The

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES

hereby issues

LARGE GROUNDWATER WITHDRAWAL PERMIT

NO. LGWP-2020-0002

to the permittee

AQUARION WATER COMPANY OF NEW HAMPSHIRE
7 D SCOTT ROAD
HAMPTON, NH 03842
(603-926-3319)

for the withdrawal of the following volumes of water from the following for the purpose of community water supply:

Production Well 22: 1,080,000 gallons over any 24-hour period

Date of Issuance: January 13, 2020
Date of Expiration: January 13, 2030

Pursuant to authority in N.H. RSA 485-C:21, the New Hampshire Department of Environmental Services (NHDES), hereby grants this permit to withdraw groundwater from Well 22 subject to the following conditions:

1. The permittee shall comply with the requirements of Env-Wq 403 and RSA 485-C at all times.

2. Water Conservation: The permittee shall implement and maintain compliance with the approved Water Conservation Plan approval dated May 13, 2010.

3. Metering Requirements: Withdrawals from Well 22 shall be metered at all times. All meters must be selected, installed, tested, and maintained in accordance with Env-Wq 2101. The permittee shall read source water meters to adequately report the following volumes to the reporting program referenced in condition No. 7 of this permit:

    a) The 24-hour peak day volume withdrawn from Well 22 during each month and the date the water use occurred; and

    b) The cumulative total volume withdrawn from Well 22 during each month.

4. Monitoring and Reporting Requirements: The permittee shall establish and maintain the monitoring and reporting program as described below:

    a) *Groundwater level monitoring*

Station ID: 20200002PWPW22, 20200002PWPW7

    a) Production wells: The permittee shall install pressure transducers and data logger or equivalent devices in Production Wells 22 and 7 and measure water levels at a frequency of at least once every four hours.
    b) Monitoring wells: The permittee shall install a pressure transducer and data logger and measure water levels at a frequency of at least once every four hours in monitoring well OBS-1. Station ID: 20200002MWOBS1
    c) Water Supply Wells: The permittee shall install a pressure transducer and data logger and measure water levels at a frequency of at least once every four hours in the water supply wells for the [redacted] Station ID: 20200002DW01, 20200002DW02, 20200002DW03, 20200002DW04 properties. Water level monitoring shall commence at least 30 days prior to initiating a withdrawal from Well 22 and shall continue indefinitely as a condition of this permit.

    b) *Groundwater quality sampling*

    a) Salinity Monitoring: The permittee shall collect water quality samples for salinity measurements from production Well 22, and private water supply wells located at Station ID: 20200002DW02, 20200002DW04 at a frequency of twice a year in the months of July and November. Sampling shall continue after initiating a withdrawal from Well 22 and continue indefinitely as a condition of this permit.

    b) PFAS Monitoring: The permittee shall collect water quality samples for PFAS analysis from production Well 22, and private water supply wells located at Station ID: 20200002DW02, 20200002DW04 at a frequency of once a year in the month of July. Sampling shall continue after initiating a withdrawal from Well 22 and continue indefinitely as a condition of this permit. The samples collected from the wells shall be

submitted to a New Hampshire accredited analytical laboratory using an approved drinking water method.

All water level monitoring and water quality sampling shall be completed by a person who can demonstrate, by education or experience, competency in collecting, recording and reporting hydrogeologic measurements. Monitoring well and sampling locations and frequencies may be added or changed if the data obtained contradict the information provided in the permittee's application, or if additional data points are required to assess the potential for adverse impacts to occur.

In the event that PFAS water quality results exceed applicable drinking water standards the permittee shall submit to NHDES the PFAS results within 30-days of receipt of the results.

An annual monitoring report and all monitoring data shall be submitted to NHDES by January 31 of each year. The annual monitoring report shall provide text, tables or figures that present a summary of all previously collected data and note any relevant observations that may affect the measurements made from the preceding year inclusive of pertinent field notes or observations that document the annual monitoring activities undertaken to comply with this permit.

The annual monitoring report shall be submitted in an electronic format only. All water level and water quality monitoring data collected shall also be submitted in an electronic format established by NHDES.

5. Wetland Assessment Requirement: The permittee shall coordinate completion of the following assessment.

    a) The permittee shall conduct an annual Functions and Values wetlands assessment in the wetland area proximate to PZ-4, to include an annual plant and soil moisture assessment at a wetland plot established at the location, and an annual plant and soil moisture assessment at the isolated wetland areas located near PZ-1 and PZ-3. The annual assessments shall be compared to conditions at the wetland reference control plot used for the Aquarion Mill Pond well field.

    b) The assessments above shall be completed by a NH-certified wetlands scientist and be initiated prior to groundwater withdrawal from production Well 22.

    c) Assessment reports shall be submitted with the first annual monitoring report for the withdrawal's water level monitoring program referenced in Condition No. 4. above.

6. Mitigation Requirements

    a) In the event that an adverse impact occurs, the permittee shall comply with all of the requirements below and with the impact mitigation and source replacement requirements of Env-Wq 403.

    b) Prior to initiating a withdrawal from the Well 22, the permittee shall notify in writing via certified mail the owners of all properties that are served by private

wells or public wells not owned by the permittee within the area estimated to be the influence area of the Well 22, as illustrated on Figure 7A, titled "Projected 180-day Drawdown in Bedrock Wells" prepared by Geosphere Environmental Management, Inc. (Geosphere), dated September 18, 2019. The permittee shall provide a copy of the notification letter and copies of the certified return mail receipts to NHDES. The notification letter shall explain to property owners with wells in the identified area that their well may be influenced by Well 22, and provide the property owners with contact information for both the permittee and NHDES in the event they believe they may be adversely impacted by the withdrawal.

c) Where the status of an unanticipated impact is not clear, the permittee shall gather information needed to quantify the impact and determine its status relative to the adverse impact criteria defined under RSA 485-C:21, V-c and provide this information to NHDES within 48 hours of being notified by NHDES about a reported impact. A verified adverse impact shall be mitigated in accordance with Env-Wq 403.

d) NHDES will routinely review the results of all monitoring data, and if water level monitoring data indicates that groundwater is being extracted at a rate that exceeds natural recharge on average, then NHDES will modify the permit in accordance with Env-Wq 403 in order to prevent adverse impacts from occurring.

7. The permittee shall register its new source of water with the NHDES Water Use Registration and Reporting Program and maintain the water use reporting requirements established by RSA 488, Env-Wq 2102 and this permit.

8. The permittee shall apply for renewal of this permit within the six-month period prior to its expiration date, but no earlier, in accordance with Env-Wq 403. The permittee shall continue to comply with all conditions in this permit until the permit is renewed or the facility is closed in accordance with all applicable requirements, regardless of whether a renewal application is filed.

Any person aggrieved by any terms or conditions of this permit may appeal in accordance with RSA 21-O:7, IV within 30 days.

Thomas E. O'Donovan, PE, PMP,
Director Water Division

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PROJECT NARRATIVE

Large Well Siting Approval/Large Groundwater Withdrawal Permit LGWP-2020-0002
Aquarion Water Company, PWS ID 1051010
Production Well 22
Hampton, New Hampshire

January 13, 2020

1. BACKGROUND

The Aquarion Water System (Aquarion) has submitted an application to the New Hampshire Department of Environmental Services (NHDES) requesting approval of one new large community production well and issuance of a large groundwater withdrawal permit for the withdrawal of up to 1,224,000 gallons per day (gpd) or 850 gallons per minute (gpm) over a 24-hour period for the purposes of municipal water supply.

The purpose of developing the new community production well, designated Well 22, is to provide source redundancy and diversification for the water system, and accommodate potential increases in water demand based on historical water use trends and projected future growth in areas served by the water system.

Production Well 22 is a drilled bedrock well located in the southeast portion of the town of Hampton about one mile west of Hampton Beach (coast) and north of the Taylor River estuary. Well 22 is installed on a relatively flat, non-developed forested lot at a location that's approximately 180 feet away from one of Aquarion's existing source wells, overburden production Well 7. To the immediate north, west and south of Well 22/Well 7 wellfield are predominantly residential areas with some mixed, light commercial development. To the east of the wellfield is non-developed woodlands, a complex of small 'pocket' wetlands and a diffuse small stream network that drains easterly, towards substantial riparian areas and wetlands nearer to the coast. Much of the immediate area surrounding the wellfield is within a divided subwatershed with easterly to northerly draining unnamed tributaries to Nilus Brook and the Little River, and southerly draining tributaries to the Hampton Flats estuary. The wellhead protection area (WHPA) for the withdrawal encompasses much of the subwatershed that drains to these tributaries, covering approximately 5.1 square miles of the surrounding area.

The surficial material overlying bedrock at the well site is a relatively permeable stratified drift deposit consisting of sand, gravel, cobbles, and boulders. This unit is the source formation for production Well 7 and, although this unit is extensive to the west/northwest, it is constrained within about 2,000 feet north, east and south of Well 22 by the fine sand/silt member of the Presumpscot formation. Based on observations during drilling, Well 22 encountered a bedrock contact between two regional, lithologic units at a depth of about 420 feet, the gray/green mica schist of the Rye Formation (lower member) and the quartz-rich Breakfast Hill Granite. The bedrock within and across the depth of this contact was observed to be highly fractured; however, the fractures present above this contact (depth of 260 to 330 feet) were observed to yield more substantial volumes of water. Borehole geophysics completed on Well 22 additionally identified that fractures intersected by the well, on average, favored an east to northeast orientation, with moderately steep dip angles to the northwest, north and southeast. Fracture orientations within Well 22 are generally consistent with regional field mapping of geologic structures, lineaments, VLF survey results, and fracture trace analysis that show unit contacts and fracture/joint features that trend north – northeast, aligned with coastal features. Well 22 was finished as a 10-inch open borehole bedrock well to 320 feet, and an 8-inch open borehole from 320 feet to the bottom of the hole at 560 feet, and included 67 feet of steel casing.

2. WITHDRAWAL TESTING AND CONCLUSIONS

A withdrawal testing program was conducted on Well 22 by Geosphere Environmental Management Inc. (Geosphere) from June 13th through July 20th, 2018. The purpose of withdrawal testing is to provide data to estimate long-term sustainable water quantity and quality of the well; observe the response of the aquifer to pumping; evaluate the degree of hydraulic connection with overlying deposits; and, assess the potential for adverse impacts to water resources and users that may result from the proposed withdrawal. The withdrawal testing program included monitoring during pre-pumping, pumping, and water level recovery periods, where Well 22 was pumped in a step-wise increasing rate from 650 gpm to 750 gpm, then to approximately 850 gpm between June 20 to July 17, 2018 [~27 days of pumping]. Discharge from the well was metered during the withdrawal testing program to track and control pumping rates. Water quality samples were collected during the pumping period to characterize the quality of the groundwater derived from the proposed production well.

Water Level Monitoring and Observations

During the withdrawal testing program, water level measurements were collected at:

- The proposed new production well Well 22;
- Seven of Aquarion's other production wells, including Well 7;
- Three bedrock monitoring wells;
- Two overburden monitoring wells;
- Twenty offsite bedrock private water supply wells;
- Four shallow overburden groundwater piezometers; and,
- Two stream gauges.

The private water supply wells monitored during the pumping test range in distance from the production well between about 600 to more than 10,000 feet away, generally to the south, west, north and northeast. Overall, relatively few private wells exist within about 5,000 feet of well field because most of the area is served by the Aquarion water system. Groundwater levels at deeper groundwater monitoring wells (bedrock) were recorded in order to observe the zone of influence of the production well, while shallow groundwater and surface water level measurements were recorded to assess the degree of hydraulic connection between the bedrock and the shallow (overburden) water table, and surrounding wetlands and streams. Based on static (pre-pumping) water levels observed from the site and surrounding area, deeper (bedrock) groundwater flow in the area is largely to the east/southeast towards the ocean and the Hampton Flats estuary located to the south of the well site. Shallow groundwater flow through overburden appears to be easterly across the Well 22 site, however, west of the well site, it appears to have a northerly component towards small tributaries in that general area. Vertical hydraulic gradients between the two units were recorded as being upward, from bedrock into overburden in areas not influenced by production from the existing Aquarion wells. This is consistent with inferred regional water level information, whereby groundwater in deeper bedrock flows upward into the shallow overburden units as it nears coastal areas and a point of discharge.

The pumping test water level measurements indicate that ten off-site water supply wells, two on-site overburden monitoring wells and two shallow piezometers responded to pumping of Well 22. Drawdown in the overburden wells and piezometers near the well field ranged from about 0.5 to 12.6 feet and the pre-pumping upward hydraulic gradient of flow approached neutral at some locations, to downward flow nearer to the production well. As for observations in private bedrock water supply wells, groundwater level drawdowns were observed on the order of 17 feet up to 4,600 feet away from Well 22. Generally, the hydraulic effects predominantly observed during the test occurred in a northeast/southwest orientation, roughly coincident with the mapped orientation of the regional bedrock structures. A secondary, lesser drawdown effect was also observed in a north-south

orientation out to shorter distances. Shallow water table impacts (vertical flow) indicates substantial hydraulic connection between bedrock and overburden at the site, with more effect in deeper overburden nearer to the bedrock surface. Drawdown in production Well 22 at the end of the test was approximately 171 to 173 feet. Based on a distance-drawdown analysis of water level responses assuming 180 days of continuous pumping of Well 22 at maximum rates, effects from the withdrawal with no net recharge from precipitation to the aquifer are projected to extend up to approximately 10,000 feet from the well site.

Water Quality Monitoring and Observations

Results of water quality sampling conducted during the Well 22 withdrawal testing program indicate that naturally occurring arsenic was detected at a maximum of 23 parts per billion (ppb), above applicable Maximum Contaminant Level (MCL), and will require treatment prior to supplying water to the system. Of the organic contaminants sampled during the test (VOCs, SVOCs and PFAS), toluene was detected at low levels in the first sample only, and one PFAS (PFOA) was detected in the last sample collected during the test at a concentration of 1.6 parts per trillion (ppt). As part of a cohort study in the region additional water quality samples were collected for PFAS from some of the private water supply wells monitored during the Well 22 test, as a result of that testing other private wells in the area were observed to have low level PFAS detections.

Additional salinity monitoring was completed at Well 22 and seven private water supply wells located to its east/southeast in order to assess for the potential to induce seawater intrusion into the formation by pumping the production well. The testing was completed before, during and at the end of the withdrawal test and no induced seawater impacts were observed at the locations monitored during the test.

Approved Production Rate for Well 22

As noted in the permit conditions [see below and attached], the production rate approved for Well 22 was 750 gpm as opposed to the maximum rate of 850 gpm targeted during the pumping test. The 850 gpm pumping rate was not approved for two reasons:

a. The pumping rate during the 850 gpm phase of the test was not constant. Per Env-Dw 302.14(e) and 302.20(a), the pumping test conducted for a new proposed large community well shall maintain a constant pumping rate. A constant pumping rate is defined in Env-Dw 301.09 as a rate that does not vary more than five percent after the first 24-hours of the test. Due to water pressure issues experienced at the water system during the 850 gpm phase of the pumping test, the absolute range of daily variability in pumping rate averaged about 60 gpm, and the max recorded variability across this phase of the test was about 100 gpm, out of compliance with pumping test criteria. And,

b. When drawdown observed in Well 22 is adjusted for a decay in the pumping rate observed during the 850 gpm phase of the test, the 180-day projected drawdown in the well assuming no recharge exceeded 90% of the available drawdown in the well, which is not in compliance with Env-Dw 302.30(d).

In review of the next, lower pumping rate conducted during the test (750 gpm), both the constant pumping rate and projected drawdown criteria were met and therefore is the permitted production volume for Well 22.

3. PUBLIC NOTIFICATION AND INVOLVEMENT

Pursuant to RSA 485-C:21, II through V-a, materials submitted in support of the large groundwater withdrawal permit (the preliminary application, final report, and supplemental materials) were sent (via certified mail) to municipalities and public water suppliers in the potential impact area of the withdrawal. Municipalities that were sent copies of the above-referenced materials are the towns of Hampton and North Hampton.

On May 11, 2017, the town of Hampton requested a public hearing following submittal of the preliminary application; the Department subsequently held a public hearing on the application in Hampton on June 5, 2017. At the hearing, a summary of the regulations governing large groundwater withdrawals was presented by the Department, a project summary was presented by Geosphere, a question and answer session was held, and oral testimony was recorded. After the public hearing, the 45-day written comment period on the application commenced, and closed on July 20, 2017. Testimony and comments received during the public hearing and written comment period related to the issue of how potential adverse impacts an any private wells or water resources (wetlands) would be monitored for and mitigated; the potential for seawater impacts to groundwater in the area; and whether groundwater recharge is adequate to sustain the withdrawals. Suggestions received included expanding the well, wetland and surface water monitoring network for the test, increasing the duration of both the ambient monitoring period and the pumping period of the withdrawal test on the order of multiple months to up to a year, and collection of groundwater samples for isotope analyses in order to age-date groundwater captured by Well 22. Oral and written comments were considered during the Department's review of the preliminary application and proposed withdrawal testing program and most issued commented on were addressed during the pumping test.

On May 7, 2019, the town of Hampton requested a public hearing following submittal of the final report; the Department subsequently held a public hearing on the report in Hampton on June 4, 2019. At the hearing, a summary of the regulations governing large groundwater withdrawals was presented by the Department, results of the withdrawal testing program were presented by Geosphere, a question and answer session was held, and oral testimony was recorded. After the public hearing, the 45-day written comment period on the report commenced, and closed on July 19, 2019. The Department received three comments and one technical review during the written testimony period of the hearing. The three comments received were in favor of Aquarion's application, the water supply development project, and issuance of a permit for Well 22. The technical review was submitted by a consultant on behalf of the town of Hampton and the North Hampton Water Commission, the review: critiqued multiple elements of the report, the pumping test, and some of the associated analyses; provided alternative analytical approach(es) to reducing the data collected during the test; and, although it acknowledged that Well 22 presented substantial capacity to supply water, it did not support approval of the well at the maximum pumping rate tested. Comments received were considered during the Department's review of the final report.

See the Section No. 5 below for the Department's response to comments received as part of the hearings held pursuant to RSA 485-C:21 V, and the associated permit decisions based on the data collected and the associated rule requirements.

4. LARGE GROUNDWATER WITHDRAWAL PERMIT MONITORING, REPORTING AND WITHDRAWAL REQUIREMENTS

The large groundwater withdrawal permit issued to Aquarion allows the withdrawal of up to 1,080,000 gpd (750 gpm) from Well 22. The large groundwater withdrawal permit also requires Aquarion to conduct a groundwater level and quality monitoring program that includes the production well and monitoring wells. General monitoring requirements are summarized as follows:

- The permit requires that groundwater levels in production Well 22 and Well 7 be monitored continuously so that water level fluctuations in nearby wells can be compared to the operation of the production well;

- The permit requires that groundwater levels at four off-site private water supply wells be monitored continuously to monitor for long term impacts to private wells within the influence area of Well 22;

- The permit requires that groundwater levels in one, on-site deep overburden monitoring well be monitored continuously to assess the long term effects of pumping Well 22 has on the saturated overburden that is source to production Well 7;

- The permit requires that salinity be monitored at two, off-site private water supply wells and production Well 22 to track the potential for seawater intrusion over time and typical usage conditions at the well field;

- The permit requires PFAS groundwater quality be monitored at two, off-site private water supply wells and production Well 22 to track this contaminant over time and typical usage conditions at the well field; and

- The permit requires a pre-startup and subsequent annual Functions and Values assessment(s) be conducted for the wetland area east of the production well. The assessment includes establishment of a wetland plot(s) within the wetland(s) with observed influences from Well 22, and long term comparison of wetland conditions against those observed in a control wetland plot outside of the influence area of the wellfield.

In the event that an adverse impact is reported and verified, an impact mitigation program would be implemented in accordance with conditions of the large groundwater withdrawal permit and Env-Wq 403. The program would implement actions necessary to mitigate the impact including reducing the withdrawal volume, establishing water use restrictions for customers of the water system, modifying or replacing an impacted source at no initial capital cost to the user, and expanding (or establishing) a monitoring network to assess the effectiveness of the mitigation program. More information concerning these requirements is provided in the large groundwater withdrawal permit under condition No. 6.

Aquarion is required to submit an annual monitoring report in an electronic format to the department by January 31st of each year. As stipulated in the permit, the annual report shall include a summary of trends and variability observed in the monitoring data, all monitoring data and records required by the permit, and an assessment of the potential impacts associated with the withdrawal from Well 22. The annual report will be available to the public for review. A complete description of monitoring and reporting requirements is presented in more detail in the large groundwater withdrawal permit under condition Nos. 4 and 5.

5. DEPARTMENT RESPONSE TO PUBLIC INPUT

Following submission of the April 1, 2019 final report for Well 22, and during the 45-day written comment period, the Department received written testimony from three individuals (two residents and one select board member of the town of Hampton) relating to Aquarion's application for a large groundwater withdrawal permit. These letters supported Aquarion's application for Well 22 and were in favor of issuance of a large groundwater withdrawal permit to Aquarion for the well.

The department additionally received a technical review of the final report from a consultant hired by the town of Hampton and the North Hampton Water Commission (Tom Ballestero dba Streamworks, LLC). The technical review was received in two parts, the first part was submitted on May 25, 2019 following submittal of Aquarion's final report for Well 22; the second part was submitted on July 19, 2019 (last day of written testimony period) after the consultant requested, and was provided, the 'raw' data files for all water level records at the monitoring points used during the pumping test. The consultant's second submittal was largely focused on an alternative analysis of the data collected during the test. Following review of all relevant comments, NHDES issued its response to the final report on August 30, 2019. NHDES' response noted some specific deficiencies in analyses of data from the pumping test as well as the need to address some requirements established in the administrative rule

and statute that govern the permitting process. Geosphere (Aquarion's consultant) subsequently submitted two responses to NHDES, on September 23 and October 24, 2019, with additional data analysis and addenda to address NHDES' response letter.

Due to the fact that the technical review comments from Hampton/North Hampton's (the town's) consultant were received prior to both NHDES' response to the final report and Geosphere's supplemental submittals, a number of the comments that the town's consultant submitted were addressed by the subsequent additional data analyses and/or revisions conducted by Geosphere. In accordance with RSA 485-C:21, V, the Department specifically considered legally and technically relevant input, and issues the additional findings below in support of its decision, with a summary of the comments made. In reference to responses below, a number of review comments were made referencing the criteria of the pumping test (and its data analysis) as established in the large community well siting rules (Env-Dw 302) as opposed to the large groundwater withdrawal permitting rules (Env-Wq 403) because some of the testing/analysis criteria in the Env-Dw 302 rules are directly referenced by Env-Wq 403.13.

a. Ambient well issues

The town's consultant provided numerous comments within a number of sections of their review(s) about the ambient well that was used as a regional groundwater level reference for the effects that pumping Well 22 had on other monitoring points. Specifically, the town's consultant states that i.) the pre-pumping monitoring period at the ambient well is/was not long enough to correct for background hydraulic conditions in the formation and should be longer; ii.) review of groundwater level data at the ambient well showed a water level rise prior to the test that was not accounted for in the pumping test analysis; and iii.) the ambient well is not a good comparative surrogate for the pumping test as its water level varies in a manner that isn't similar enough to Well 22. The following statements are emblematic of multiple references to these issues by the town's consultant:

From the consultant's May comment letter -

Page 18, The report does not demonstrate the relationship between ambient water level in all wells. This is the reason for requesting in 2017 a much longer-term pre-pumping date monitoring period. The ambient well data relationships are used to correct the water level data in all wells during the pumping in order to accurately represent well drawdowns as well as to accurately then analyze these drawdowns. This is a basic aquifer hydraulic analysis standard of practice that was ignored. The analysis of ambient stresses on well water levels and the correlation of well water levels between wells should have been performed prior to analysis of the pumping test data. No such analysis is presented in the report. This is a very serious oversight. The precipitation, regional water decline and atmospheric precipitation, all have the ability to change well water levels on the orders of feet. While this change is not significant in the pumping well, it is extremely important in much farther away from the pumping well..

..It is recommended to use the same monitoring well network and collect three or more months of ambient climatologic and well water level data. This data should then be analyzed to understand how ambient stresses effect water levels as well as the interwell water level relationships (for example long term water level declines in the summer).

Env-Dw 302.14(d)(1) requires a minimum 7-day antecedent groundwater level monitoring period prior to the start of pumping at the proposed production well and all monitoring points in order to record static groundwater level conditions in the monitoring network. Env-Dw 302.14(f)(2)c. requires that at least one background monitoring well located outside of the influence area of the proposed production well be included in the pumping test monitoring network.

In general, the ambient (background) well is commonly located in the same physiographic area of the proposed production well and is intended to track regional groundwater level trends that may affect groundwater levels in

the proposed well and it's monitoring network before/during/after the pumping test. This well additionally records the effects of any incidental hydraulic events (like rain events, etc.) on groundwater levels should they occur during the testing program, thereby allowing for any adjustments of groundwater level observations within the monitoring network as it relates to interpreting the effects of the production well at other locations. Commonly, the ambient well is located in the contributory recharge area of the proposed production well (usually in the same subwatershed) but outside of its direct hydraulic influence area.

Aquarion used an 863 foot deep bedrock well, designated RW4, located approximately 12,000 feet northwest of Well 22 in a small watershed that drains into the Taylor River (Section 2.5.2, Figure 5. – April 2019 report). Continuous groundwater levels were recorded at RW4 from June 11 to July 22, 2018 and included over eight days of pre-pumping groundwater level data. Groundwater levels in RW4 were not observed to be affected by pumping of Well 22 but did record both a summer season trend (decline) in groundwater levels for the area, and the effects of a few precipitation events that occurred during testing [see further discussion below].

From the consultant's July comment letter-

During the 13-20 June 2018 pre-pumping monitoring period, the well 22 pumping test report indicated only traces of rain from the North Hampton rain gage, yet Durham received 0.31 inches on June 18, 2018. Because of the very large zone of influence, the one rain gage reported for precipitation is insufficient to describe the areal recharge over the bedrock formation for the pre-pumping, pumping, and recovery phases. The Figure 2 demonstrates that the ambient well water level increased at least 0.5 ft, and most likely more as the pre-pumping period ended while this water level continued to increase, as a result of precipitation in the area. [this comment also provided a graph developed by the town's consultant that depicted groundwater levels in the ambient well prior to the pumping phase of the test from the raw data in the groundwater level data files].

The town's consultant based their analysis and their associated [re-analyzed] hydrograph of the groundwater level in the ambient well on their own processing of the data from the groundwater level data files that were provided to them by the applicant. In review of the data record used by the town's consultant to generate their graph and their statement above, NHDES notes that the town's consultant erred in interpreting the data record in the data file as height of the water level in the ambient well, when it was, in fact, the depth to water in the well; so the above statement that the water level in the ambient well increased 0.5 feet prior to the start of the test is incorrect, in fact the groundwater level in the ambient well decreased by about 0.5 feet prior to the pumping test. The decrease in groundwater levels in the ambient well prior to the test is described and graphed correctly in Geosphere's April 2019 final report (section 2.5.2, appendix D, part 3). Based on their analysis of groundwater levels in the ambient well, Geosphere interprets the decline as part of a typical seasonal (summer growing season) decline in groundwater levels in the recharge area for Well 22 that resulted in about a 1.84 foot decrease in groundwater levels in the ambient well from June 13 to July 17 (see further discussion below).

From the consultant's July comment letter-

Figure 4 plots the ambient well water level against that of well 22 for elapsed times between 3,400 minutes and 8,600 minutes of the pre-pumping period (to avoid the human interferences identified in the well22 pre-pumping data discussed in the last paragraph). If the ambient well was a good surrogate for well22 and unaffected by well22 pumping, this plot should have been close to a simple line. It is far from that, indicating that the ambient well was not a good choice for this pumping test. Two years ago, I recommended drilling a few ambient wells and gave suggested locations. This recommendation was not followed. [this comment also provided a graph developed by the town's consultant that plotted groundwater

levels in the ambient well against those in Well 22 for the period prior to the pumping phase of the test, the plot shows a 0.4 to 2 foot variability in the groundwater levels between the two wells].

The pre-pumping groundwater levels in the ambient well (RW4) and production well Well 22 do not plot in a straight line for two primary reasons:

a. The pump was installed on Well 22 on June 13, and then a power system check was completed that required operating the pump for a 30 to 60-minute period. Operation of the pump in Well 22 for the power check caused an approximate 0.5 to 1.5 foot drop in groundwater level in the production well that did appear to shift the well water level, possibly due to re-installation of the well's groundwater level monitoring device after pump installation. Additionally, on June 19th (a day before the start of the pumping phase of the test) the depth of the groundwater level monitoring device in Well 22 was reset in preparation of pumping, and caused an approximate 0.5 shift in the water level record for the well (ref. section 2.5 final report and timeline on figure 1, Appendix D, part 1). And,

b. Being located in the coastal area, both Well 22 and the ambient well recorded the effects of ocean tides (wave signal) on an approximate 12-hour schedule. Well 22 is located about a mile from the coast whereas the ambient well is located a little more than 3 miles inland, as a result, the tidal signal observed at the ambient well is slightly more attenuated (dampened) and time shifted than that recorded at Well 22, this dampening appears to cause about a +/- 0.2 foot variability between the two wells.

Although there were some changes in water levels during the pre-pumping phase of the pumping test in Well 22, the issues experienced were minor in the context of the full testing period and are not significant enough to invalidate the pre-pumping data or the groundwater level record of the ambient well. Additionally, multiple months of background groundwater level data collection during the antecedent period is not required by rule nor is it necessary to track groundwater level trends or address hydraulic stresses occurring on the scale of the duration of the test [see additional discussion below]. The department finds that Aquarion met the requirements Env-Dw 302.14(f)(2)c. to establish an ambient monitoring point outside of the influence area of the proposed production well, and conduct at least seven days of antecedent groundwater level monitoring in compliance with Env-Dw 302.14(d)(1) prior to the pumping portion of the test.

b. Correction for precipitation events on groundwater levels and zone of hydraulic of influence of Well 22

The town's consultant provided numerous comments in their review about the lack of correction of groundwater levels for precipitation events that occurred during the pumping test between June 22 and June 30, 2018. Specifically, groundwater level observations in the ambient well and multiple monitoring points showed the effects of a little over 3 inches of precipitation that fell between 5 and 10 days into the pumping portion of the test. In its April 2019 submittal (final report), Geosphere did not correct for these effects by 'adding' more drawdown to those locations that showed an effect of precipitation. The town's consultant stated that the groundwater levels at multiple locations in the monitoring network, both overburden and bedrock, show the effects of precipitation and require correction, and the zone of influence of Well 22 is underestimated without correcting for these events. The following statements are emblematic of multiple references to these issues by the town's consultant:

From the consultant's May comment letter -

The 3.32 inches of rainfall that fell over the pumping test period should not be converted to a daily average: that number is meaningless. The pre-pumping water level data should be correlated with pre-pumping

precipitation in order to correct the pumping test water level data on days with precipitation. This should have been down for ALL monitored wells. This correction does not seem to have been employed in the data analysis. The conclusion that rainfall during the pumping test had no effect on water levels is seriously flawed without this pre-pumping calibrations of well water levels to natural environmental stresses. By not doing this calibrations, precipitation during the pumping test increased well water levels and therefore masked actual drawdowns.

..As mentioned previously for the bedrock wells, because precipitation was not factored into overburden well water levels, report conclusions such as (page 22), "These projected drawdowns are not significantly greater than observed natural/seasonal downward trends observed at monitoring locations that showed no response to pumping." are completely hollow because the report did not adequately address environmental stresses and well water levels.

..The expected cone of depression is optimistic given that well drawdowns were not corrected for environmental stresses. This is particularly troubling because the direction of greatest drawdown distance is to the southwest and very close to salt water marshes and the estuary. As described previously in the Cooper-Jacob analysis, by not correcting for the effects of precipitation, drawdowns at distances were underestimated and therefore actual hydraulic consequences will be much farther than the report estimates.

..The pumping test affected wells almost 1 mile away. The true distance may be farther as the consultants did not include the effects of precipitation during the pumping test in the data analysis.

The July 2019 comment letter from the town's consultant also provided comment about/reference to the need to correct drawdowns observed at multiple observations points for precipitation effects as these effects likely bias the assessment of the zone of influence of Well 22.

Env-Dw 302.29(e)(4)a.3 and d. require that the applicant develop a table of groundwater level responses observed at monitoring locations corrected for hydraulic influences (like precipitation) and distance-drawdown plots with corrected water levels to estimate the zone of influence of the withdrawal based on 180-days of pumping at constant production rates. Env-Wq 403.09(e) and 403.17 require development and update of a potential impact area for the withdrawal based on a conceptual hydrogeologic model of 180-days of continuous pumping without the effect of recharge from rainfall.

In the August 2019 response letter to the final report, NHDES concurred with the need to address other hydraulic stresses and required a correction for the influence of precipitation to the drawdown observed at all monitoring locations that showed some level of influence from the rain events. The letter additionally required a revision to the projected drawdown (distance-drawdown analysis) used to estimate the extent of hydraulic effects of Well 22 once the corrections for precipitation were made (Sections 1.a. and 1.b.).

In its September 23, 2019 supplemental submittal, Geosphere revised its analysis of drawdown and generated precipitation correction factors for 10 bedrock wells and five overburden wells used to monitor groundwater levels during the test (section 1a. and 1b., Tables A and B, plots in Appendix A). The correction factors were developed based on the response observed at each specific location, and ranged from 0.16 to 2.71 feet. In that same submittal Geosphere revised its assessment of the projected zone of influence of Well 22 to include distance-drawdown analysis with the corrected drawdown data. The revised drawdown projections include estimates coincident with the primary axis of drawdown observed during the test (SW-N/NE) and the secondary axes (NW-SE). Geosphere estimated that projected drawdowns along the primary axis of influence, without constraint from likely hydrologic boundaries, may be on the order of 10,000 to 15,000 feet from Well 22 (section 1.c, Tables A and B, appendix B, revised Figures 7A, 9, 11, 12 and 15); however, they also estimated that these drawdowns are likely constrained to distances less than about 10,000 feet by very large wetland complexes, marshes, and associated riparion zones in those areas. Geosphere revised its estimated potential impact area to include the updated (expanded) projected zone of influence of Well 22, and subsequently revised the estimated wellhead protection area (Env-Dw 302.22) and water budget for Well 22 (Env-Wq 403.17) accordingly.

Based on the September 2019 revisions, the department finds that Aquarion met the requirements of Env-Dw 302.29 to correct drawdowns at monitoring locations for the effect of precipitation recorded at the site during the test and revise associated drawdown plots. Additionally, the department finds that Aquarion complied with Env-Wq 403.09 and 403.17 to develop a potential impact area that includes the zone of influence of Well 22 that is based on those water levels assuming a 180-day of constant pumping with no recharge.

c. ***Cooper Jacob analysis and distance-drawdown data***

The town's consultant provided comments on the adequacy of the Cooper-Jacob analysis (distance-drawdown plots and analysis) presented in Appendix F of Geosphere's April 2019 final report. Geosphere's analysis in the final report provided an estimate for the transmissivity of the bedrock based on the Well 22 pumping test results using the Cooper-Jacob Recovery method. The town's consultant stated that the Cooper-Jacob analysis is misapplied to this site because the hydraulic setting and response to pumping violates the method's assumptions. The town's consultant then provided alternative values (for both transmissivity and storage coefficient) in their May 2019 submittal based on a method that was not specified, and later revised those values in their July 2019 review letter. The consultant's comment follows:

Page 18. The Cooper-Jacob analysis (Appendix F) is flawed. One of the assumptions of the method is that well drawdown is small compared to the aquifer thickness (here, the well depth). This assumption is not true for the pumping well, which has a major influence in the analysis presented in the report and discussed later in the critique.

The report completely avoids discussing storage coefficient, which is the parameter that determines the unsteady progression of the cone of depression (how fast the drawdown progresses through the bedrock domain away from the pumping well). However T=1,000 ft2./day matches well with the 1,600 ft2/day I estimated in 2017 from the step test data. My 2017 analysis generated a storage coefficient of 0.0006. This storage coefficient is characteristic of a confined aquifer which then describes why the well 22 signal (drawdown) can move so far from well 22.

Completion of a Cooper-Jacob analysis with estimation of transmissivity and storage coefficient are not required by rule for proposed large bedrock well supply wells under Env-Dw 302.29 because assumptions related to this analytical method(s) are not commonly met by groundwater flow through fractured bedrock. Therefore, the department makes no finding with respect to either Geosphere's or the town's consultant estimation of these parameters. Generating distance-drawdown plots based on 180-day drawdown projections to estimate the potential extent of influence of the production well is required per Env-302.29(e)(4) and has been completed by the applicant in accordance with the rules (see response #5b above).

In reference to the adequacy of Geosphere's evaluation of which locations did and did not response to pumping at Well 22 and their development of the distance drawdown plot, the town's consultant provided the following comments:

The report (page 20) states that, "... No response to pumping of Well 22 were observed at six(6) of the private bedrock wells monitored during the pumping test." These wells were not named or identified but should be explicitly identified in order that the claim be verified.

This statement is incorrect. In Table 6 (parts 1 and 2) of Geosphere's April 2019 final report, each monitoring location is identified in the table by location and address and, under the column titled "Drawdown Effect due to Pumping?" (yes/no), each well is designated as either responding to the pumping of Well 22 or not. In review of the hydrographs for the monitoring points (Appendix D), the department does concur with Geosphere's assessment of well specific responses.

In addition, the report states (page 20),"...No response to pumping of Well 22 were observed at Aquarion's two bedrock water supply wells (Wells 20 and 21) or the nearby bedrock observation wells (SB-1, SB-7)." No data is provided to support these claims.

This statement is incorrect. In Appendix F, part 2 of Geosphere's April 2019 final report, water level plots [hydrographs] are provided for both Aquarion bedrock production wells Well 20 and 21 for the antecedent, pumping and recovery periods of the test. Based on these hydrographs, neither well appeared to respond to pumping at Well 22. Monitoring wells SB-1 and SB-7 near these two production wells were not proposed to be monitored during the test, however Geosphere did record and report the depth to water level in these wells right before pumping started (static water level) and right before the end of pumping period and reported the values on Table 6 of their final report. SB-1 and SB-7 also did not respond to pumping at Well 22.

This Cooper-Jacob analysis magnifies another oversight of the pumping test itself: the need for monitoring wells within the radius of 100 to 1,000 feet from the pumping well. This was also a recommendation in my 2017 critique of the preliminary report. Wells in this range would help significantly in the hydraulic analysis of the data.

This statement is incorrect. Six of the 20 bedrock monitoring locations and two of the overburden monitoring wells were located between 100 and 1,000 feet from production Well 22 as reported by Geosphere's Table 2 - April 2019 final report, and Attachment B – September 2019 final report response. As noted previously (item 5.b. above) the department determines that the applicant complied with the requirement to project drawdowns, complete the distance drawdown analysis, and estimate the potential zone of influence of the well in accordance with the administrative rule.

d. Hydrogeologic conceptual model development/refinement and water budget/recharge estimate

Within their response to both the preliminary application and the final report, the town's consultant provided a series of comments on the interpretation of geologic data and deficiencies of the hydrogeologic conceptual model developed for the site. In a related issue, the town's consultant states that the wellhead protection area (zone of contribution) for Well 22 and the associated water budget is inaccurate by including an overestimate for recharge volume. The following comments are emblematic of those related to the conceptual hydraulic model for the Well 22 site.

The conundrum presented 2-years ago remains in this report: if precipitation does not affect bedrock water levels, then what is the source of the pumped water? This question is never answered, yet the report insinuates that it is precipitation. The ambient well demonstrates a water level reaction on days it rains. This could be due to recharge, barometric pressure or loading; the report does not bother to assess these effects or include them in the conceptual hydrogeologic model. The report makes the bold assumption that water that infiltrates the land and escapes evapotranspiration is available to the bedrock. ..

..The use of surface piezometers (PZ-1 through PZ4), provides almost no useful information. Instead of just shallow piezometers, it was recommended in 2017 that vertical couplets be installed capable of determining vertical gradients especially below wetlands. This is a serious omission and no ability to address impacts on wetlands is possible...

..Attendant to the overburden data, no technical data synthesis and discussion of interactions between the overburden and bedrock (vertical gradients, leakage) was presented in the report. The report does a very poor job of the hydrologic and hydraulic description of the bedrock aquifer.

In their November 2017 response to NHDES' comments on the preliminary application, Geosphere provided a detailed discussion of regional structural features in bedrock that likely act as controls on groundwater flow through the shallow fracture network encountered by Well 22. The discussion provided by Geosphere was based

on regional lineament analysis, site specific geophysics [VLF], borehole geophysics on Well 22, pumping test results from Aquarion's Mill Pond wellfield located northwest of Well 22, and initial step test results at Well 22. Specific to the issue of groundwater flow between overburden and bedrock, based on water level measurements collected prior to the start of pumping, Geosphere described that groundwater gradients at the Well 22 site are upward, out of bedrock into overburden within areas overlain by coarse grained soil deposits. Capture of a significant amount of this upward flow with a lesser amount of induced recharge through coarse grained material within the capture zone of Well 22 was described by Geosphere as playing a substantial role in the well's capacity (Item no. 4, pg. 10). Based on the data collected during the pumping test, Geosphere provided an updated discussion on vertical hydraulic gradients and flow between overburden and bedrock that validated their pre-test estimates regarding upward gradients (from bedrock into overburden), and noted that within about 1,000 feet of Well 22 upward gradients were reduced to near neutral conditions in areas overlain by fine-grained soil units, but that upward hydraulic gradients may reverse in areas overlain by coarse grained units closer to Well 22 (section 1.e. in September 2019 submittal).

In reference to the need for multi-level overburden monitoring locations; within about 1,000 feet of Well 22, the overburden monitoring locations for the site included two shallow water table piezometers, two mid-depth overburden monitoring points, and one deep overburden monitoring point. Although the focus of most of the monitoring network for Well 22 was necessarily on bedrock monitoring points, collectively, the configuration of overburden points allowed for estimation of vertical gradients across the site, estimation of the influence area of pumping Well 22 on the overburden aquifer, and projection of the potential effects of pumping Well 22 on the water level/yield of nearby overburden production Well 7 (Section 1.e. and revised figures 11 and 12 – September 2019 submittal). Due to observations made during the pumping test, the permit issued to Aquarion for Well 22 (see above) includes monitoring of groundwater levels in overburden at the site to track long-term influence on the source formation for Well 7, and implementation of a long-term monitoring program in wetlands proximate to the PZ-3 and PZ-4 piezometer locations. Based on the regional and site specific data used by Geosphere's to develop and revise the description of site hydrogeology, the department finds that Aquarion met the requirements to develop a hydrogeologic conceptual model in accordance with Env-Wq 403.09 and revise it based on observations from the pumping test in accordance with Env-Wq 403.17.

The study area water budget in the report is flawed for many reasons. One of the most egregious is the conclusion that the well head recharge area enjoys 2.3 times more recharge than the requested well 22 production rate, it assumes that nothing else in that area is using water. (Note, in the Preliminary Report this estimate was estimated at 12 times the pumping rate.) There are other Aquarion water wells and there are environmental uses for the groundwater (wetlands, stream baseflows, and preventing saltwater intrusion) in this delineated well head recharge area. The reported water budget neglects any and all other groundwater uses in the recharge areas to make their conclusion. Just as important, well 7 was not pumping during the test of well 22. The report does not address the consequences of the long term pumping of both of these wells.

The statement that no other groundwater use in the recharge area of Well 22 was included in the water budget is incorrect. In its preliminary application (March 2017-section 4.5.6) Geosphere included in its water budget estimate for the inferred recharge area for Well 22 both the annualized groundwater withdrawal volumes from all other Aquarion production wells, and estimated private well withdrawal volumes from private lots within the recharge area for Well 22 that are not served water by the Aquarion Water Co. Estimates for these non-Well 22 groundwater withdrawal volumes were carried through by Geosphere into the updated water budget estimates in the final report (April 2019-seciton 3.2.5) and its revised water budget in the final report addendum (September 2019-attachment C. part 1.). The water budget revision(s) following the pumping test were based on the updated recharge area for the zone of influence observed for Well 22. Based on the description above, the department finds that the application did complete a water budget for Well 22 in accordance with Env-Wq 403.09(i) and revised the water budget in accordance with Env-Wq 403.17.

In the above-referenced water budget, Geosphere estimated a wide range of recharge rates (0.24 to about 23 inches per year) across the inferred recharge area for Well 22 based on the varying overburden characteristics observed in the region (lower rates in areas of silt/clay surficial deposits vs. higher rates in areas of coarse grained deposits). Additionally, Geosphere estimated that between 58 and 66 percent of the precipitation in the recharge area of Well 22 was lost to a combination of evapotranspiration and other groundwater uses/discharges, resulting in an estimated recharge volume to withdrawal volume ratio over the 5.1 square mile recharge area that ranges between 1.8 to 3.8 dependent on withdrawal volumes from other sources. The department finds that the range of recharge rates used for the water budget were reasonable for the material characteristics observed in the region and in-line with the hydrogeologic conceptual model for the site (see determination above), and the approach taken to include groundwater use from other sources was technically conservative. The department notes that the long-term monitoring well network proposed by the applicant for Well 22 and established in its permit includes groundwater level monitoring at both overburden and bedrock wells within the influence area of the well in order to track/validate related assumptions about rate of recharge to the formation over time.

Overburden production Well 7 was not operated during the Well 22 pumping test, this was proposed by the applicant in the preliminary application, and approved by NHDES, due to the fact that both wells are connected to the same pumping station and only one well could be pumped at a time. As referenced in the comment above, Well 7 was instrumented with a groundwater level monitoring device before, during and after the pumping test which did enable an estimate of effects caused by pumping of Well 22. Based on the data collected, Geosphere estimated that pumping for 180-days at a constant rate from Well 22 at the tested production rate may result in a decline in groundwater levels in Well 7 by up to 16% (Section 1.e. - September 2019 submittal). Due to this estimate, recording of groundwater levels in production Well 7 is part of the long term monitoring program for Well 22. Based on the data collected, the department determines that the applicant met the requirements of Env-Dw 302.14(f)(2)b. to monitor groundwater levels in the applicant's other water supply wells located within the influence area of the proposed new well, and assess effects of the new proposed well on those other water supply wells in accordance with Env-Dw 302.29(h)(1).

e. Well 22 sustainable yield analysis and partial derivative analysis

The town's consultant stated that the pumping test analysis method and the associated sustainable yield estimate developed for Well 22 by the applicant may not be accurate and additionally provided an alternative analysis of the pumping test data using partial derivative analysis to independently estimate the potential sustainable yield of the production well.

The town's consultant provided the following comment relative to the sustainable yield estimate completed by the applicant.

Page 18. The significant recovery of well 22 is not due to recharge, rather due to the fact that the formation is hydraulically characterized as a confined aquifer: the cone of depression collapses when the pump is shut off due to the extreme hydraulic gradient created at well 22 due to pumping plus the low storage coefficient. This is not recharge, it is recovery. A more accurate indicator of recharge is how the cone of depression completely refills (all drawdowns go to zero) rather than just the pumping well alone. 90% recovery in 13 hours is a hollow metric if the remaining 10%, especially aquifer-wide, never recovered. Pumping 850 gpm for 14 days is 17.1 million gallons. Over a 5,000 ft radius cone of depression (figure 7 and page 20), with a bedrock porosity of 1% represents a uniform drawdown of 3 feet over this entire area. Four days after pumping ceased, there was still a significant drawdown in well 22 (Appendix D) on the order of a few feet. The very simplified metrics, analysis, and conclusions in the report do not adequately describe the system performance sufficiently to predict long-term future pumping.

The department does agree that the formation responds similarly to a confined aquifer system but it is better characterized as a semi-confined system that induces recharge vertically into fractured bedrock through overlying coarse grained deposits where they are present, and some leakage through fine grained overburden materials. This is evidenced by the data collected during the pumping test from shallow, mid-depth and deep overburden wells located within the influence area of Well 22, as described in the April 2019 final report (sections 2.4 and 2.5, Appendix D) and the September 2019 addendum (section 1.e.ii., table A and revised Figure 11).

Env-Dw 302.14(d)(3) requires the recovery period be at least as long as the pumping period or a period of time that allows for recovery of 90% of the drawdown recorded in the pumping well during the test. The static depth to groundwater in Well 22 prior to pumping was 6.6 feet, this depth increased to a maximum drawdown of approximately 173 feet at the end of the pumping period. After about 13.4 hours of recovery following cessation of the 27-day pumping period, the groundwater level in Well 22 recovered to 90% of the pre-pumping water level (~23.2 feet). After approximately 2.5 days of recovery, the groundwater level in Well 22 recovered to a level of about 9.9 feet or approximately 98% of the pre-pumping level once the value is adjusted for both precipitation and seasonal groundwater decline effects. Therefore, the department determines that the recovery requirement established in Env-Dw 302.14 was met. Neither the rule nor statute require that groundwater levels recover *fully* at any or all locations monitored during the pumping test in a specified timeframe. The premise that a withdrawal is not sustainable unless full recovery occurs in short time frames across the entire influence area is flawed in that groundwater necessarily comes out of storage in the formation around the pumping well and a new equilibrium is established between induced recharge and a lower groundwater level. This condition is typical in groundwater hydraulics and does not invalidate the sustainable yield of a production well, provided that the withdrawal rate does not exceed the formation recharge rate and cause continual groundwater level decline such that groundwater is mined from the formation and water users in the influence area of the withdrawal are not able to meet their water supply needs.

Using a recharge volume estimate based on uniform drainage from a fixed radius area (5,000 feet) surrounding the production well (a.k.a 'water table fluctuation' model) as described in the consultant's comment above, is not technically correct because that approach is largely applicable to gravity drainage of groundwater from saturated soil of an overburden water table aquifer screened by a shallow overburden production well. As evidenced by the pumping test data for Well 22 and described in the final report, the response to pumping the well clearly shows that most of the groundwater flow to Well 22 is through a regionally discreet shallow bedrock fracture system that experiences drawdown along preferentially oriented bedrock structures at depth. The recharge to the well in this system, as inferred from the monitoring network data, is substantially from enhanced capture of deeper base flow bedrock discharge into the region, induced recharge through coarse-grained material only where it overlies the fracture system, or from large scale surface water features that act as boundary conditions where they are hydraulically connected to the bedrock fracture system. The intent of the long-term monitoring network established in the large groundwater withdrawal permit (Condition No. 4.a.) is to monitor groundwater levels in the primary influence area of Well 22 over time, to validate assumptions made from the pumping test observations, and to assess the production well's impact on formation groundwater levels over time.

The town's consultant provided the following comment in the July 2019 review relative to their own derivative analysis of water level responses at two locations during the test, production Well 22 and the residential well at [redacted]:

Figure 6 presents the well 22 drawdown data from the last figure as well as a derivative plot of the same data. The derivative plot is simply the slope, at any point, along the semi-log plot of drawdown versus time. A derivative plot magnifies irregularities in the raw water level (drawdown) data as well as fingerprints aquifer characteristics. The derivative plot indicates that the first pumping level of 648 gpm stabilized. This conclusion is made from the derivative plot where it can be seen that for the initial pumping rate, the shape of the curve is an

inverted 'U ', which indicates that the well has stabilized and achieved an amount of recharge equal to the pumping rate. However after that time (elapsed time greater than 1,600 minutes which occurred at 12:40 PM on 21 June 2018) there were a number of complicating factors that challenge simple analysis of the raw well 22 data. One factor was the previously mentioned well 22 non-constant pumping and the Aquarion well field pumping variability. A more important issue was that in Durham from 24-28 June 2018, almost 3 inches of rain fell and from 15-17 Jul2018 almost another 3 inches of rain fell. The climatological data reported in the well 22 report for North Hampton showed similar days and rainfall totals for the same periods (3.32 in. and 1.41 in., respectively). The net effect of these factors (highly variable pumping and precipitation) makes the well22 drawdown plot and the derivative plot extremely noisy (highly variable). However what is clear is that well 22 cannot sustain/support the two higher pumping levels during the pumping test. For the two latter pumping levels, no such conclusion can be drawn because the well 22 water level (drawdown) did not stabilize. This conclusion contradicts the Aquarion/Geosphere conclusion presented at the June 4, 2019 public hearing. When viewing the well 22 derivative plot, after 1,600 minutes, there is no clear indication that the water level stabilized or that recharge was secured to match the pumping rate.

Because of the great variability of the well 22 water level (drawdown) data, better well water levels to analyze would be farther from the pumping well. In previous comments, I noted that I had made suggestions for such monitoring wells two years ago, which had not been followed. A nearby homeowner well was selected as an example to analyze well drawdown data. The well selected was [redacted] In figure 8, [redacted] drawdown versus time (Black squares) and its derivative (gray squares) is presented. This data was created from the monitored data set, however the effects of the homeowner pumping were removed. The [redacted] water level did not stabilize over the course of the well 22 pumping test. The derivative plot for [redacted] closely mirrors that of well 22, however it is much smoother. The initial well 22 pumping rate for almost 1,600 minutes at an average pumping rate of 648 gpm stabilized, as indicated in the smooth decrease in the derivative plot from 300 to1,600 minutes. Although the well drawdown data after 1600 minutes looks relatively smooth, the derivative plot reveals a much more complex signal. This is most likely due to the regional (system-wide) highly variable Aquarion well pumping as well as precipitation. In addition what appears to be the well "stabilizing" at about 9,000 minutes (derivative plot going to near zero) is more related to the fact that almost 3 inches of rain fell during this time over a large area. It should be recognized that the precipitation did not necessarily recharge the bedrock groundwater and effect water levels, but rather the load (weight) of that recharge does (what is known as the aquifer loading efficiency): this is pronounced in confined aquifer systems. Without any correction for how precipitation affects water levels, this then biases understanding the effects of pumping on water levels: if well water levels increase due to precipitation, then monitored drawdowns are much less than reported. This then also biases the estimates of the cone of depression and the well head areas. The most important conclusion from the [redacted] derivative plot is that for the last, and longest well 22 pumping level (over 800 gpm), the derivative plot is increasing, meaning that recharge has not been found and the aquifer system is not stabilized: well 22 pumping is mining the groundwater and has not secured recharge equivalent to pumping.

Derivative plots are basically a method that looks at the change in the rate of drawdown with time in a well instead of just the traditional time vs. drawdown plots. The practical benefit of derivative analysis is that it magnifies certain processes that may be difficult to see in a simple time-drawdown plot. One of the problems with derivative analysis is that you have to have very clean, accurate, noise-free data because small changes in drawdown measurement can cause a large effect on the derivative and be open to all sorts of spurious interpretations. This is especially true for measurements made in pumping wells which are greatly affected by

borehole storage, skin effects, small variations in the pumping rates, and effects from a recharge event(s). Although derivative analysis is slowly being used more in the field of hydrogeology, the fact that it is so effected by relatively small perturbations of groundwater levels limits its use in evaluating well capacity in many situations. The town's consultant has submitted two derivative plots (the production well and a residential well) with the interpretation and conclusion that the pumping of Well 22 at a rate higher than 650 gpm is not sustainable. However, in reference to the consultant's comments above, they 'backed into' the conclusion that 650 gpm is the sustainable limit for Well 22 based on the fact that the derivative analysis at the pumping rates above 650 gpm were confounded by a.) the variability in the pumping rate of Well 22; and b.) the effects of precipitation events that occurred in the region between 5 and 10 days into the test that caused too much noise in the water level data. The town's consultant provided no technical basis beyond the inability of derivative analysis to 'see' past these effects for the conclusion that the production well has limited capacity for higher production rates. These two issues (fluctuating pumping rate and precipitation effects) did confound the derivative analysis as they represent intrinsic limitations of using the method for all situations and make the conclusions drawn from this analysis non-determinable in many instances (like this one). It is therefore incorrect to extend the limitation of this analytical method to infer that it equates to a production well capacity limit.

Env-Wq 403 does not specify that derivative plots be developed, rather an applicant is required to use drawdown observed during the pumping test, correct for any precipitation effects and project potential drawdowns at the production well and monitoring locations out to 180-days assuming no recharge and assess for potential impacts to water users (private wells) and sustainable capacity of the production well (Env-Wq 403.12 and Env-Dw 302.20).

Aquarion completed this evaluation and summarized results of this analysis in the April 2019 (Table 6) and September 2019 (Table A) submittals. Aquarion monitored 20 residential wells during the withdrawal testing program and ten of the wells monitored exhibited no response to pumping. The water level in the ten remaining wells exhibited a response to pumping that, when projected out to 180 days under the condition of no recharge to the groundwater, will dewater the water column in wells from about 7% to 12%. In comparison to well depths, the maximum amount of projected drawdown in the water column of an influenced well was approximately 36 feet, leaving approximately 330+ feet in the water column found in the private well, this provides sufficient storage in the borehole of the "worst case" well. Therefore, projected effects across the influence area of Well 22 do not imply that the capacity of the formation will be exceeded or groundwater will be mined and the department finds that Aquarion met the requirements of Env-Wq 403.12 to assess withdrawal effects on water users.

With respect to this same analysis for proposed production Well 22, as noted previously, the department does not approve the 850 gpm rate because a constant pumping rate was not maintained during this portion of the test per the requirements of Env-Dw 302.14; and the 180-day projected drawdown in Well 22 at this rate does not comply with Env-Dw 302.30 because it appears to intersect the upper-most water bearing fracture and thereby exceed the available drawdown in the well. The department does approve the production rate of 750 gpm for Well 22 as it was the next lowest production rate tested at the well that met both of the above-referenced criteria.

f. ***Water quality issues***

The town's consultant commented on the potential for seawater intrusion in the formation due to pumping from Well 22, and the occurrence of a groundwater contaminant in the influence area of the production well, as follows:

The Aquarion discussion at the June 4, 2019 public hearing concerning saltwater intrusion, again obfuscated reality. The statement was made, when talking about salinity, that,"...35 ppt would be an indicator of salt water..." 35 ppt is the salinity value for sea water, but the salinity in a homeowners well does not need to get that high before salt water intrusion can be determined to occur and/or be causing problems. Rather than the "

ten times increase" represented by Aquarion, doubling of the salinity in a homeowner well would certainly be indicative of salt water intrusion.

Water quality samples were collected and analyzed for salinity and specific conductance (a measure of total dissolved solids) at Well 22 and seven private water supply wells as part of the pumping test monitoring program. Screening for salinity concentrations was completed between 25 and 34 times at each of the locations monitored for sea water intrusion before/during/after the pumping portion of the test, subject to owner availability and site accessibility. The locations included in salinity screening were generally to south and southeast of Well 22, between it and the both the Hampton Landfill, tidal flat marsh areas and the ocean. The salinity data collected from all of the locations ranged between 0.1 and 0.4 parts per thousand (PPT) and specific conductance measurements were all generally below 600 microSiemens (uS) (Section 2.6.1, Table 7, Appendix J – April 2019 submittal). The ranges of variability in these measurements were generally quite small (+/- 0.1 PPT and +/- 50 uS) at most locations monitored as part of the test, with no apparent increasing/decreasing trends at any particular location. Generally, with all results being below 0.5 PPT for salinity and 1,000 uS for specific conductance, these data compare favorably to values typical of groundwater that is not influenced by seawater or other high dissolved solid (salt) containing groundwater. The department finds that Aquarion complied with requirements to asses for saltwater intrusion into a freshwater aquifer as part of the pumping test in accordance with Env-Dw 302.29(h). In order to track the potential for seawater intrusion into the aquifer over time, the large groundwater withdrawal permit for Well 22 requires semi-annual monitoring for salinity at the production well and two private wells (see condition no. 4.a.).

PFAS were detected at [redacted], a well within the hydraulic influence of well 22. The source of this contamination is unknown; however, since it is in the cone of depression, the PFAS will move towards well 22 into regions of the aquifer presently not impacted by the pollutant.

As part of a companion sampling program in this area of Hampton/North Hampton at the time of the Well 22 pumping test, numerous water quality samples were collected from area private wells and analyzed for per- and polyfluoroalkyl substances (PFAS). Some of the private wells sampled were also part of the 20 private wells monitored during the pumping test on Well 22. The above-referenced private well had detections of six PFAS ranging in concentration from 1.6 to 8.2 parts per trillion (ppt) and below applicable drinking water standards. In comparison to about 15 other private wells sampled for PFAS in the same area, incidental PFAS detections at concentrations less than about 10 ppt appear to occur routinely and may be related to the density of development in this area. Therefore, the results observed at the residence referenced above do not appear to be anomalous for this area such that influence by the production well will not substantively cause a change in PFAS distribution in area groundwater. Additionally, the private well sampled at the above referenced residence is a standing column, open-loop geothermal well that, as part of its typical operation, circulates its well water through a heat-pump (compressor unit) in the residence and re-injects it back into the well. The well water contact with the heat pump material may also contribute to the presence of PFAS in this well water sample. Given the general low-level presence of PFAS in groundwater within this area the department determines that effects of Well 22 on groundwater do not trigger an adverse impact under RSA 485-C:21; however, annual sampling and analysis for PFAS compounds is required under condition no. 4.b. at Well 22 and the two private well locations that are also monitored for salinity.