

**New Hampshire Geological Survey
New Hampshire Department of Environmental Services
National Ground-Water Monitoring Network Project
(Cooperative Grant Agreement No. G20AC00182-2)
7/15/2020 – 12/31/2023
Final Report**

Submitted to:

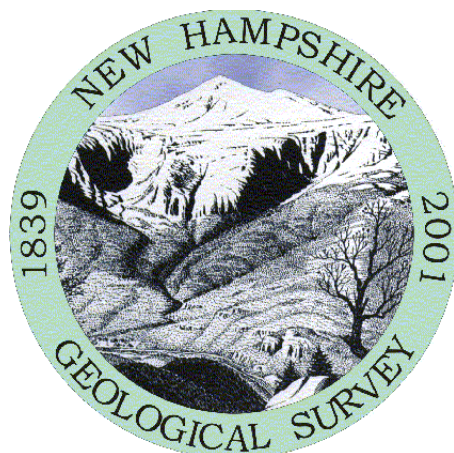
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Introduction

The New Hampshire Geological Survey (NHGS) began participation in the National Groundwater Monitoring Network (NGWMN) in June of 2016. This document is meant to fulfill our obligation of a final report for our 2020 grant, Cooperative Grant Agreement No. G20AC00182-02, effective date 07/15/2020 as amended on 11/09/2021 and 07/12/2023.

In our proposal, NHGS proposed the following tasks:

Objective 2, Part A:

- NHGS proposed to continue to collect, database, and make groundwater data available through our web services.

Objective 3:

- NHGS proposed to fill gaps in information at 3 new NGWMN sites drilled under Objective 5 of this proposal, including GPS location and elevation, lithology, construction details, and slug testing.

Objective 4:

- NHGS proposed to replace the surface casing at one existing NGWMN site, NHGS:LCW-01.

Objective 5:

- NHGS proposed to drill replacements for 3 network wells, NHGS:CVW-04, NHGS:FKW-01, and NHGS:CTW-73. NHGS additionally proposed to purchase and install continuous data loggers and transducers into the replacement wells for NHGS:CVW-04 and NHGS:FKW-01.

Objective 2, Part A: Data and Web Service Management

NHGS continues to collect, curate and store groundwater level data from our network of monitoring wells. The current NHGS well network that provides data to the NGWMN Portal can be seen in Figure 1. These data are then exposed to the public through both our web services and a GIS web mapping application which displays the statistical analysis of the most recent groundwater level data. During the grant performance period, NHGS have been engaged with USGS to ensure our web services are operating and providing data to the NGWMN network. Specifically, over the last year NHGS has worked with the USGS New England Water Science Center to align statistical methods and to include NHGS' NGWMN sites on the interim replacement for the now discontinued USGS GroundWater Watch site. The Groundwater Levels

in New England website is operating, and now includes the NGWMN-funded wells in New Hampshire. Inclusion of the NHGS NGWMN data alongside other USGS monitored sites in New Hampshire has benefitted both the internal New Hampshire stakeholders and federal partners at the NWS and US Drought Monitor map authors.

Objective 3: Network Data Gap Filling

Under Objective 3, NHGS proposed to fill gaps in information at 3 new NGWMN sites drilled under Objective 5 of this proposal to replace NHGS:CVW-04, NHGS:FKW-01 and NHGS:CTW-73. These activities were completed in October 2022 soon after installation of new NGWMN wells NHGS:CVW-04R, NHGS:FKW-01R and NHGS:CTW-73R. Lithology determined during drilling, well construction details, and elevation and GPS survey positions were captured to determine the vertical and horizontal locations of the replacement wells. The GPS and elevation data were entered into the NGWMN Well Registry, and lithology and construction details have been made available to NGWMN through our web services. Slug testing was conducted in NHGS:CVW-04R, NHGS:FKW-01R and NHGS:CTW-73R to empirically determine hydraulic conductivity in the new wells. Testing was conducted using a steel slug and a barometric water level logger recording at high-frequency.

Objective 4: Network Well Maintenance Activities

NHGS proposed to perform an extension of the protective well casing that is part of well LCW-01 and resurvey the elevation of the measurement point. The replacement well casing was purchased in March 2022 and installed in April 2022. The elevation of the new measurement point and GPS coordinates of the well were recorded and have been updated in the NHGS database and NGWMN Well Registry.

Objective 5: Drill Well Replacement for 3 Network Wells

NHGS proposed the replacement of network wells CVW-04, FKW-01 and CTW-73. Over the past year NHGS has:

- Finalized the locations for the 3 replacement wells.
- Negotiated access agreements on two State of New Hampshire-owned properties and a property owned by a charitable organization.
- Solicited bids and selected a drilling contractor to perform the well installation.
- Entered into a contract with the selected drilling contractor.
- Completed installation of replacement wells NHGS:CVW-04R, NHGS:FKW-01R, and NHGS:CTW-73R.
- Calculated initial well hydraulic conductivity for each replacement well.

- Monitored groundwater levels at both the existing and replacement wells in tandem for 12-months.

The replacement overburden well sites are located in the same mapped surficial geologic units as the existing wells. Drilling logs and samples retrieved during drilling show the stratigraphy at the replacement wells are consistent with the glaciofluvial deposits at wells NHGS:FKW-01 and NHGS:CTW-73, and consistent with the glaciolacustrine deposits at well NHGS:CVW-04. Replacement wells NHGS:CVW-04R, NHGS:FKW-01R, and NHGS:CTW-73R were installed to depths of 35, 38, and 40 feet below ground surface, respectively. Each well was constructed with 10-feet of screen. A surface protective casing was installed at each well.

Tandem monitoring for 12 months was conducted in Concord and Franklin in the existing and replacement NGWMN wells. Access to the existing NGWMN well in Colebrook was denied by a landowner whose land had to be crossed to access the well, which prohibited tandem monitoring at this location. Of the two sites that will provide the opportunity to correlate the groundwater records of each paired well through a full water year, the Franklin wells (NHGS:FKW-01 and NHGS:FKW-01R) were found to have perfect linear correlation (Pearson correlation coefficient of 1). The mean \pm standard deviation of offset between paired groundwater level measurements at the two sites was determined to be 0.3 feet, as shown in Figure 2a. The relationship between measurement in both wells is described by the formula of regression line fit to the correlation plot, where $FKW-01R = 0.98 * FKW-01 + 0.55$. The historic groundwater level record from FKW-01 measured between 1966 and September of 2022 is now being associated with the nearby replacement well FKW-01R. The Concord wells (NHGS:CVW-04 and NHGS: CVW-04R) were found to have moderate linear correlation (Pearson correlation coefficient of 0.674). The mean \pm standard deviation of offset between paired groundwater level measurements at the two sites was determined to be 12.1 feet, as shown in Figure 2b. Additional tandem groundwater level measurements at the two sites are needed to determine if the historic record from NHGS:CVW-04 can be associated with NHGS:CVW-04R.

Slug testing was conducted in replacement wells NHGS:CVW-04R, NHGS:FKW-01R, and NHGS:CTW-73R in April of 2023. Subsequent analysis of the slug-testing data was conducted using AQTESOLV v4.5 software. Hydraulic conductivity (K) was determined using the straight-line methods of Bouwer and Rice (1976) for unconfined aquifers from an overdamped slug test. Multiple slug-in (falling head) and slug-out (rising head) tests were conducted in each well, and the K values determined for each well are presented in Table 1. The mean K values vary between the three new wells that were drilled in this project, and are likely attributable to the different transmissivity of overburden materials that the wells were completed in. The screened portion of NHGS:CVW-04R is installed in a glaciofluvial silt and clay surficial deposit. A mean hydraulic conductivity value of 0.11 feet/day (3.9×10^{-5} cm/sec) was determined from slug

testing in NHGS:CVW-04R, which is reasonable value for a silt and clay aquifer. The screened portion of NHGS:FKW-01R is installed in a well-sorted sand surficial deposit. A mean hydraulic conductivity value of 34.12 feet/day (1.2×10^{-2} cm/sec) was determined from slug testing in NHGS:FKW-01R, which is reasonable value for a well-sorted sand aquifer. The screened portion of NHGS:CTW-73R is installed in a silty sand, sand, and gravel surficial deposit. A mean hydraulic conductivity value of 12.83 feet/day (4.5×10^{-3} cm/sec) was determined from slug testing in NHGS:CTW-73R, which is reasonable value for a silty sand to gravel surficial aquifer (Freeze and Cherry, 1979).

Table 1. Hydraulic Conductivity from slug tests in NHGS:CVW-04R, NHGS:FKW-01R, and NHGS:CTW-73R

Well	Test #	Test Type	Solution	Aquifer Model	Calculated K (feet/day)	Calculated K (cm/sec)
NHGS:CVW-04R	1	Falling Head	Bouwer-Rice	Unconfined	0.109	3.8×10^{-5}
NHGS:CVW-04R	2	Falling Head	Bouwer-Rice	Unconfined	0.109	3.8×10^{-5}
NHGS:CVW-04R	3	Rising Head	Bouwer-Rice	Unconfined	0.111	3.9×10^{-5}
Mean Hydraulic Conductivity (\pm std. dev.)					0.110 (\pm 0.0012)	3.9×10^{-5} (\pm 4.1×10^{-7})
NHGS:FKW-01R	1	Falling Head	Bouwer-Rice	Unconfined	35.18	1.2×10^{-2}
NHGS:FKW-01R	2	Falling Head	Bouwer-Rice	Unconfined	33.68	1.2×10^{-2}
NHGS:FKW-01R	3	Falling Head	Bouwer-Rice	Unconfined	33.51	1.2×10^{-2}
Mean Hydraulic Conductivity (\pm std. dev.)					34.12 (\pm 0.92)	1.2×10^{-2} (\pm 3.2×10^{-4})
NHGS:CTW-73R	1	Falling Head	Bouwer-Rice	Unconfined	13.03	4.6×10^{-3}
NHGS:CTW-73R	2	Falling Head	Bouwer-Rice	Unconfined	13.11	4.6×10^{-3}
NHGS:CTW-73R	3	Rising Head	Bouwer-Rice	Unconfined	12.34	4.4×10^{-3}
Mean Hydraulic Conductivity (\pm std. dev.)					12.83 (\pm 0.42)	4.5×10^{-3} (\pm 1.5×10^{-4})

References:

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Bouwer, H., 1989. The Bouwer and Rice slug test--an update, Ground Water, vol. 27, no. 3, pp. 304-309.

Freeze, R.A., and J.A. Cherry, 1979. GROUND-WATER. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 604 pp.

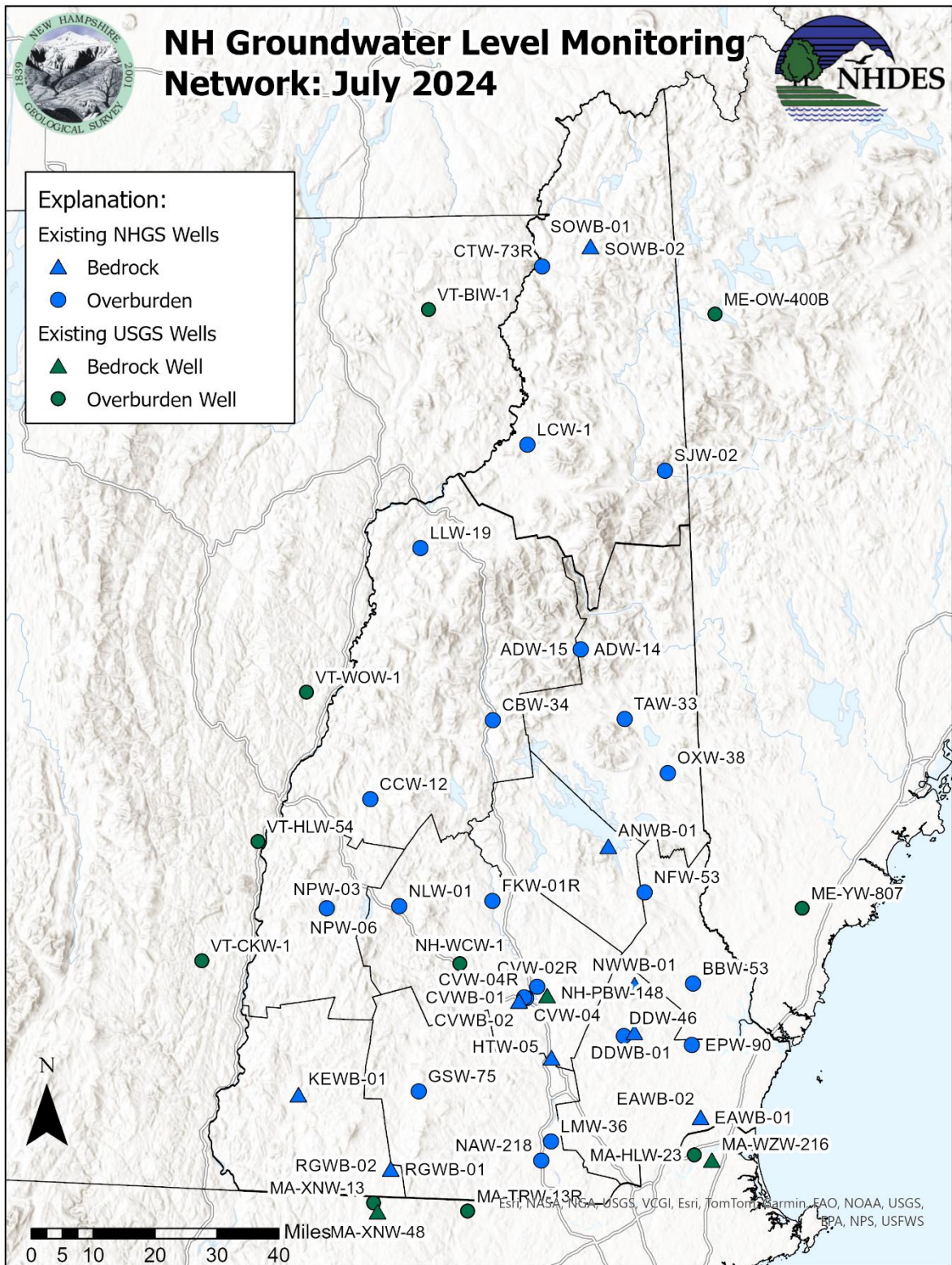


Figure 1 – Existing NHGS and USGS Groundwater Level Monitoring Network wells that are part of NGWMN in and near New Hampshire.

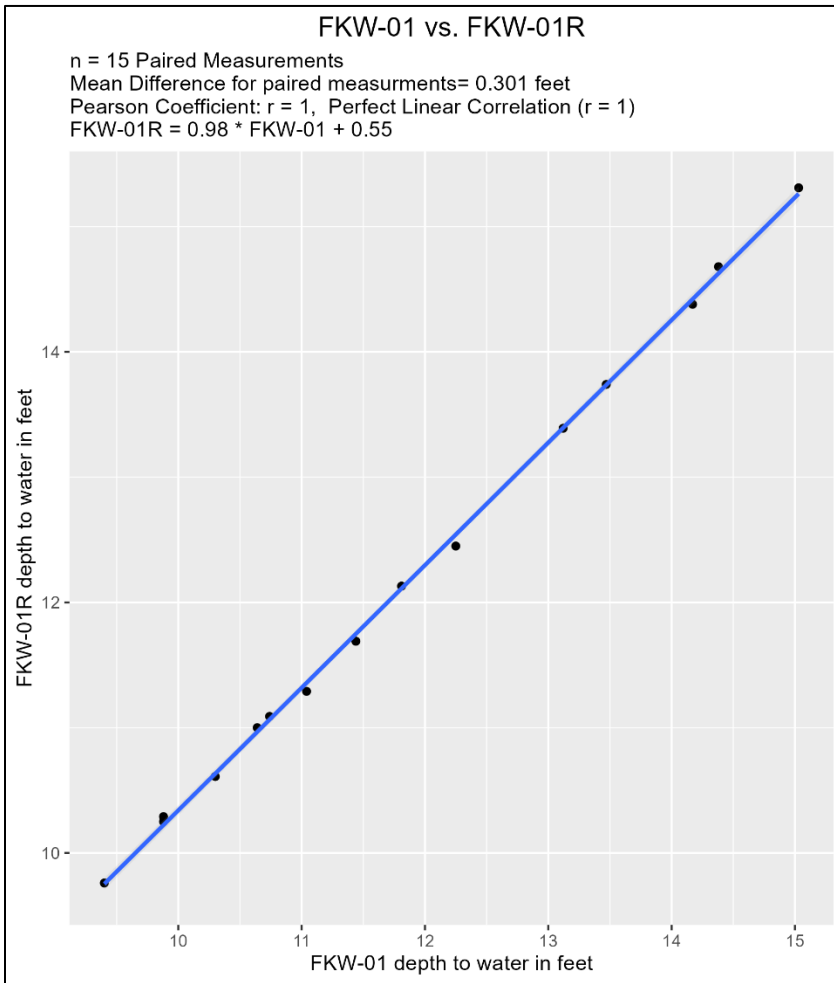


Figure 3a - Double mass plot showing paired groundwater level measurements collected over 12 months in NHGS:FKW-01 and NHGS:FKW-01R. A perfect linear correlation ($r=1$) exists between the two monitoring wells, with a mean offset of 0.3 feet.

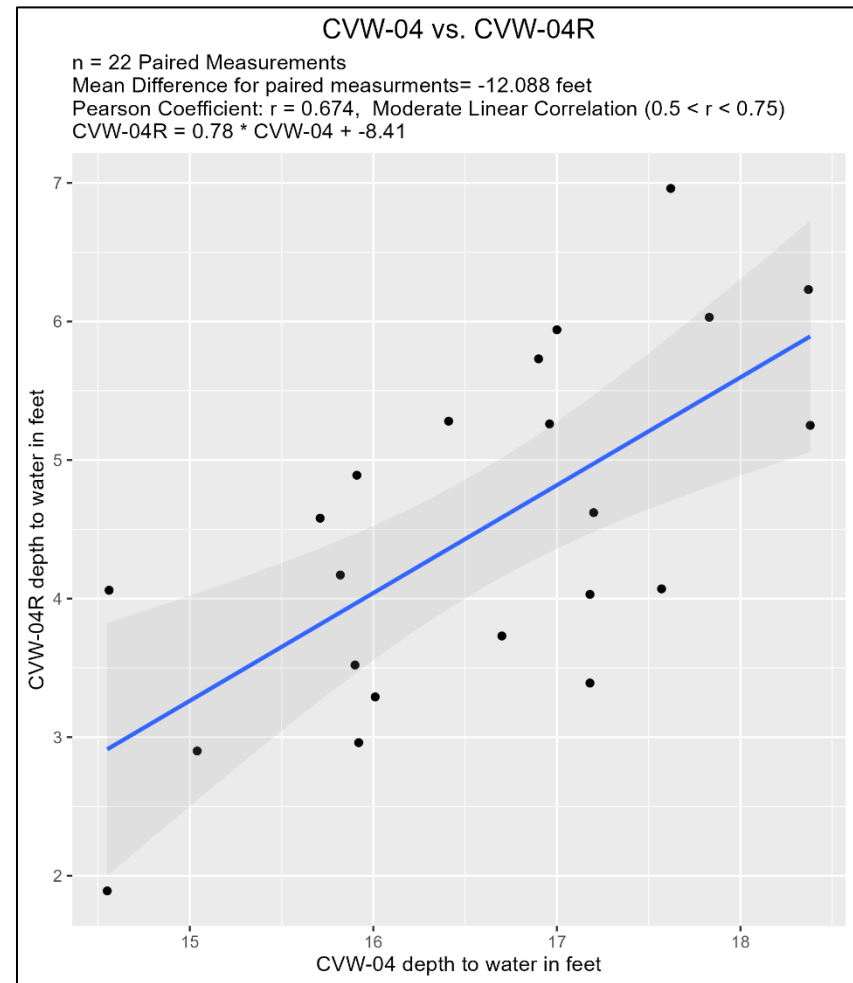


Figure 2b - Double mass plot showing paired groundwater level measurements collected over 12 months in NHGS:CVW-04 and NHGS:CVW-04R. A moderate linear correlation ($r=0.674$) exists between the two monitoring wells, with a mean offset of 12.09 feet.