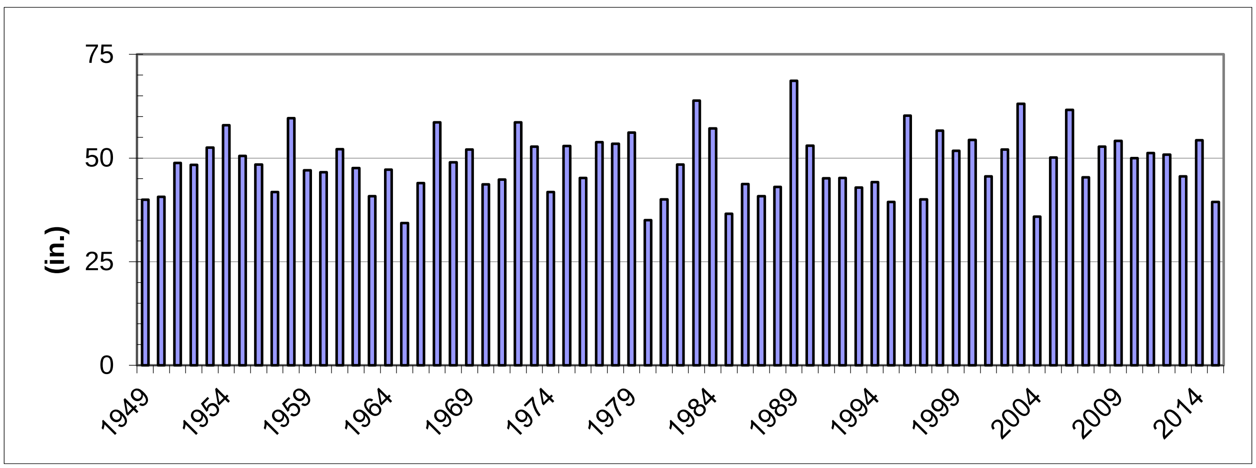

Figure 4. Annual precipitation records from Upton NY (Brookhaven National Laboratory) (mean = 48.84 in/yr)

Reliance on a single monitoring point to draw judgements about the general nature of an aquifer is either reasonable or foolhardy; it is reasonable if the aquifer as a whole tends to react similarly across its breadth and depth to changes in forcing conditions. It is improper to use one well as an aquifer representative if wells in the aquifer tend to react differently as environmental conditions change over time.

To determine the value of well 3529 (or other sampling points) as a proxy for general aquifer conditions, comparisons were made to the change in head over the sampling periods (this range of time was extended back to the start of the recent set of monthly head measurements, in September 2014, and data from January 2016 were included).

First, comparisons were made for wells in a single cluster. Figure 5 gives a representative result: when all of the wells in the cluster were screened in the Upper Glacial aquifer, there was no noticeable difference in the change of heads from one sampling period to the next. However, that was not necessarily the case when wells were screened in the Upper Glacial aquifer and the confining layer (Figure 6), or the Upper Glacial aquifer and the Magothy aquifer (Figure 7).

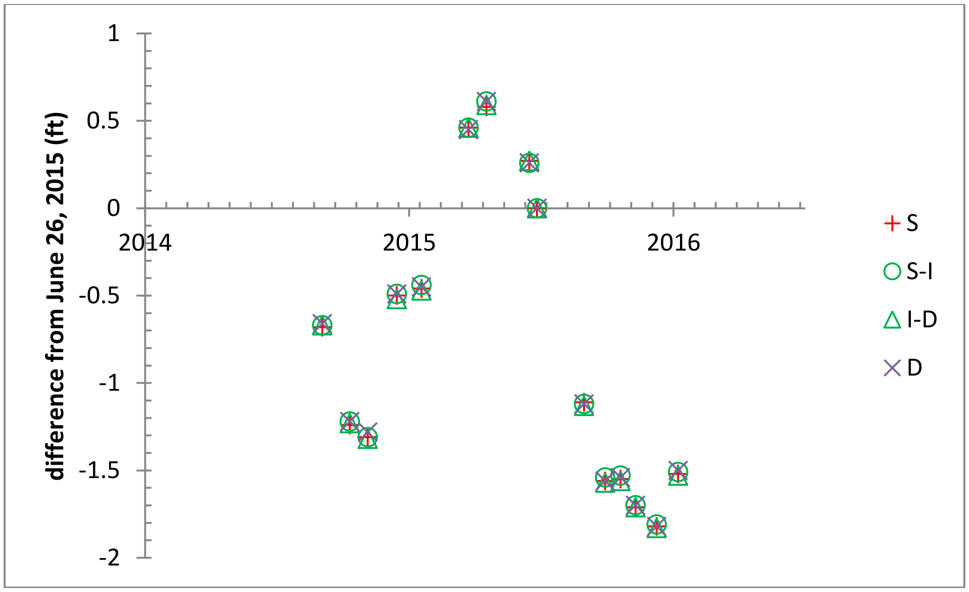

Figure 5. Change in head measurements across wells in a well cluster, all wells screened in the Upper Glacial aquifer (all data relative to 6/26/15) (representative cluster 73758-73757-73756-73759)

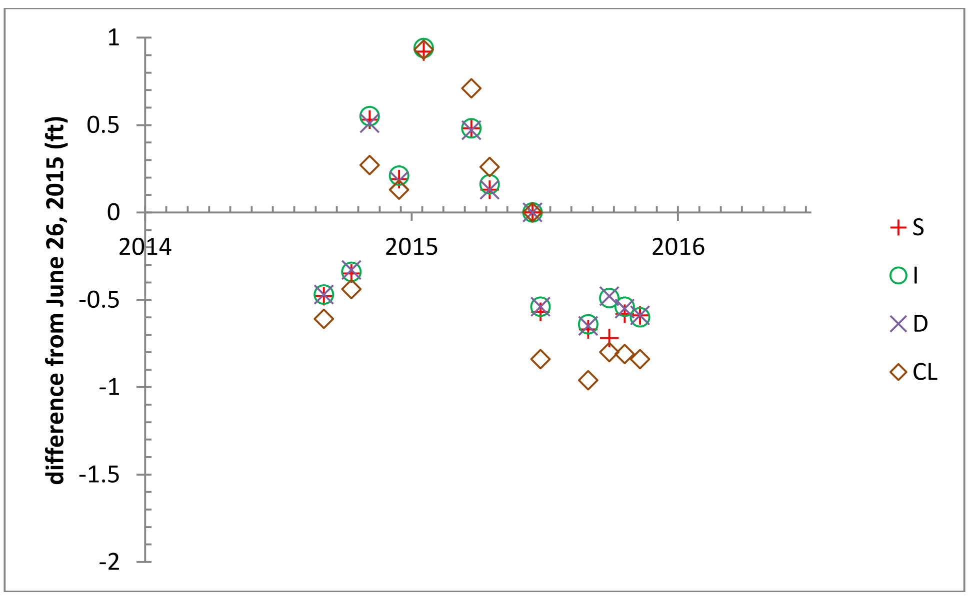

Figure 6. Change in head measurements across wells in a well cluster, three wells screened in the Upper Glacial aquifer, one well screened in the confining layer (all data relative to 6/26/15) (cluster MW-101S-98434-96201-96202)

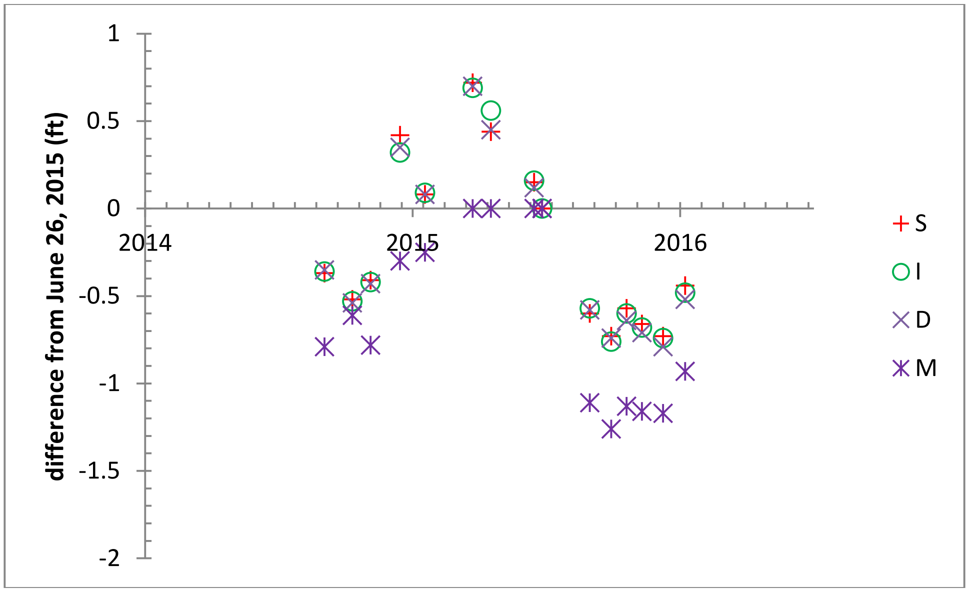

Figure 7. Change in head measurements across wells in a well cluster, three wells screened in the Upper Glacial aquifer, one well screened in the Magothy aquifer (all data relative to 6/26/15) (cluster 95323-98436-98437-72151M)

Figures 5, 6, and 7 support constancy of reactions by wells at a single location to change, if they are all screened in the same aquifer system component. So, changes in a shallow, mid-depth or deep well screened in the Upper Glacial aquifer are likely to reflect changes in head across the entire Upper Glacial aquifer at that location, but may not accurately reflect changes in pressure in the underlying confining layer or Magothy aquifer.

Next comparisons were made across transects, using the water table well if a cluster of wells was used in the transect. Figure 8 shows the location of the first transect (east-to-west across the top of the landfill), and Figure 9 show the changes in head data relative to data for June 26, 2015; Figure 10 shows a second transect (north-to-south, east of the landfill) and Figure 11 shows the change in head data relative to June 26, 2015.

Figure 8. Transect 1.

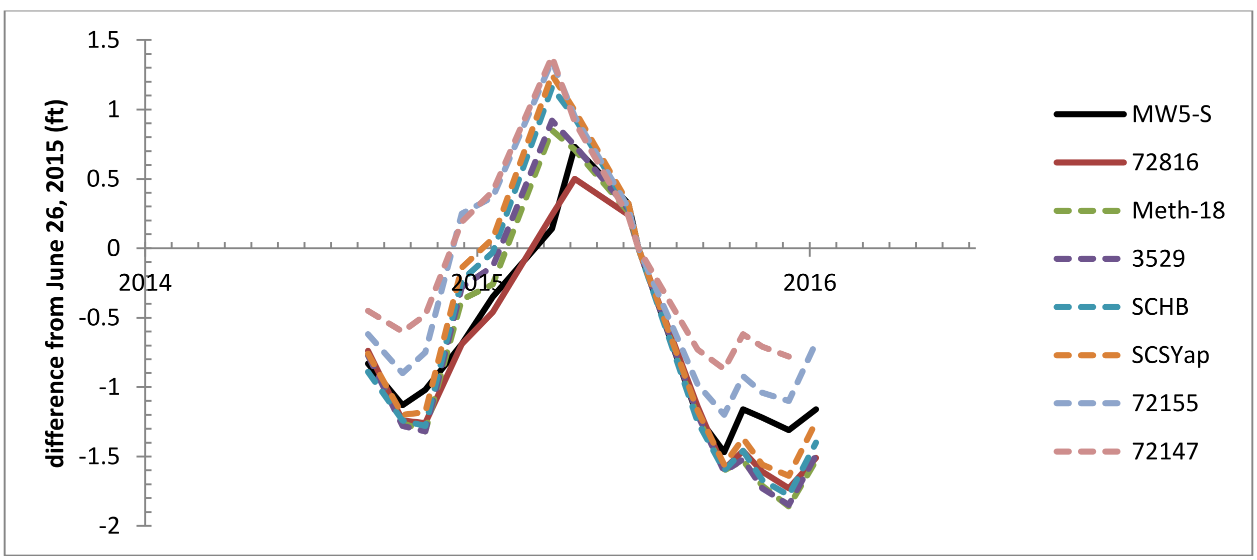

Figure 9. Change in head data across Transect 1 (all data relative to 6/26/15)

Figure 10. Transect 2

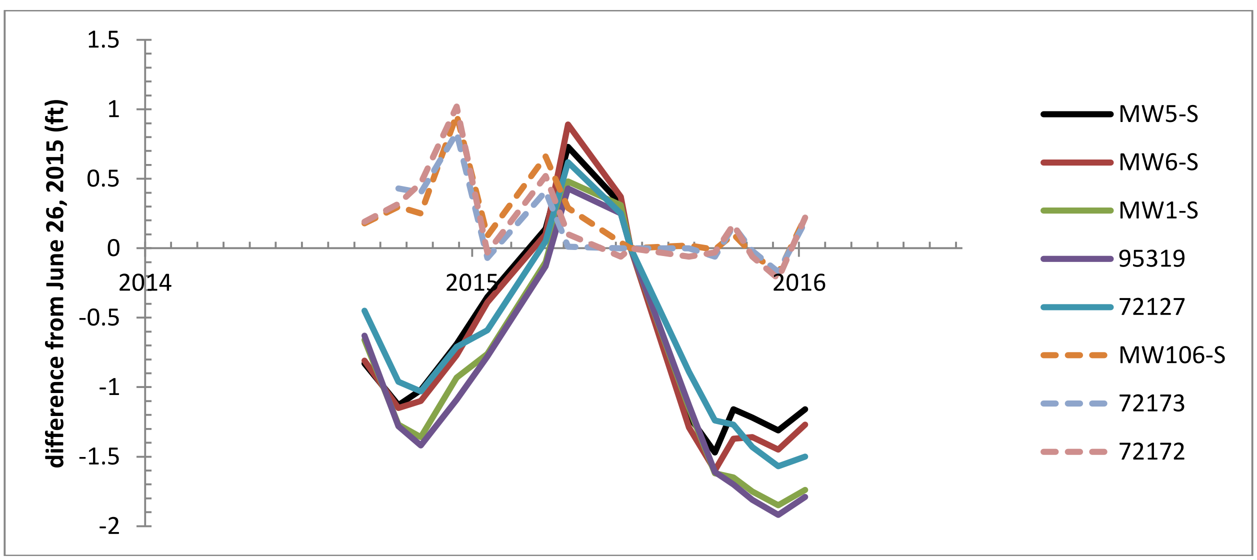

Figure 11. Change in head data across Transect 2 (all data relative to 6/26/15)

The order of the wells listed in Figure 9 are from west to east; solid lines reflect wells with more than 25 ft depth to water (a larger vadose zone). In Figure 11, the wells are ordered north to south, and the solid lines again represent wells with more than 25 ft depth to water. There is a strong suggestion in Figure 11 that the depth to water differences results in different reactions to changing conditions over time; a smaller difference is found for the depth to water difference in the winter-spring period shown in Figure 9; Figure 9 might better be interpreted as suggesting the two eastern wells are different from the others. The data in Figure 11 could also be interpreted geographically, with southern wells being different from more northerly wells.

Another transect was prepared to try to differentiate between geographical and vadose zone thicknesses. Transect 3 (Figure 12) essentially tracks the center line of the plume from the landfill (although it begins upgradient of the landfill).

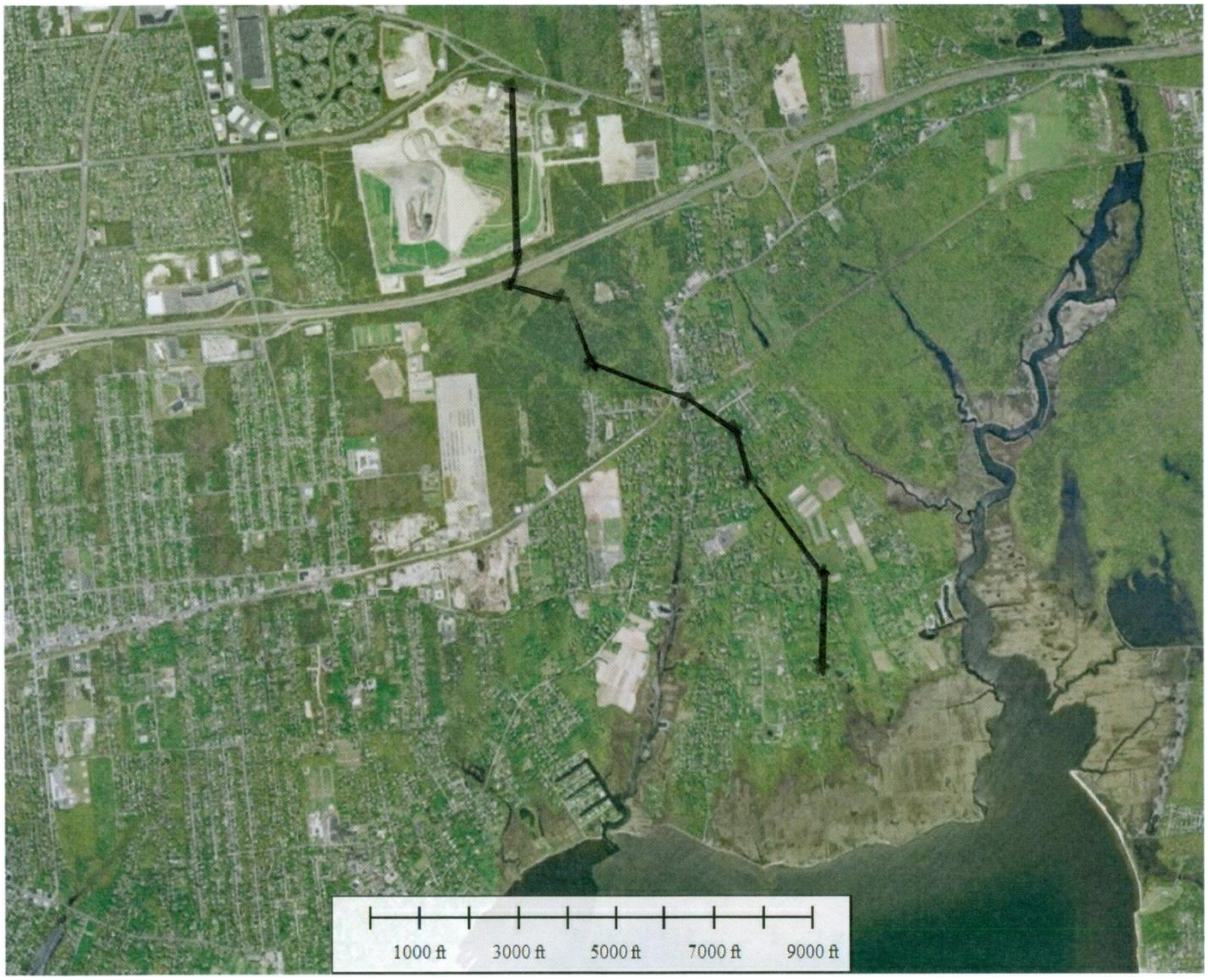

Figure 12. Transect 3.

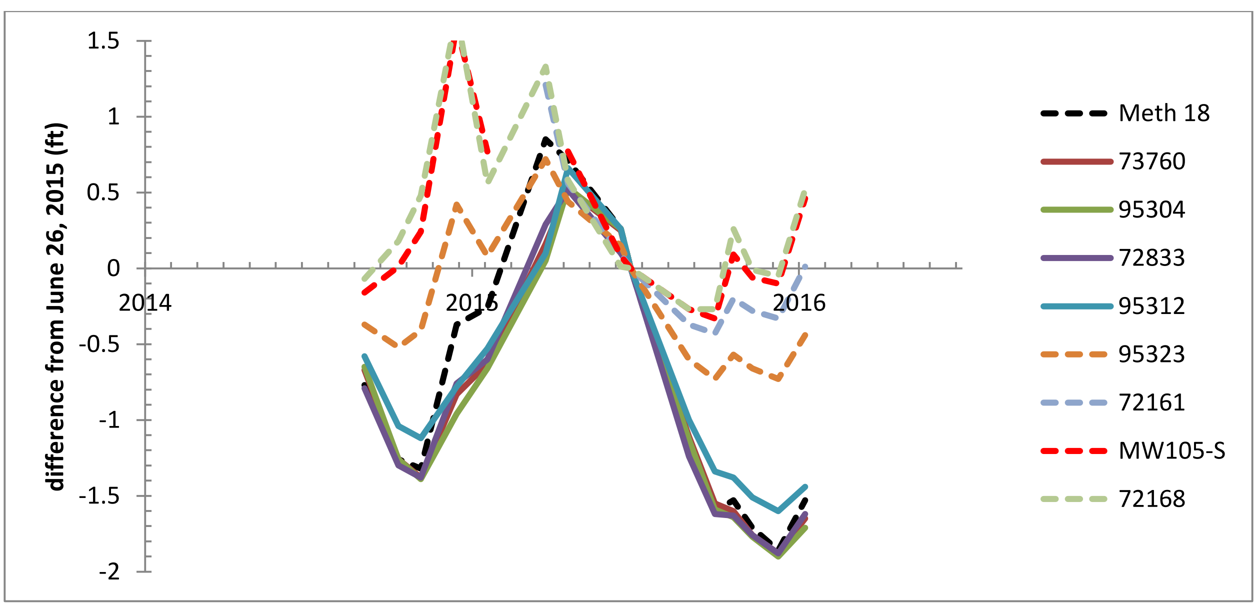

Figure 13. Change in head data across Transect 3 (all data relative to 6/26/15)

Well Meth-18, the farthest north well but one with a shallow vadose zone, generally tracked with the northern wells and reacted differently from those farther to the south. However, when the water table was rising in late winter and spring, it was a little stronger in its reaction than wells with larger vadose zones. This suggests that a smaller vadose zone allows more rapid responses to recharge. This finding should be tempered by understanding the setting is experiencing generally dry conditions; it may be that recharge has to fill more pore spaces in a drier vadose zone than one which has been under wetter conditions, thus slowing and reducing responses to precipitation where the depth to water is greater. Generally, however, geography seems to have more control over responses to recharge: wells north and west are more similar in their reactions than wells south and east. The reactions to changes in conditions for the wells to the south (south f the LIRR tracks) appear to have little correlation to the way wells react farther north.

Conclusion

Therefore, 3529-45 may capture the general trajectory but potentially not the magnitude of change for the Upper Glacial aquifer in its near vicinity. The reaction of wells in this network that are south of the railroad tracks are not well represented by 3529-45. Thus, drawing conclusions about drought or flood conditions gnerally on Long Island from a single sentinel monitoring well is not well-founded; instead, a network of wells need to be monitored. It is interesting to note that the groundwater system between two discharge areas (a common condition on Long Island's shorelines) may be disconnected from the dynamics of the larger aquifer system.

This research was partially supported by a grant by the Town of Brookhaven (NY). Although the Town of Brookhaven supported the research described in this article, it does not necessarily reflect the view of the Town and no official endorsement should be inferred. The Town makes no warranties or representations as to the usability or suitability of the materials and the Town shall be under no liability whatsoever for any use made therefrom.