New Sites and Gap Filling at New Sites in the Maine Groundwater Level Monitoring Network

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Introduction

The Maine Groundwater Monitoring Network was created by the Maine Geological Survey (MGS) in 2017 by a selection of 32 wells at 22 unique site locations that are monitored by the Maine Department of Environmental Protection (MEDEP). This selection was made specifically for inclusion in the National Groundwater Monitoring Network (NGWMN), and the work was performed under a US Geological Survey (USGS) cooperative agreement (Award Number G16AC00077). In 2018-2021, MGS performed further work on the NGWMN under Award Number G18AC00079 to fill information gaps about existing network wells and maintain network operations.

In 2020, MGS was awarded additional funding from the USGS to add new wells to the network and collect information about the new wells (Award Numbers G20AC00178 and G20AC00381). Project tasks included maintaining the current network infrastructure and connections, adding new wells to the network, and filling gaps in information at the new sites (Objectives 2A, 2B, and 3, respectively, as described in the Program Announcement document). Because the two projects awarded in 2020 were conducted concurrently and focused on the same set of wells, this report serves as the Final Technical Report to the USGS for both awards G20AC00178 (Objectives 2A and 2B) and G20AC00381 (Objective 3).

Description of work

Overall, the project was very successful. During the first field season in 2021, we researched and then visited the locations of 24 potential wells that were described in our proposal or were located nearby. For wells that were still in existence, we measured dimensional, spatial, and water level data to collect information required for the NGWMN. We ultimately selected 9 existing wells for inclusion in the network, and returned to these wells in 2022 with a survey-grade GPS system and a down-hole video camera to take visual logs of the well casing, screens, and lithology where exposed. Water levels were measured between 1 and 3 times in each well at field visits during the project period. As part of our support and maintenance work, we made improvements to our internal database, diagnosed and repaired two issues with database connections that were preventing timely updates to our web services, and kept up to date the list of sites and attributes in the well registry and MGS databases.

Objective 2A: Support and maintenance of persistent data services

Goals of the support and maintenance objective included maintaining our database infrastructure and connections to EGAD and ArcServer, maintaining our web services and updating them as needed, keeping the list of sites in the well registry and our database current, and routine updates to site information in our existing network of sites.

Well removals and replacements

There were no existing wells removed from Maine's contribution to the NGWMN during the project period. We did modify the well registry to remove the 20 proposed wells (prop01

through prop20) that were created in the registry only (but never displayed on the portal) for the purpose of our proposal and replaced these with the 9 new wells (1001 through 1009) described below in Objective 2B. Of the 9 new wells, seven were from the proposed list. Table 1 lists the proposed wells that were removed from the registry, and Table 2 lists the new wells that were added as a result of this project. The map in Figure 1 shows the locations of the new wells from Table 2.

Table 1. Proposed wells removed or replaced in the NGWMN registry.

proposed SiteNo	name	selected for network?	new SiteNo
prop01	Maine Yankee	No	
prop02	Stonington 4	Yes	1003
prop03	Sugarloaf 2 (SWA-2)	Yes	1004
prop04	Sugarloaf 6 (SWA-6)	No	
prop05	Moose Run 2	Yes	1005
prop06	Pretty Barrens 10-inch	No	
prop07	Pretty Barrens 3	No	
prop08	Chewonki East Pasture	Yes	1007
prop09	McFarland Hill	No	
prop10	Crooked Road	No	
prop11	Norways	No	
prop12	Pretty Pond 99-59	Yes	1006
prop13	Duck Pond 99-65	No	
prop14	OW 89-3	Yes	1008
prop15	OW 89-6	No	
prop16	OW 90-7	No	
prop17	OW 90-17	No	
prop18	OW 93-7	No	
prop19	OW 93-6	Yes	1009
prop20	Moosehorn	No	

Table 2. New wells added to the network during the project.

SiteNo	proposed SiteNo	Name	Latitude	Longitude	Depth (ft)	National Aquifer
1001		Rolling Dam Tall	44.19665884	-69.76195728	59.33	Sand and gravel aquifers (glaciated regions)
1002		Allen House	43.87588707	-69.31194324	249.50	New England crystalline-rock aquifers
1003	prop02	Stonington 4	44.17027965	-68.68457139	395.17	New England crystalline-rock aquifers
1004	prop03	SWA-2	45.05038995	-70.29552385	567.96	New England crystalline-rock aquifers
1005	prop05	Moose Run 2	44.81798583	-67.88943089	494.00	New England crystalline-rock aquifers
1006	prop12	Pretty Pond 99-59	44.83108595	-67.90574913	51.37	Sand and gravel aquifers (glaciated regions)
1007	prop08	East Pasture	43.94458665	-69.71564536	384.64	New England crystalline-rock aquifers
1008	prop14	OW 89-3	44.55741766	-70.71141543	31.35	Sand and gravel aquifers (glaciated regions)
1009	prop19	OW 93-6	44.94287167	-68.39518024	62.39	Sand and gravel aquifers (glaciated regions)

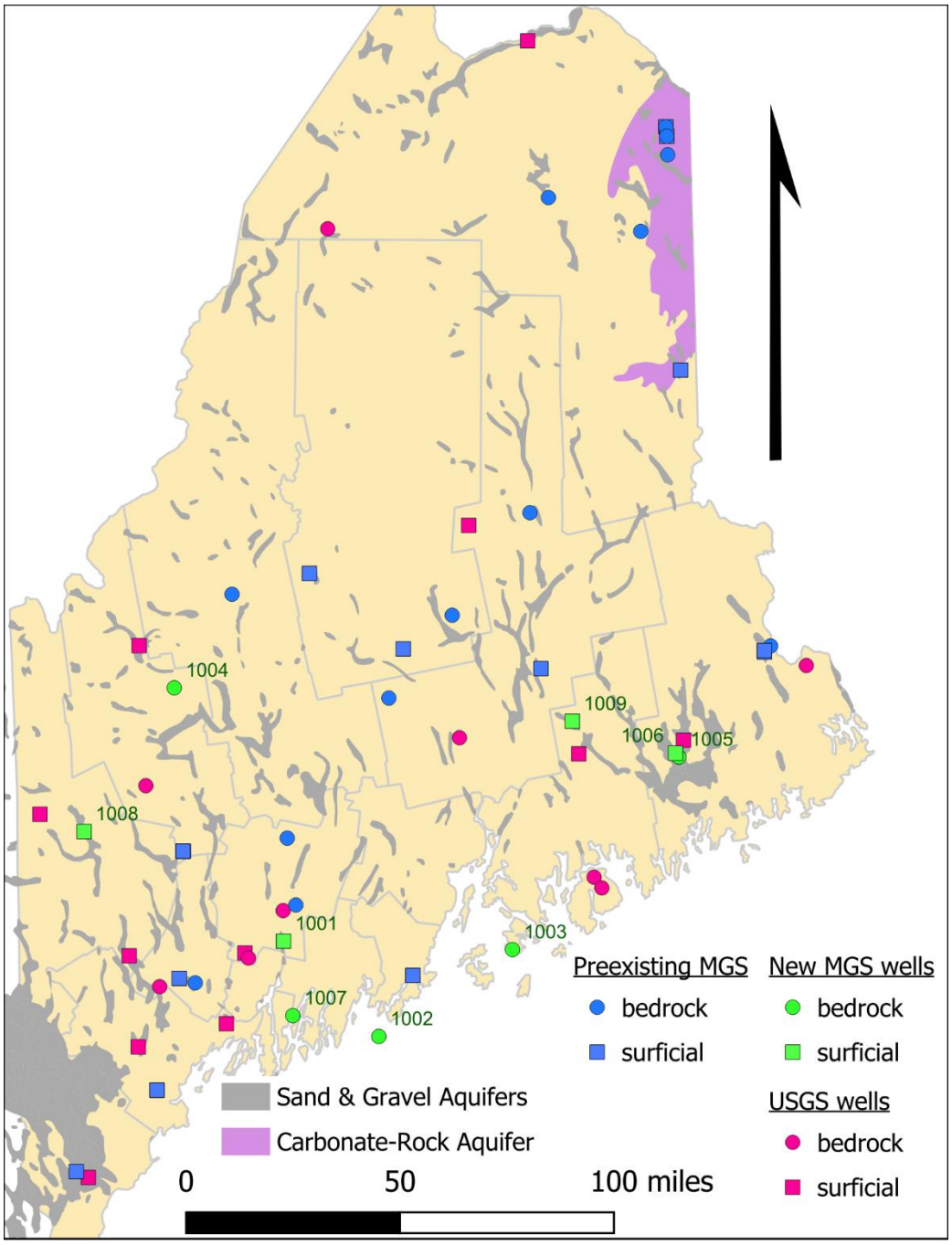

Figure 1. New wells added to the NGWMN as a result of this project (green symbols with NGWMN site numbers 1001 through 1009). Area not marked as Carbonate-Rock Aquifer is underlain by bedrock of the New England Crystalline-Rock Aquifer.

Internal database modifications

During the work period, we initiated a project to make improvements to our internal database and data entry interface. The purpose of these improvements was to make it possible to

add wells to our network that do not appear in the MEDEP's EGAD database, so that we could add the new wells to the NGWMN as described in Objective 2B. As part of these changes, we added the ability to enter our own water level observations to any well, and the ability to import data downloaded from pressure transducer data loggers. We also made improvements to the quality control component of the interface. Now wells monitored and maintained by both MGS and MEDEP can coexist in our database and be served identically to the NGWMN Portal using our preexisting web services.

Changes to IT infrastructure and problems serving data to the NGWMN

During the project period, there were two instances when the MEDEP or State IT administrators upgraded the Oracle database version or database connection methods, which required us to update the client drivers and configuration that are used when fetching data from the EGAD database to the MGS database. These changes caused limited periods of time (several days) when new data were not delivered to MGS for quality control processing but caused no downtime to our NGWMN web services. Otherwise, there were no problems encountered serving data to the NGWMN Portal.

Updates to web services

Besides the changes to internal database connections and procedures, described above, there were no changes made to the external-facing web services during the project period.

Future changes to web services

We do not anticipate any changes in the near future to our databases or web services that would impact integration with the NGWMN Portal.

Objective 2B: Add new wells to the NGWMN

Goals of the new well objective was to add approximately 10 new wells to the NGWMN that were known to MGS from previous projects but are not monitored by the MEDEP and do not appear in the EGAD database. Ultimately, 9 new wells were added to the NGWMN as a result of this objective.

Identification and selection of new wells

Our proposal for this project identified 20 potential wells that were known to MGS from previous projects such as aquifer mapping and geothermal logging studies (Table 1), and we added several more potential wells to the list after the proposal was submitted or as we explored field areas. During the field component of the project, we visited the locations of 24 potential wells. We found that many wells that were known from past years were missing, damaged, or destroyed, especially wells from our sand and gravel aquifer mapping efforts. These wells were often installed in farm fields, gravel pits, or other areas with active machinery and human modifications. Several other potential wells were not selected because of issues with access or landowner permission.

When wells were found to exist and in good condition, we documented the wells and environs with notes and photographs, and we measured the depth to water in feet using an electric tape measure with a resolution of $1/100^{th}$ ft. We noted and investigated any potential groundwater or surface water withdrawals in the surrounding area. Some wells were not selected because we determined that nearby groundwater pumping might be likely in the future.

Ultimately, after the documentation and classification tasks described below, we selected 9 new wells for addition to the NGWMN (Table 2 and Figure 1). Four of the 9 are completed in surficial sand and gravel aquifers, including eskers (wells 1001 and 1009), glacial outwash (1006), and river terrace (1008), and the remainder are drilled bedrock wells in intrusive granite or diorite plutons (1003, 1004, and 1005) or metasedimentary units (1002 and 1007). Two of the bedrock wells are near the ocean in areas that may experience saltwater intrusion (1002, on a narrow peninsula, and 1007, on a small ocean island). These selections filled many of the gaps in aquifer coverage that we had previously identified and caused us to initiate this project, and the new wells will help MGS meet monitoring and research needs in the State of Maine going forward.

Documentation of required data elements

For each selected well and for many that we did not end up selecting, we compiled the required data elements listed in the "Tip Sheet on Minimum Data Requirements for Candidate Sites". Some of these came from direct observation of the well in the field, but most came from preexisting documentation about the wells, including drilling and geophysical logs. We were not able to acquire logs of lithology for 5 of the wells (1001, 1002, 1003, 1004, and 1007); however, all but one of these (1001) had open bedrock bores that were observable using the video camera used in Objective 3, below. We also compiled information about the mapped units surrounding the wells from MGS bedrock, surficial, and aquifer maps.

Classification of sites into Subnetworks and Monitoring Categories

The selected wells were classified into monitoring categories using guidance from the NGWMN Framework Document and the "Tip Sheet on Defining Monitoring Categories". We determined that all 9 are appropriate for "trend" monitoring, because we are committing to quarterly or continuous monitoring, and the new wells are fairly evenly distributed within the state's primary aquifers at an appropriate density according to the NGWMN well density spreadsheet. All 9 new wells have been entered as trend wells in the NGWMN registry.

None of the selected wells have completed their 5-year baseline process, as specified in the "Tip Sheet on Defining the Subnetwork"; however, we anticipate that many if not all of them will end up in the Background Subnetwork. To the best of our ability, we determined that the wells are in areas where anthropogenic effects (e.g., withdrawals, urbanization, etc.) are limited or non-existent. We have begun the 5-year baseline process with this project, and will observe the records as we continue to collect water level readings. We will determine the final classification when the baseline period is complete, as specified in the Framework Document.

Populate the NGWMN Well Registry with site and network information

At this time, all required data elements have been entered into the NGWMN Well Registry using the Well Registry Management System and we are currently serving data for the new wells through our web services.

Objective 3: Fill gaps in information at new well sites

The goal of the gap-filling objective was to collect additional information about the wells that were not collected in the original selection work described above in Objective 2B. Information gaps that were filled included land surface and measuring point altitudes, latitude and longitude, casing diameter and material, screen length and dimensions, and lithology. Gap-filling tasks involved fieldwork to survey well and measuring point locations using a survey-grade real-time kinematic (RTK) global positioning system (GPS), take physical measurements and observations of the well dimensions and materials, and perform a down-hole submersible video camera survey to collect information about lithology, well competence, well casings, and screens. All tasks were completed at all 9 of the new wells indicated in Table 2.

GPS survey of measuring points

At all new wells, we used a survey-grade global navigation satellite system (GNSS) to survey the water-level measuring point on the top of the well casing, collecting latitude, longitude, and elevation in the NAD83(2011) horizontal and NAVD88 (Geoid 12B) vertical datums. The GNSS equipment consisted of a Leica GS14 smart GPS antenna mounted on a leveling rod or tripod and a Leica CS15 field controller (Leica Geosystems AG).

At all the surveyed wells, cellular data connections were available and the GNSS system was able to use real-time kinematic (RTK) correction using base station information from the Continuously Operating Reference Station (CORS) network maintained by the Maine Department of Transportation. The RTK corrections allowed us to collect precise locations with an average accuracy of 0.007 meters horizontally and 0.012 meters vertically.

As a result of this surveying work, information gaps related to spatial location, elevation, location accuracy, survey method, and vertical datums were eliminated for all the new wells.

Measurement of physical well dimensions and materials

At all new wells, we recorded physical observations and measurements of the wells and their environment. We measured the height of the measuring point (surveyed in Task 1) above the ground surface, the diameter of the well casing, the depth to water using an electric water level measuring tape, and the depth to the bottom of the well using a weighted fiberglass tape measure. We recorded the casing material, a description of the measuring point, and other dimensional notes and observations about the well. We also recorded observations about site and well access and the condition of the well, and took photographs of the well and immediate environment.

As a result of this task, information gaps related to the casing material, casing diameter, casing stickup (difference between measuring point and ground surface elevations), and well depth were eliminated for all new wells.

Down-hole camera inspection for well screens and lithology

At all new wells, we recorded color digital videos of the well casings, screens, bores, and bottoms. The video system consisted of a submersible GeoVISION Nano Camera (Alleghany Instruments, Inc.) suspended on a graduated cable with a digital depth encoder.

At each well, we set up the camera so that the lens was positioned three feet below the monitoring point, zeroed the depth counter, then began recording video while lowering the camera slowly to the bottom of the well. At interesting or ambiguous locations, the camera could be raised and lowered repeatedly to get better views of the casing, screen, or bore. The videos were saved as mp4 digital video files, and the depth encoder printed the camera depth in feet at the corner of the videos, so that the depth of observed features was recorded. By taking notes and recording voice observations in the field and watching the recorded videos later in the office, we were able to use this system to record the depths of casings, screens, and lithologic features (rock type and features, contacts, fracture zones), and to observe the screen material and size. For the 5 bedrock wells with uncased bores, the camera inspection allowed us to create detailed lithologic logs with descriptions of rock type, color, texture, and fractures that were observable on the walls of the well bore.

As a result of this task, information gaps related to casings and screens were eliminated for all new wells, and information gaps related to lithology were eliminated for all wells but one: we were not able to acquire any information about the lithology for the one fully cased surficial well for which we found no drilling log (well 1001). Lithology for this well remains unknown, but it is assumed from the surrounding geology and the well depth to be completed fully within a cobble-gravel-sand esker.

Quality control and data entry

All project data were collected and stored in accordance with the Data Management Plan from our original proposal. Spatial data were collected in digital form and stored as latitude, longitude, and geodic and orthographic elevation coordinates in known datums. Manual measurements were recorded on paper field sheets that were later digitized and stored. Videos of the well camera inspections were recorded by a digital video recorder on an SD flash card and then transferred to our network storage in the office, where they remain archived in a common video format (MP4, or MPEG-4 H.264). The videos include on-screen depth values provided by a digital depth encoder and are accompanied by voice recordings taken in the field and transcriptions of field notes. Final data elements for the NGWMN were entered into the appropriate locations in the MGS monitoring database and NGWMN registry by MGS staff. MGS hydrogeologists reviewed the final information for errors and inconsistencies before publishing it to the NGWMN portal through our web services.

Conclusion

Maine's NGWMN Projects G20AC00178 and G20AC00381 conducted September 1, 2020 through February 28, 2023 and December 30, 2020 through December 29, 2022 were very successful. Project tasks that were completed included the addition of 9 new wells to the Maine Groundwater Monitoring Network and the NGWMN, the filling of information gaps for these 9 wells, and the maintenance of network infrastructure including internal databases, web services, and the Well Registry. At this time, we are currently serving data for a total of 37 wells in Maine through our web services to the NGWMN portal. As a result of this project, several important monitoring locations have been added to the network in Maine, and we are excited to continue monitoring at these sites to collect water level data far into the future.