A ten-year record of well water levels in the central hamlet of Gardiner – a summary of the transducer monitoring program from 2014 to 2024

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Gardiner Ad-Hoc Drinking Water Committee

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Summary

This report summarizes the genesis and results of the well monitoring program in the central hamlet of Gardiner, which used pressure transducers to measure water levels in five wells in the hamlet from September 2014 to May 2024. The results showed that water levels in the wells stayed steady over this ten-year period, with no concerning declines. Water levels may decline in the future in the event of overdevelopment of the central hamlet and/or a decrease in rainfall.

Background

The Town of Gardiner lacks a municipal water supply, relying entirely on wells to meet its water needs. Most wells in Gardiner extract water from fractures in the shale bedrock (the Martinsburg formation), usually at a depth between 100 and 400 feet. A challenge for a town in Gardiner's situation is balancing the goal of economic development with sustainable use of our bedrock aquifer: drilling too many wells in a small geographic area such as the central hamlet (or pumping too much water out of the wells that exist) runs the risk of overextracting from the aquifer, potentially leading to a declining water table.

The Town has made efforts over the past three decades to address this challenge, commissioning reports by hydrogeological experts in 1995 (Beinkafner), 1998 (the Chazen Companies) and 2001 (Randall), which attempt to provide guidelines for how much water extraction our aquifer can support. These reports, along with the Town of Gardiner's 2004 Comprehensive Plan, also explore options for developing a municipal water supply, which could ease potential water-related restrictions on economic development.

In addition, a small number of pumping tests have been performed in the central hamlet over the years, including in 2011 and 2013 by Bob Miller (Miller Hydrogeologic Inc., Pine Bush), in order to determine if additional water extraction could be supported by the aquifer. These tests entailed pumping water from a central well for a period of time while measuring water levels in surrounding wells to determine if they were adversely affected. While it was found that some surrounding wells were affected during these pumping tests, the Planning Board decided that the magnitude of the effects was acceptable and the developments could proceed.

In 2014, then-Town Supervisor Carl Zatz, working with Bob Miller, decided to use pressure transducers to monitor long-term trends in the water levels in selected wells in the greater hamlet area, including the Commerical Light Industry District (CLI), in order to determine if the Town's extraction of water from the aquifer was sustainable.

This approach is an accepted method for monitoring trends in ground water levels over time (Taylor and Alley 2001), but there are two limitations specific to Gardiner's use of this technique. First, it is preferable to monitor water levels in *unused* wells, as pumping drawdown and recovery affect water levels when wells are in active use. However, this was not a practical option in Gardiner's case when the study was being designed.

Second, water levels and flow patterns in shale bedrock aquifers such as Gardiner's are anisotropic (meaning non-uniform), and depend on interconnections between different fracture systems deep underground. As such, well water levels in a given well may not be directly interpreted as indicative of the height of the water table.

In addition, monitoring well water levels gives no information on the volume of water available underground in the hamlet, nor its recharge rate when water is pumped out of the fractures in the bedrock. As such, the data cannot be used to make planning decisions about whether there is sufficient water available to support additional development. For this, pumping tests are required on a case-by-case basis (Rubin and Beinkafner 2023; see Discussion).

In spite of these caveats, long-term trends in the well water level data collected by Gardiner's program can be used as an approximate indicator of whether the water table in the hamlet has stayed steady, risen, or declined over the ten-year period from 2014 to 2024. If no declines are apparent in the data, it suggests that the *current* level of water extraction from our hamlet aquifer is sustainable, provided year to year rainfall in the future roughly tracks the long-term average.

Materials and Methods

Six Solinst Levelogger pressure transducers were installed by Bob Miller in wells in the central Gardiner hamlet in August 2014, and one additional transducer was installed on Osprey Lane in the CLI in front of the karate studio. The six central hamlet locations included five town-owned properties (the Gardiner fire station, the Town Hall, Majestic Park, the former library (across from the rear door of Pasquale's restaurant), and the new library), and one well on privately owned property (the residential duplex at 18 Second Street) (**Figure 1**). The transducers were programmed to record water level hourly. Two transducers (Osprey Lane and the former library) malfunctioned within two years and were removed from the wells; the remaining five transducers in the central hamlet continued to record data until they were removed in May 2024.

Figure 1. Red dots indicate the location of the five transducers in the Gardiner hamlet for which there is a full ten-year record of water levels (modified from a graphic by Steve Winkley, New York Rural Water Association).

The data from the transducers was downloaded four times. The first download was in September 2016 by Bob Miller, who submitted graphs to the town showing water level data for the first two years (Appendix A). The second download was in April 2022 by Bob Miller, and the final two were in May 2023 and May 2024 by members of the Gardiner Ad-Hoc Drinking Water Committee (DWC). At the final download in May 2024 the transducers were removed from the wells and stored in the Gardiner Town Hall. Notably, the transducer memories had become full by 2021 and were reset in April 2022 by Bob Miller, accounting for the approximately one-year gap in the data observed in Figures 3 through 7 in the Results section.

The entire span of data from September 2014 to May 2024 was analyzed and graphed by DWC member Jon Benner using Microsoft Excel. The water level data were compensated for barometric pressure using barometric pressure data from the High Falls station of the New York Mesonet program (Brotzge et al. 2020).

Because the wells monitored were in active use, water levels fluctuated due to pumping drawdown and recovery, creating considerable “noise” in the data. For ease of presenting the data, water levels were plotted as monthly averages, with each data point on the graphs in Figures 3 through 7 representing the average of roughly 700 separate water level measurements (24 hourly measurements each day of the month). The error bars around each data point are the standard deviation of these monthly averages,

with the magnitude of the error bars representing primarily the amount of pumping-related noise in the data – the more frequently the water level was drawn down by active well use (e.g., running the faucets or the washing machine), the greater the standard deviation. (For an example of what the data looks like when plotted hourly, showing all the pumping-related changes in well water levels, see the Miller Hydrogeologic graphs for 2014-2016, Appendix A).

Because of the one-year gap in the data from 2021 to 2022, it was not possible to use linear regression to statistically analyze the trends in water levels over time. Instead, the trend over time was visually assessed for declines.

Precipitation data was obtained from the Poughkeepsie meteorological station (NYTPOU, accessed from the Iowa State Data Plotter) as well as the climatological records for the Mohonk Lake station (NOAA 2024).

As of August 2024, all data and analysis files are available on a thumb drive stored in the box containing the retired transducers in the Gardiner Town Hall.

Results

There were no long-term declines in water levels in any of the five wells assessed (**Figures 3** through **7**). Water levels in each well fluctuated seasonally, showing the sinusoidal curve typical of the water table in our region: water levels are usually lowest in autumn due to transpiration through vegetation and evaporation over the warm growing season, and highest during the spring snowmelt after the cool winter months.

Precipitation over the ten-year period from 2013 to 2023 was not markedly different from normal, with several dry years and two wetter-than-average years (2018 and 2023) (**Figure 2)**. Over this ten year period, year-to-year variability in precipitation had no clear impact on water levels in the measured wells.

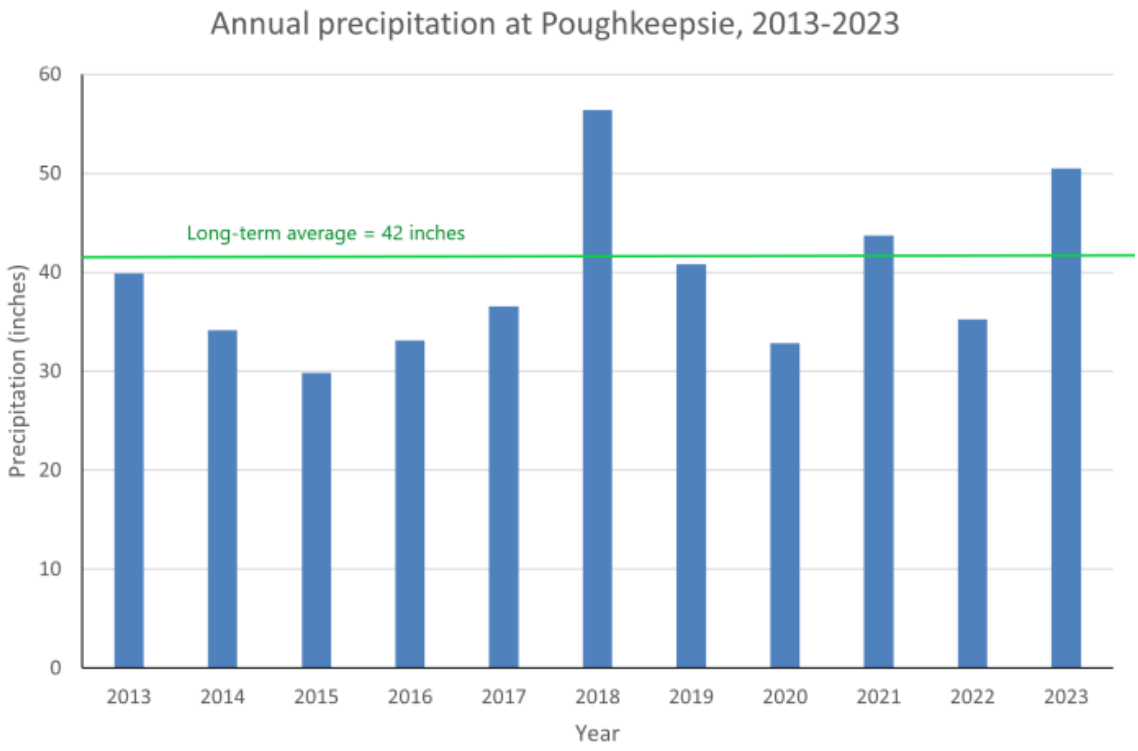

Figure 2. Annual precipitation at Poughkeepsie station (NYTPOU), 2013-2023. Long term average (1931-2023) is 42.0 inches.

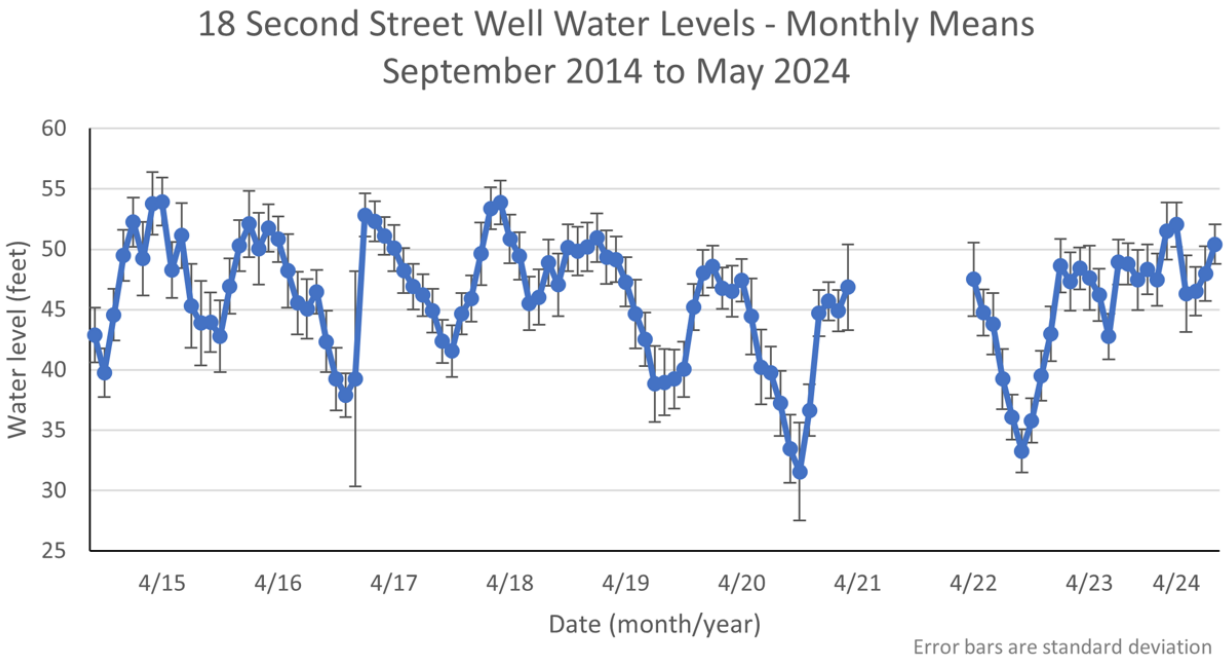

Figure 3. 18 Second Street well – monthly average water levels, September 2014-May 2024.

The well at 18 Second Street (**Figure 3**) shows a possible small drop in water levels around 2020, with subsequent peak water levels not recovering to pre-2020 levels, although more data would be needed to confirm this. Although the reason for this potential drop is unknown, the data does not show a pattern of continued decline in this well.

Note that the typical low point in autumn is not as pronounced in the autumn of 2023 in any of the five wells. This is likely due to the large amount of rainfall received in the summer of 2023.

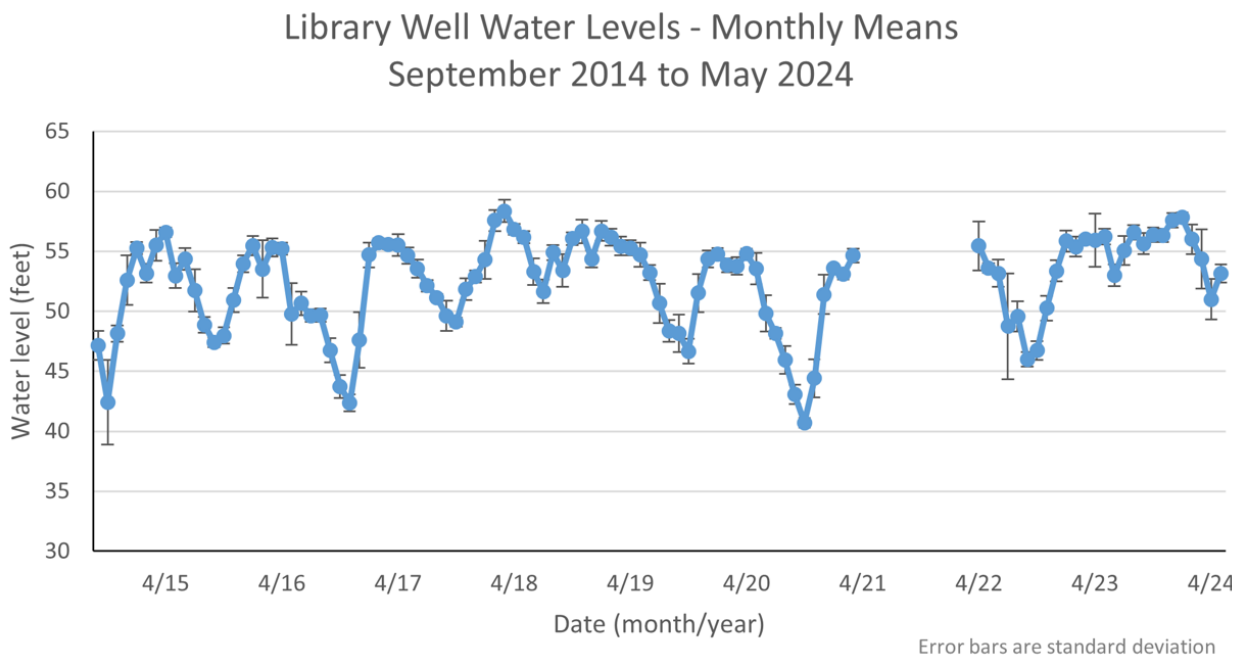

Figure 4. Library well – monthly average water levels, September 2014-May 2024.

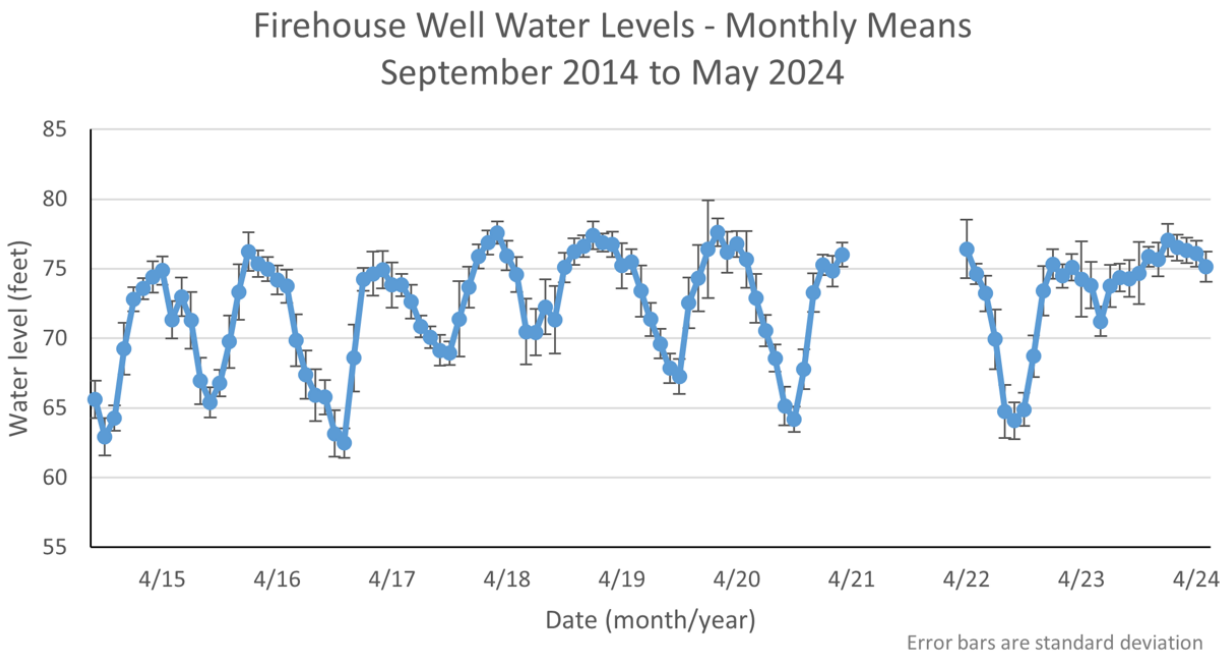

Figure 5. Firehouse well – monthly average water levels, September 2014-May 2024.

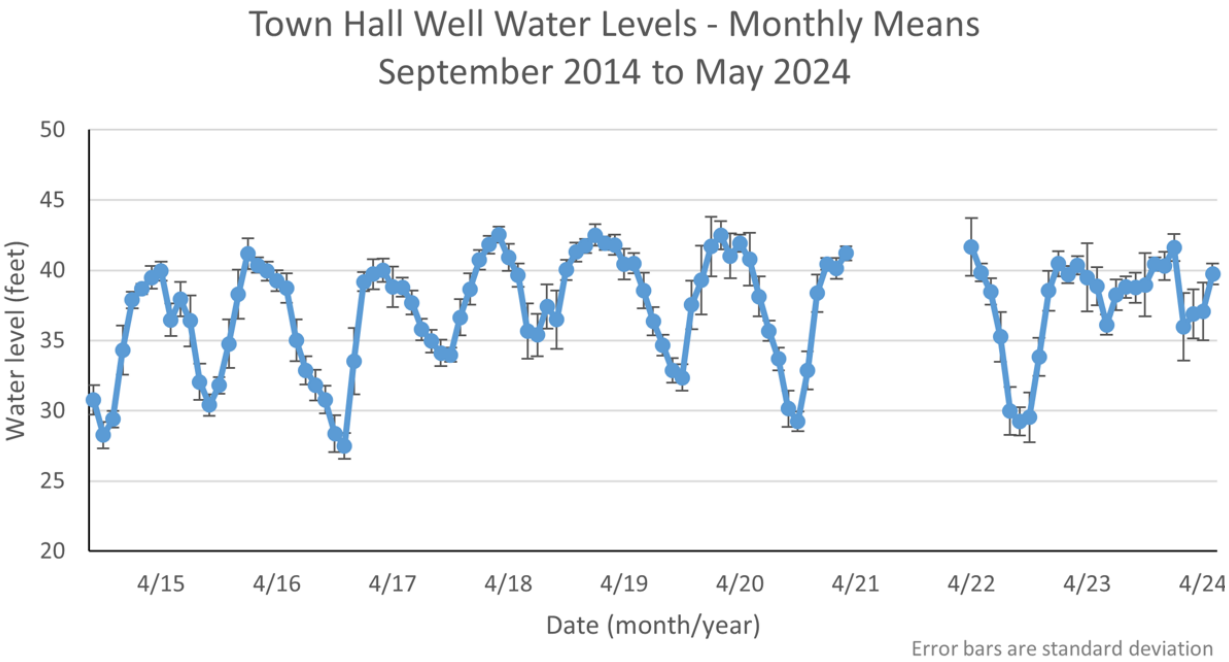

Figure 6. Town Hall well – monthly average water levels, September 2014-May 2024.

The Town Hall and Firehouse water levels follow nearly identical curves (**Figure 5** and **Figure 6**), suggesting that they are closely hydrologically connected.

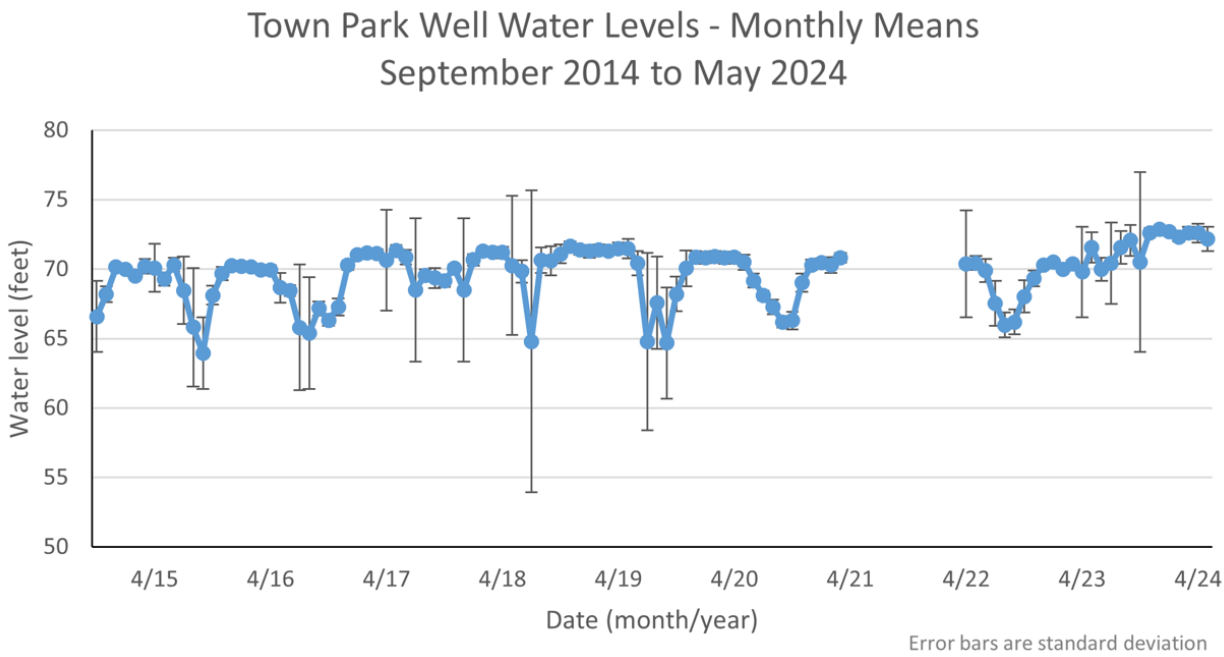

Figure 7. Majestic Park well – monthly average water levels, September 2014-May 2024.

The amplitude of the seasonal fluctuations in water levels in the Majestic Park well (**Figure 7**) is not as large as for the other four wells. The large error bars for this well's data are likely due to periods when there is heavy use of the well, such as during events at the park or during the Gardiner summer camp.

Discussion and conclusion

The nearly ten-year record in these five wells in the Gardiner hamlet shows that water levels do not appear to be declining in any of the wells, suggesting that the current level of water extraction from our bedrock aquifer is sustainable. The water table could decline in the future if too many additional wells are drilled (or if rates of water extraction from existing wells increase), or if rainfall decreases.

The Ad-Hoc Drinking Water Committee had intended as of 2023 to continue the hamlet transducer monitoring program and possibly expand it to monitor additional wells. However, over the course of interviewing hydrogeologic firms in the summer of 2023 to continue this work, the Committee came to understand the limitations of this approach – namely, while it can give a rough idea of whether the water table is declining or staying steady, it cannot answer the question of how much additional development can be supported by the aquifer. This is because the data does not give information on the volume of water contained in the underground fissures, nor how quickly those fissures recharge (or refill) when water is pumped to the surface.

To make planning decisions about whether additional wells or greater rates of water extraction can be supported, the standard approach is pumping tests on a case-by-case basis for new developments. This is most important in areas of high well density in Gardiner, such as the central hamlet or future large subdivisions. Paul Rubin of Hydroquest and Katherine Beinkafner of Mid-Hudson Geosciences were particularly helpful in enabling the Committee and Town reach this understanding.

Given that the Town had already obtained a 10-year record of well water level data (including some drier-than-average years) indicating that the water table did not appear to be declining, it seemed reasonable to conclude that the current level of water extraction in the hamlet was sustainable, and that there were diminishing returns to continuing the monitoring program.

It is important to emphasize that overextraction of water is not the only reason the water table could decline in the future. If the amount of rainfall decreases (i.e., a drought), recharge of the underground fissures in the bedrock would also decline, and there would be less water available for extraction.

A drought such as this occurred in the 1960's, affecting the entire United States Northeast (**Figure 8**). Anecdotal reports from those who lived in Gardiner at the time suggest that shallower wells did run dry as the water table lowered.

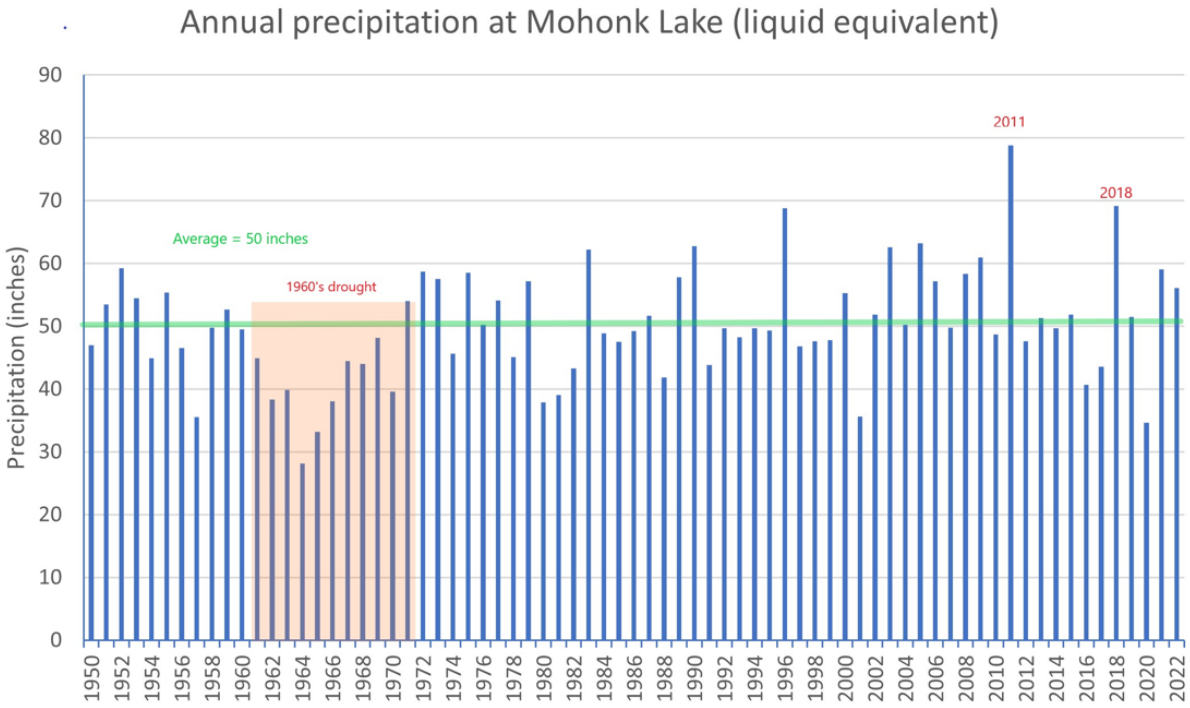

Figure 8. Annual precipitation (including melted snow) at the Mohonk Lake weather station, 1950-2022. The pink-shaded box highlights the 1960's drought that affected the entire U.S. Northeast.

Although climate models predict that the United States Northeast will become on average wetter as the climate changes in the coming decades, they also predict that rainfall patterns will become more erratic, including an increased likelihood of prolonged droughts (e.g., Ning et al. 2015).

Given the increase in well density in the central hamlet since the 1960's, coupled with much greater modern per capita water usage, a similar or more severe drought could cause widespread problems were it to occur now. It would behoove Town of Gardiner policymakers to keep this possibility in mind when thinking about how to safeguard our town's water supply into the future.

Acknowledgments

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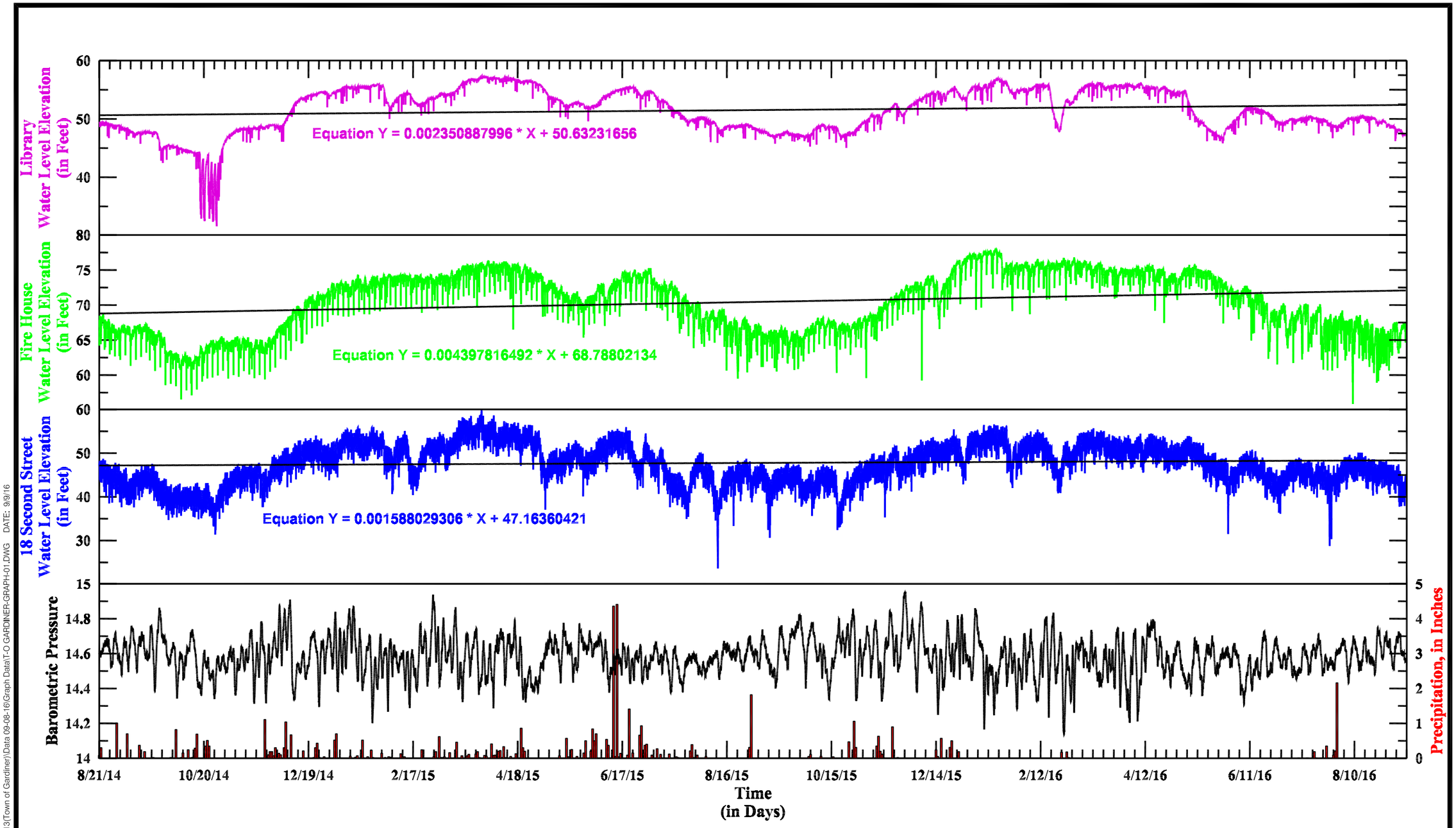
Appendix A: Miller Hydrogeologic, Inc. graphs for 2014-2016 data



MILLER HYDROGEOLOGIC INCORPORATED

Project No.	*054-13*
Date:	*9/9/16*
SCALE:	*AS SHOWN*
Drawn By:	*KAH*

FIGURE 1

PLOTS OF WATER-LEVEL DATA FOR TOWN MONITORING WELLS

TOWN OF GARDINER
ULSTER COUNTY, NEW YORK

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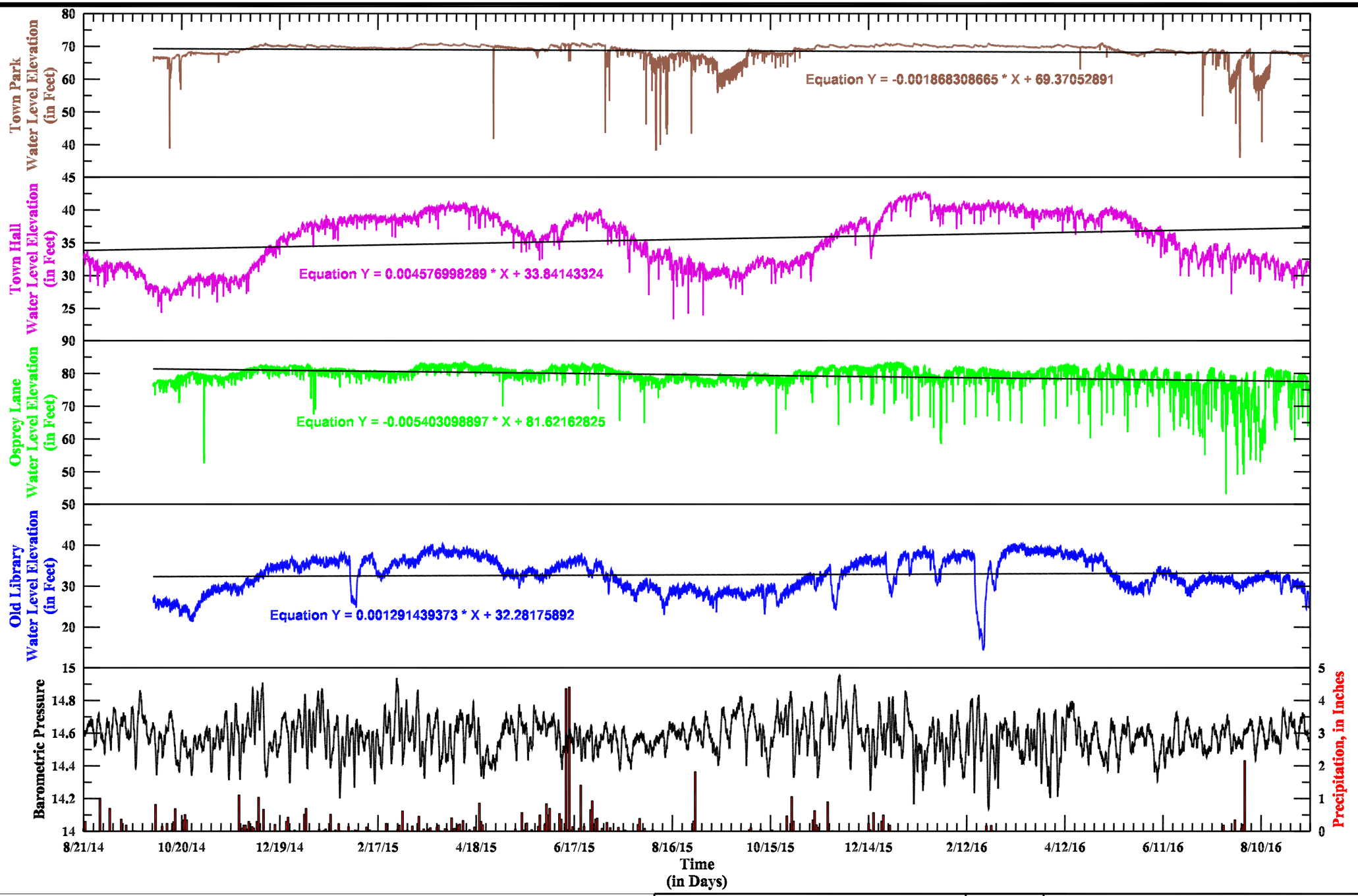

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MILLER HYDROGEOLOGIC INCORPORATED

Project No.	*054-13*
Date:	*9/9/16*
SCALE:	*AS SHOWN*
Drawn By:	*KAH*

FIGURE 2

PLOTS OF WATER-LEVEL DATA FOR TOWN MONITORING WELLS

TOWN OF GARDINER
ULSTER COUNTY, NEW YORK