

Technical Memorandum

To: Saint-Gobain Performance Plastics
From: Barr Engineering Co.
Subject: Recommended Design Specifications for New and Replacement Wells: Bennington, VT
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This memo describes recommended design specifications for new or replacement potable water supply wells (potable wells) in the Bennington area, specifically within Corrective Action Areas I and II (CAAI and CAAIL)¹. The recommended design specifications are based on available results of the potable well replacement pilot study (Pilot Study) performed as described in the *Revised Work Plan - Domestic Water Well Replacement: Bennington, Vermont* (Work Plan) (Barr, 2017), which have shown reductions in per- and polyfluoroalkyl substances (PFAS) concentrations in replacement wells relative to the corresponding original wells. The recommendations include well design specifications that supplement what is required by the *Vermont Agency of Natural Resources – Department of Environmental Conservation, Environmental Protection Rules, Chapter 21* (Water Supply Rule). The current well construction requirements in the Water Supply Rule that are pertinent to these recommendations for additional design specifications in CAAI and CAAIL are discussed in this memo.

Due to variability that results from a number of factors, a potable well that is constructed to the recommended specifications may or may not have PFAS concentrations below the associated regulatory standard, i.e., the Groundwater Enforcement Standard for PFAS in the State of Vermont's Groundwater Protection Rule & Strategy, adopted July 6, 2019; and may or may not have concentrations below existing nearby wells.

Water Supply Rule Well Construction Requirements

The Water Supply Rule allows for the construction of potable wells using the driven-casing method in aquifers designated as Class I, Class II, or Class III groundwater as defined in the Groundwater Protection Rule & Strategy, revised July 6, 2019. The driven-casing method does not require installation of a grout seal in the annular space between the well casing and a drilled pilot hole, provided the pilot hole is a smaller diameter than the casing. If a pilot hole with a larger diameter than the diameter of the casing has been drilled below the depth of the frost line or pitless adapter, grouting of the annular space is required.

¹ This memorandum has been revised since it was originally published. Edits include changing references to "private well" to "potable well".

The Water Supply Rule requires that a minimum of 20 feet of water-tight casing be used to construct a well in bedrock or unconsolidated material. If a well is to be constructed in bedrock, the casing is required to be securely set into competent rock (no depth specified) or a minimum of 10 feet into competent rock for a drilled well. The depth to competent bedrock will vary depending on the conditions encountered during the normal course of drilling. The original wells in the Pilot Study were found to have casing set to depths ranging from above the top of competent bedrock to approximately 37 feet into competent bedrock, with over half the wells having casing extending 10 feet or less into competent bedrock. Annular seals were found to be in marginal to poor conditions.

The Water Supply Rule requires additional protective measures, such as additional casing, grouting of annular space, or other measures as specified by the Secretary of the Agency of Natural Resources or the Secretary's designee, when the location of the subsurface disposal field (e.g., septic leach field) cannot be determined or if meeting the minimum isolation distances specified in the Water Supply Rule is physically not possible. In accordance with the Water Supply Rule for wells requiring additional protective measures, grouting of the annular space along the full length of the unscreened portion of the casing or the portion below the frost line or pitless adapter is required so no fluids can move in the annular space.

Recommended Well Construction

The overall premise of the recommended well construction techniques for new or replacement bedrock wells is to seal off shallow groundwater that is likely in communication with the existing water well. The recommendations focus on the steel casing installed to maintain an open hole and the integrity of the annular space seal between the steel casing and the upper bedrock and unconsolidated materials. These recommendations are designed to limit shallow groundwater in the unconsolidated materials and upper portions of the bedrock from being drawn into the new or replacement well. Extending the casing depth and sealing the annular space with grout has been shown to reduce PFAS concentrations in the initial samples from wells replaced during the Pilot Study. The driven-casing construction method is not recommended for new or replacement wells in CAAI and CAII because an adequate seal between the casing and the borehole wall is not formed, thereby potentially allowing vertical flow of shallow groundwater to occur (Driscoll, F.G., 1986, *Groundwater and Wells*, 2nd ed., *Johnson Filtration Systems, St. Paul, MN.*), facilitating transport of shallow groundwater to deeper portions of the well.

Drilling the well boring using the cable tool method is not recommended due to the tendency to produce fractures in the bedrock that allow vertical flow of groundwater.

Completion of wells in unconsolidated materials is not recommended due to the potential presence PFAS at concentrations greater than the Regulatory Standard in shallow groundwater in CAAI and CAII.

Recommended well design specifications to supplement requirements of the Water Supply Rule include casing depth, borehole diameter, and casing grouting, as described below.

- Casing Depth
 - For new wells completed in bedrock, it is recommended that the casing extend at least 50 feet below the top of competent bedrock.
 - For properties with existing wells completed in bedrock, it is recommended that the casing for replacement wells be installed 30-50 feet below the base of casing in any original well. This will vary depending on how far the casing of the original well is set into bedrock. The total well depth of new wells may vary from the original well depth in order to provide sufficient yield and/or casing storage to meet water supply needs.
- Borehole Diameter and Annular Space
 - It is recommended that the borehole diameter be four inches in nominal diameter greater than the casing to be installed in order to create a 2-inch annular space around the casing. For example, when installing a 6-inch-diameter casing, a 10-inch-diameter borehole is recommended.
- Casing Grouting
 - It is recommended that the annular space between the borehole and the casing be fully grouted from the bottom of the casing to the bottom of the pitless adapter or frost line, whichever is deeper.

Due to site variability, no specific recommendation is made regarding total depth of the well, except that it be sufficiently deep to provide adequate supply for domestic use or other water supply requirements, either through well yield or wellbore storage. This is currently the common practice for construction of wells in the area.

Estimated Cost of Recommended Well Construction Practices

The estimated cost of the recommended well construction practices to supplement the Water Supply Rule are dependent on three main factors related to constructing an extended casing length: the depth of the casing, the diameter of the borehole in which the casing is set, and the amount of additional grout required for a deeper and larger diameter borehole for the casing. The variability in subsurface conditions across CAAI and CAII and flexibility of the Water Supply Rule leads to uncertainty in the approach to drilling and constructing wells in the area. Decisions related to construction methods and materials are typically made in real-time by the driller based on property-specific conditions, and costs will be substantially affected by these decisions. For this reason, accurately predicting construction costs of a new well cannot be done without location-specific information.

Accordingly, for purposes of illustrating the potential cost of the recommended well construction methods, we have provided unit costs for the three main factors identified above using recent unit costs provided by a Vermont-licensed well driller. The unit costs are outlined below.

Borehole Diameter for Casing and Depth:

- Cost for drilling a 10-inch borehole: approximately \$50 per foot.

Additional Casing:

- Cost for additional 6-inch casing installed beyond what would be installed following standard well construction practices (estimated to be 30 to 50 feet): approximately \$30 per foot.

Additional Grout:

- Cost for grouting the length of additional 6-inch casing (estimated to be 30-50 feet): approximately \$10 per foot.

When compared to a driven-casing well (allowed by the Water Supply Rule, but not recommended for new or replacement wells), the increased costs resulting from the recommended well construction methods would include, but may not be limited to:

- Drilling a borehole 4-inches in diameter larger than the casing for the full depth of the casing,
- Installing an estimated additional 30-50 feet of casing into competent bedrock, and
- Fully grouting the casing up to the pitless adapter or the frost line, whichever is deeper.

Costs to manage and dispose of soil cuttings and groundwater produced during well construction and development activities are not included and will depend on requirements to be set by the State of Vermont.

Costs to install a new pump and associated drop pipe are not included and will depend on the depth of the well, depth to water in the well, and distance from the well to the house.

Also, costs to connect the replacement well to the home's existing water supply, and to seal the existing well with grout are not included.