



North Central Massachusetts Private Well Program Pilot

# EVALUATION REPORT

January 15, 2022

Kim Dash, PhD, MPH  
Education Development Center

With funding from the Health Foundation of Central Massachusetts



# Table of Contents

<b>Introduction</b> .....	<b>2</b>
<b>Key Stakeholders</b> .....	<b>2</b>
<b>Program Elements</b> .....	<b>2</b>
<b>Main Questions</b> .....	<b>5</b>
<b>Data Collection</b> .....	<b>7</b>
<b>Analysis</b> .....	<b>9</b>
<b>Results</b> .....	<b>9</b>
<b>Implications</b> .....	<b>16</b>
<b>Citations</b> .....	<b>18</b>
<b>Appendices</b> .....	<b>19</b>
A. North Central MA Private Well Program Stakeholders .....	19
B. Household Pre- and Post-Questionnaires .....	22
C. Additional Tables .....	33
1. Number of Households by Town Interested and Participating in the Pilot Program .....	33
2. Percentage of Households Satisfied with Pilot Program, by Town .....	33
3. Household Questionnaire Pre/Post Item Response .....	34
4. Pre/Post Differences in Household Private Well Belief Scores by Item .....	35

## Introduction

The Centers for Disease Control and Prevention (CDC) Evaluation Framework (CDC, 1999) guided the RCAP Solutions' evaluation of its North Central MA Private Well Program. This framework outlines five critical steps in the evaluation process:

- 1. Involve key stakeholders** including those who will be implementing program elements; those served or affected by the program; and primary users of evaluation results.
- 2. Describe the program elements** including the need, expected effects, activities, resources, stage, context, and logic model.
- 3. Focus the evaluation design with key questions** to assess the issues of greatest concern to stakeholders while using time and resources as efficiently as possible.
- 4. Collect credible data**—keeping in mind quality, quantity, sources and limitations of available data—to strengthen evaluation judgments and the recommendations that follow.
- 5. Justify results** by linking them to the evidence gathered and judging them against agreed-upon values or standards set by the stakeholders.
- 6. Ensure use and share lessons learned** during all phases of the pilot evaluation—from design to dissemination of results and consider implications for policy and scaling.

In addition to following the steps above, methods adhered to sets of standards that determined the quality of program evaluation efforts (CDC, 1999). Specifically, the pilot evaluation: produced results that were useful to RCAP's various stakeholders, helping inform regulatory decisions about private well testing that has administrative, health, and economic impacts; was realistic to implement given the time constraints, data available, and budgetary requirements; was conducted with oversight from EDC's Human Protections Administrator to protect the rights and welfare of those involved in the evaluation and those affected by its results; and conveyed accurate and credible information about the merits of the North Central MA Private Well Program.

## Key Stakeholders Informed Program Development and Evaluation

To ensure that the North Central MA Private Well Program and its evaluation were responsive to local needs and likely to be implemented with greater success, RCAP Solutions engaged multiple stakeholders who have different roles and interests in program implementation and evaluation. Many of these organizations and their representatives were involved during the planning phase of the Program. Appendix A provides a list of key stakeholders and describes how they helped inform program implementation and evaluation.

## Program Elements Address Key Risk Factors and Local Needs

The North Central MA Private Well Program and evaluation were informed by a logic model that depicted the shared relationships among the problem RCAP was trying to address; factors contributing to this problem; activities to address those factors; tangible products, capacities and deliverables that resulted from the activities; and changes that occurred because of the activities and outputs. The Program's logic model also acknowledged contextual factors that are out of control of the program but may help or hinder achievement of the anticipated outcomes.

As shown in the logic model, RCAP designed the Private Well Program to address high rates of well-water contaminants in North Central MA, where private well testing and remediation rates are relatively low. These low rates of testing and remediation are associated with multiple factors. First, evidence from other states shows that residents may not be aware of potential contaminants in their private wells, do not see themselves as likely to get sick if they drink the water, do not know how often they should test their well water or how they might go about doing that, and/or live in communities with low testing norms (e.g., Flanagan, Marvinney, & Sheng, 2015; Imgrund, Kreutzwiser, & de Loe, 2011; Munene et al, 2020). Second, while some homeowners in MA do have their well water tested, most of this testing is conducted by private companies at the homeowner's request; and information on such testing and results are not tracked in any systematic way. Therefore, MA does not have a complete picture of contaminants by town nor any understanding of how often such tests are completed in regions suspected to be at high risk for groundwater contamination. Moreover, many homeowners are not able to pay for remediation when their well water tests indicate that contaminants are present. Thus, it is possible that homeowners forgo testing knowing that they will not be able to afford to address any problems found.

Further complicating matters, private well testing regulations vary by town. Evidence from New Jersey that, since 2002, has required arsenic testing during real estate transactions, shows that this testing requirement results in identification of significantly more wells with arsenic. The proportion of wells identified by respondents as having an arsenic problem was five times higher among those who faced requirements (20% vs. 4%), in an area where an estimated 21% of wells exceed MCL (Flanagan et al, 2016). Only two towns in North Central MA have model private well regulations such as those found in New Jersey.

During the planning phase, RCAP solutions and its partners designed a program to address the myriad factors that contribute to lack of private well testing and remediation in North Central MA. Education, that includes educational materials for homeowners, renters, buyers, and realtors on sound wellhead protection and well remediation as well as in-person outreach and well water assessment are designed to address resident health beliefs about the importance of sound well structure, well water testing and remediation. Sustained community engagement efforts to support private well testing and follow-up actions are necessary, particularly among socially and biologically vulnerable populations, as evidence indicates that, even when model regulations such as those in NJ are in place, only a fraction of wells are likely to be tested due to the slow pace of housing turnover (Zheng & Flanagan, 2017).

Still, development of and advocacy for model well regulations as well as testing, reporting, and data collection guidelines based on those implemented in other states such as New Jersey should address issues with sporadic testing and limited data sharing that currently is not supported by best practice in well water sanitation. For example, New Jersey maintains a database of over 35,000 private well tests for arsenic, geocoded at fine-scale, which serves as a significant resource for follow-up with residents whose water supply puts them at increased health risk (Zheng & Flanagan, 2017). To that end, RCAP Solutions worked with key stakeholders (see Appendix A) to develop and adopt new statewide private well regulations based on model guidelines as well as lessons learned during the piloting of the North Central MA Well Program. Finally, to address costs associated with remediation, RCAP Solutions offered intensive review of positive test results and their meaning as well as financial counseling on cost-effective ways to address contamination issues.

### Figure 1. North Central MA Private Well Program Logic Model

**Problem:** Relatively high rates of well-water contaminants and low rates of testing and remediation in North Central MA

Contributing Factors	Activities	Outputs	Short-term Outcomes	Long-term Outcomes
Low perceived risk; lack of awareness about importance of testing or what to test for	Education that includes: Online curriculum & educational materials for homeowners, renters, buyers, realtors re: sound wellhead protection & well remediation; BOH Staff training on outreach and well water assessment	<ul style="list-style-type: none"> <li>• # of educational materials distributed</li> <li>• # of homeowners, buyers, realtors, renters participating</li> <li>• # of staff trained to conduct outreach and assessments</li> </ul>	<ul style="list-style-type: none"> <li>• Changes in resident knowledge, beliefs, and practices related to well safety</li> </ul>	More educated private well owners in the state
Sporadic testing done by private companies & mainly at request of homeowner	Adopt state model well regulations which includes well testing guidelines	<ul style="list-style-type: none"> <li>• # and % and location of well's tested</li> <li>• # of refusals</li> </ul>	<ul style="list-style-type: none"> <li>• Increase in # of wells tested for DEP-advised contaminants</li> <li>• Increase in # of positive tests for contaminants</li> </ul>	<ul style="list-style-type: none"> <li>• Increase in regular well-water testing by private well owners</li> <li>• Increased BOH knowledge of water quality in their town</li> </ul>
Many are unable to afford remediation when well tests indicate contaminants are present	Education/guidance on payment options for remediation	<ul style="list-style-type: none"> <li>• Remediation costs for water contamination</li> <li>• Repair costs for structural problems</li> </ul>	Increase in # and % of remediated wells	Decrease in contaminants found in private drinking water in the region
Regulations vary by town; no statewide regulations requiring universal testing	Assist local BOH to adopt new private well regulations and support development and passage of statewide model regulations.	Written policy (common base regulation) that communities are likely to adopt to present to state legislature (with DEP)	Stricter statewide regulations requiring domestic wells be tested for contaminants during real estate and new construction transactions.	Less variation in private well-water testing policies by towns in Central MA

DEP = Department of Environmental Protection; BOH = Board of Health

RCAP Solutions expected these activities to result in a number of short-term outcomes during the pilot phase, including changes in resident perceptions about the importance of well assessment and water testing, increase in the number of wells tested for DEP (Department of Environmental Protection)-advised and other contaminants, increase in the number of remediated wells, and stricter state regulations requiring domestic wells to be tested for multiple contaminants during real estate transactions and new construction. In turn, RCAP Solutions anticipated these short-term outcomes to lead to better informed private well owners, increases in regular well water testing and board of health knowledge of water quality in their towns, decrease in contaminated drinking water, and less variation in private well water testing regulations by towns in Massachusetts (MA).

Several contextual factors were thought to affect evaluation/pilot study results. MassDEP was testing in North Central MA for PFAS at the same time as the pilot. While DEP focused first on public water systems and, then, drew a relatively small sample of private well owners, these efforts competed with RCAP's to encourage private well testing. Therefore, RCAP Solutions modified its efforts to focus on contaminants other than PFAS. COVID-19 pandemic restrictions delayed travel for well-water testing, sample retrieval, education and training. Other factors likely to affect outcomes included variation in town regulations (e.g., stricter regulations encourage more testing), number of private wells per capita (e.g., more private wells may affect numbers interested in participating), and presence of known contaminants (e.g., may be associated with testing norms such that if no contaminants are found, people will be less likely to test). RCAP Solutions aimed to adjust or control for these factors in its study design by selecting communities with larger numbers of private wells per capita, less strict regulations, and greater known presence of contaminants.

## The Evaluation Addressed Three Main Questions

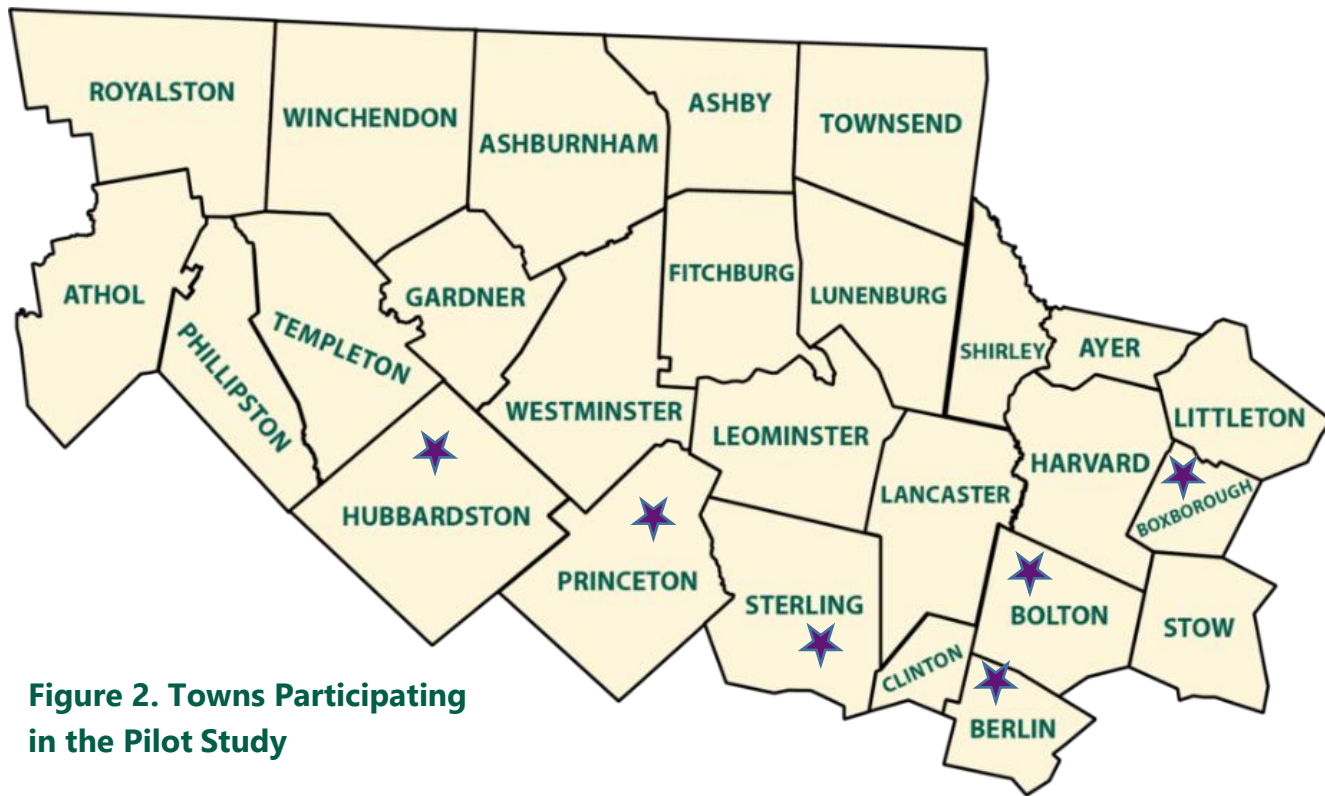
The evaluation was guided by three questions that helped RCAP Solutions understand how the North Central MA Private Well Program is being implemented, whether it produces anticipated results, and what these results mean for state and local decision-makers:

1. Is the North Central MA Private Well Program implemented as planned? If not, why not? What factors facilitated implementation? What factors hindered implementation? What, if any modifications were made to the program based on process measures?
2. What short-term outcomes are associated with program implementation? How much did outcome indicators change from before program implementation to afterward?
3. Can these outcomes be used to inform stricter private well regulations in local towns?

RCAP Solutions hypothesized that towns participating in the North Central MA Private Well Pilot Program would show:

- Positive changes in resident practices and intentions regarding well and well water safety after their participation in pilot program activities
- Positive changes in resident knowledge and beliefs about well water safety after their participation in pilot program activities
- Increase in the proportion of wells tested for MassDEP-advised contaminants
- Increases in number and proportion of well tests with contaminants present, in addition to PFAS

Moreover, RCAP Solutions expected that the Pilot Program would produce data that can be used to advocate for model state-wide regulations (i.e., requiring domestic wells to be tested for multiple contaminants during real estate transactions and new construction) during the Implementation Phase.



**Figure 2. Towns Participating in the Pilot Study**

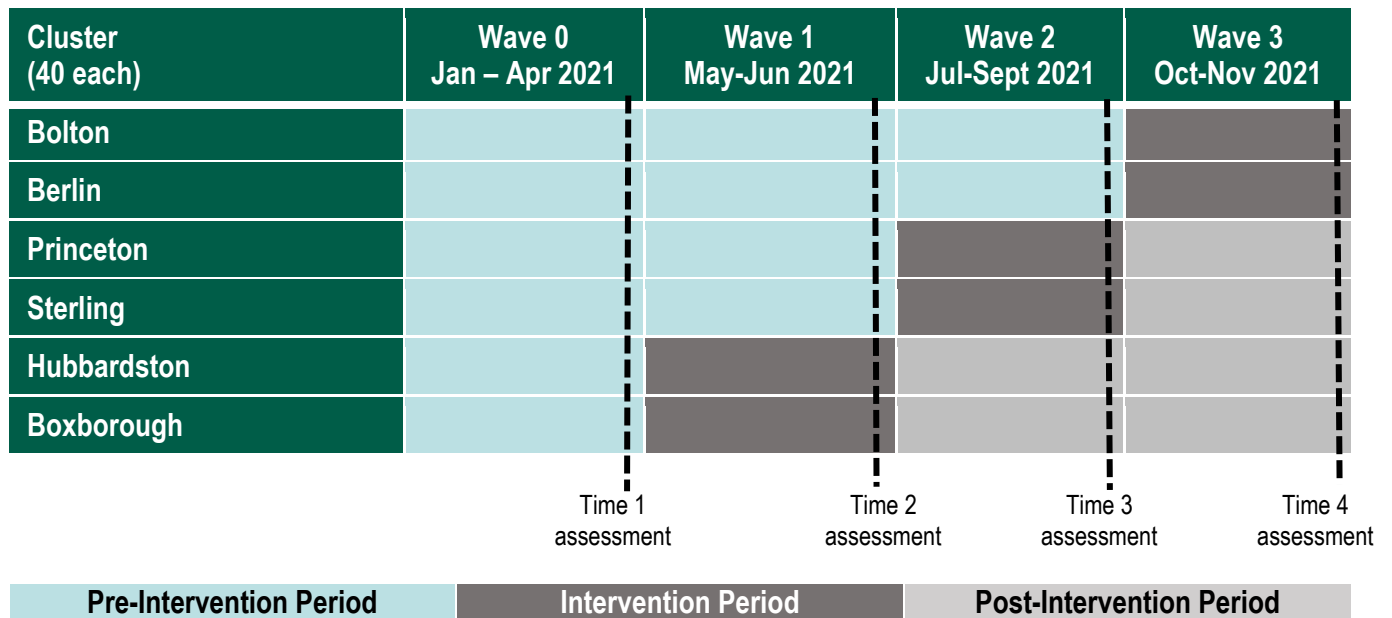
### Participating Towns

Twenty-six communities were eligible to participate in the pilot of the North Central MA Well Program (See Figure 2). This area has some of the highest documented levels of groundwater contaminants in MA. From these 26 towns, RCAP Solutions and the EDC Evaluator selected a purposive sample of six to participate based on the following criteria: total population size, number of private wells per capita, percentage of households with economic or biological vulnerabilities; and interest in participating with active local health department involvement. These towns included Berlin, Bolton, Boxborough, Hubbardston, Princeton, and Sterling.

### Evaluation Design

To answer the evaluation questions noted above, RCAP Solutions set out to implement a complete, stepped-wedge design. In this design, towns receive the intervention at different time points, the order in which they received it was determined at random, and the data were collected from towns and residents in those towns over time (see, Copas et al, 2015). Figure 3 shows 3 waves, each with 2 towns and 40 residents/households per town seeking well water tests (for a total of 240 well tests). This design also includes an initial period (Months 1 – 4), when no towns are exposed to the Private Well Program, and during which RCAP and EDC secured human protections approvals, and finalized data collection tools, training materials and other programmatic elements. Then, starting in month 5 and at regular intervals (or steps), two towns were selected to cross from the control condition to the Well Program under evaluation. This process continued until all of the 6 towns were exposed to the Well Program. As shown, at the end of the pilot study, all 6 towns were exposed. Data collection continued throughout the study so that towns and residents contributed observations under Well Program observation periods.

**Figure 3. Initial North Central MA Private Well Program Study Design**



A major challenge to implementing this design was lack of availability of well assessment and water testing data in the six participating towns. RCAP had hoped to show increases in well assessments and water testing by using data available from one of its key stakeholders and partners, Nashoba Analytical, LLC, as baseline data (time 1 assessment). However, Nashoba Analytical, LLC, was reluctant to share their data, even in aggregate form. Given limited access to well testing data for comparison purposes (and to show significant increases in proportion of wells assessed and water-tested between intervention and wait-listed comparison towns via stepped wedge), the evaluation design shifted to a pre/post assessment of changes in household knowledge, attitudes, and beliefs about well assessment and water testing. The evaluation design also included tracking well assessment and water testing results from Program activities and comparing these results with aggregate test results provided by SafeWell.

## Data Collected on Program Processes and Outcomes

During the pilot phase, RCAP Solutions and its partners, as appropriate, collected data on a number of indicators to determine whether and how RCAP implemented Program elements. Table 1 presents these indicators and their sources.

**Table 1. Implementation/Process Data Collection Indicators and Sources**

Data Source	Key Indicators
RCAP client tracker	Number of requests for well-testing Number of well owners/households participating
Well assessment forms	Number of well assessments conducted
Household pre-questionnaire	How participants learned about the program Perceived barriers to well assessment and water testing
Household post-questionnaire	Participant satisfaction with program
Local boards of health	Local private well regulations



In addition to data on program implementation, RCAP and partners also collected information on anticipated program outcomes. To preserve confidentiality of well testing results, RCAP worked closely with Nashoba Analytical, LLC, to obtain household data, but did not provide identifying information to EDC. Details on outcome data are included in the table below.

**Table 2. Outcome Data Collection Indicators and Sources**

Data Source	Indicators
MA DEP Data Portal*	Number of private wells
Local boards of health	Percentage of population served by domestic/private wells
SafeWell	Number of private wells tested at baseline
Household pre- and post-questionnaire	Self-report knowledge, beliefs and practices related to well safety
Household post-questionnaire	Number/percent of remediated and/or repaired wells and associated costs
Lab reports	Number of wells tested Number and percent of wells with contaminants exceeding recommended limits
Well assessment form	Well has permanent treatment Well previously disinfected Well construction meets standards

\*MA DEP Data Portal: <https://eeaonline.eea.state.ma.us/portal#!/search/welldrilling>

**Household Assessment.** RCAP implemented a household questionnaire at two points in time. One representative from each household completed the pre-assessment shortly after registering and receiving notification that they were selected to participate in the program based on their pre-screen (to determine presence of private well and water usage) and the order in which they registered (as participation and selection was on a first-come-first-served basis). After receiving results of their well assessments and water lab tests, participants completed a post-assessment questionnaire. RCAP administered both questionnaires online. Participants took approximately 15 minutes to complete the questionnaire.

Both pre- and post-questionnaires included four items that assessed *well practices* (e.g., *frequency of well water tests*), 12 assessing *health beliefs about well safety* (e.g., *feel confident in understanding water well*), four assessing *knowledge about well safety* (e.g. *how often should homeowners test their well water*, *The water in most wells comes from rain/snow in the local area.*), and eight assessing perceived factors that facilitate well water testing (e.g., frequent reminders). The pre-questionnaire included items asking about household demographics (e.g., education and income), barriers to well assessment (e.g., *finding a lab or agency to do the test*), reasons for not having well water tested in the past (e.g., *testing is too expensive*) and how participants learned of the Program. The post-questionnaire also asked about well water remediation and well structure repairs made or planned resulting from well assessment and asked about program satisfaction. Responses to items were either *yes* or *no* or used Likert scales. Complete copies of the pre and post-questionnaires are included in Appendix B.

**Well Assessment.** RCAP used the Private Well/Spring Assessment instrument developed at the University of Illinois, Urbana-Champaign, to conduct well assessments. Well assessors use the tool to collect information on well location, water use, well structure and maintenance, water level and flow, household plumbing, septic, water quality, water treatment, and area geology. Well assessors also use the tool to guide onsite education of well owners. Key information extracted from the tool for evaluation

purposes included information on water use, well construction, and well water disinfection and permanent treatment systems.

**Lab Reports.** Nashoba Analytical, LLC, analyzed water samples collected from each of the 240 households for contaminants that affect water quality including bacteria (coliform/*Escherichia coli*), nitrate, arsenic, lead, mercury, zinc, copper, iron, manganese, cadmium, sulfate, and fluoride. Analyses also assessed other indicators of water quality including PH, hardness, alkalinity, and turbidity. RCAP extracted the following key information from these reports for evaluation and reporting purposes: contaminants exceeding the MassDEP public drinking water health-based limit, and levels of contaminants exceeding primary or secondary standards (MassDEP, 2020).

## Analyses Focused on Changes in Household Outcomes

Analyses were designed to determine whether towns participating in the North Central MA Private Well Water program showed improvements in outcomes of interest from pre-test to post-test. RCAP analyzed process data as counts, frequencies, rates, and descriptive statistics as appropriate and shared with partners on a quarterly basis to ensure continuous quality improvement.

As noted above, RCAP/EDC worked with SafeWell, LLC, to obtain data on well tests performed in participating towns prior to Program implementation. These data include SafeWell customers signed on for annual inspection and testing. Analyses noted increased rates of well testing in participating towns after program implementation, using population data from each town as well as MassDEP data obtained from its well database. Similarly, using comparative tests (i.e., matched pairs t-tests and chi-square tests) we compared pre- and post-test findings from household questionnaires administered to participants before and following their participation in the Program.

## Results Provide Answers to the Three Main Evaluation Questions

In total, all 240 households (40 in each of the 6 towns) enrolled in the pilot program completed pre-questionnaires, and 197 of these same households (or 82%) completed post-assessment questionnaires (29 from Berlin, 31 from Bolton, 40 from Boxborough, 39 from Hubbardston, 28 from Princeton, and 30 from Sterling. RCAP completed well assessments for each participating household ( $N = 240$ ) and Nashoba Analytical produced lab reports, one for each participating household. Below findings are organized according to three main questions.

### Program Implemented As Planned

**Households were interested in participating in the Program.** Results show that demand for well assessments exceeded the number RCAP was able to provide, especially in the town of Princeton, MA (Appendix C). RCAP maintained waitlists for each of the six towns. Table 3 presents characteristics of the households enrolled in the pilot Program. Participants were, for the most part, highly educated with household incomes above the state average. Most participants use their well water for drinking and household purposes and know where their well is located. Moreover, the majority are aware of tests of water quality and have had their well water tested for contaminants at least once. Conversely, few households have *ever* had a well inspection/assessment onsite, had their well water tested in the *past year* for contaminants, or attended a workshop or educational program on water wells.

**Table 3. Characteristics of Households Participating in the Pilot Program, N = 240**

Characteristics	N	%
Use well water for drinking	229	95.4
Use well water for other household purposes	221	92.1
Know where well is located on property	235	97.9
Ever had a well inspection or site analysis	89	37.1
Had well inspection in the past year (out of 93)	11	4.6
Aware of water tests for bacteria or harmful chemicals and minerals	216	90.0
Had well water tested for bacteria or other chemicals and minerals	148	61.7
Had well water tested in the past year	13	5.4
Prior test found contaminants in well water	71	29.6
Attended workshop or educational program on water wells	11	4.6
Household member has bachelor's degree or higher	200	83.3
Household income below \$75,000/year*	35	14.6

\*Note: 2021 median household income in MA is \$81,215, <https://www.census.gov/quickfacts/fact/table/MA/INC110219>.

**All enrolled households received onsite well assessments and water quality tests.** RCAP met its goal to conduct 40 well assessments in each of the six towns for a total of 240 assessments. As of December 31, 2021, 100% of enrolled households had received their water test results from the lab. Meeting the goal of 240 well assessments was not without challenges. See Appendix C for a town-by-town report of requests made, households enrolled, onsite assessments conducted and site analysis/water test results reported. In the early months of the pilot study, RCAP placed one of two assessors on medical leave, leaving only one assessor to conduct all remaining home visits and well assessments as well as gather water samples. Having only one assessor and navigating COVID restrictions caused delays in program rollout. Towns participating in the last wave or step of the pilot study received site visits and well assessments into November (several months past the projected August date). As of November 19, 2021, RCAP solutions had presented well-water test results to local boards of health in Boxborough, Princeton, and Sterling. Presentations are scheduled and pending for Hubbardston, Berlin and Bolton.

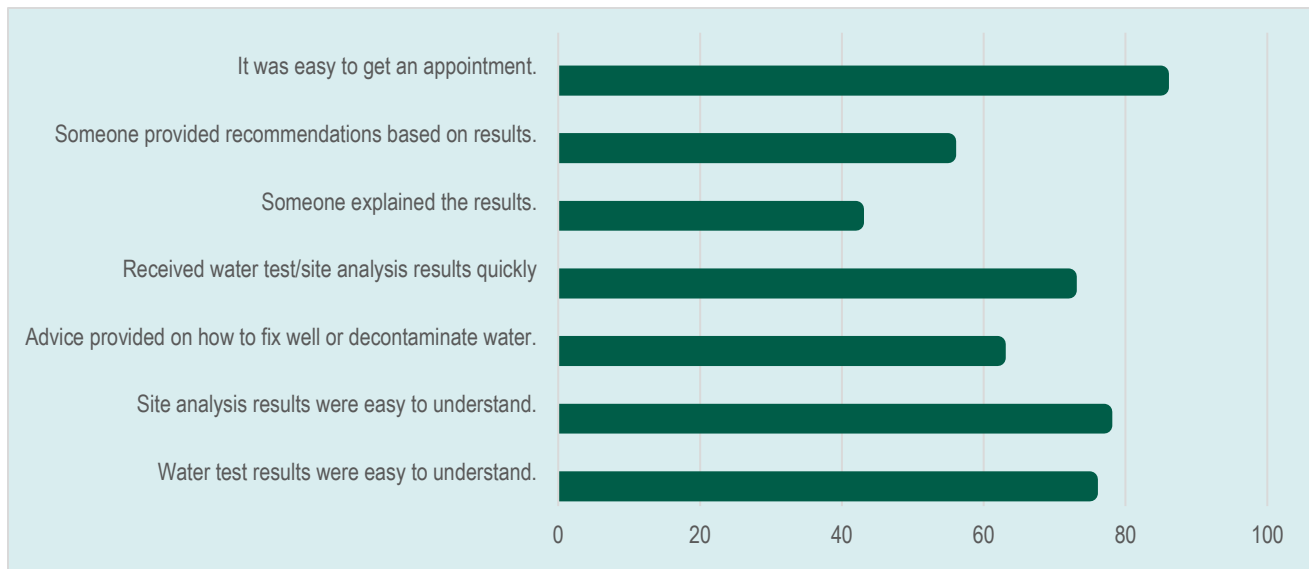
**Most participants learned about the Program from friends or relatives.** Given the widespread campaign to identify and recruit households for participation in the Private Well pilot study, RCAP wanted to know how households learned about the Program. Answers to the question about sources of information varied widely, with most common sources being friends or relatives (49 or 20.4%), other sources (45 or 18.8%), and a town employee or town outreach (44 or 18.3%). Many of those who had learned about the program from “other” sources indicated that a realtor had told them.

**Low perceived risk and habituation, as well as high costs, affect participant well assessment and water testing behaviors.** Of those households participating, the majority indicated that they had not had their well water tested in the past year. The most common reason cited (by 27.2% of 81 respondents): *We have lived here for a long time and no one in my household has gotten sick so the well water must be clean.* Given the latent nature of health effects associated with drinking contaminated water, it seems that this is an area requiring more education. Participants also reported barriers to having their well water tested. Most common reasons included the following: forgetting to do the testing ( $N = 112$ ; 46.7%); affording treatment if contaminants are found ( $N = 81$ ; 33.8%); and worrying about the cost to have the sample analyzed ( $N = 78$ ; 32.5%).

**Participants were satisfied with services provided.** The majority of households participating in the pilot study indicated that they were satisfied with services that RCAP provided and would recommend to

others in their community: 92% were satisfied with the water test and 78% with the onsite well assessment, 86% would recommend the water test to others, and 85% the well assessment. *Satisfied* = those indicating that they were *satisfied* (vs. *somewhat satisfied*, *neutral*, *somewhat dissatisfied* and *dissatisfied*); *Likely* = those indicating that they would *definitely* or *probably* recommend (vs. *neutral*, *probably not recommend*, and *definitely not recommend*). There was some variation in satisfaction by town with those in Berlin, Bolton, and Sterling reporting highest rates of satisfaction. See Appendix C for percentage of households satisfied with private well program by town.

**Figure 4. Percent of Households That Agree/Strongly Agree about Receipt of Program Services, N = 197**



On the post-questionnaire, participating households offered feedback on the specific services provided. Table 4 presents the number and percent of favorable responses and shows that participants were satisfied with multiple aspects of the Program. Lower percentages, such as those related to having someone explain site analysis or water test results, may be affected by what those results showed. For example, those who received some indication of contaminants or well structure problems might have been more likely to engage, whereas someone who was notified that their well had no structural problems or water contamination, might have been less likely to want an explanation.

***At Program start, the proportion of wells tested in participating towns was low.*** Based on data from the 2010 census of domestic well locations and populations served, 6.6 percent of the MA population uses domestic wells (Johnson, Belitz, & Lombard, 2019). However, in the communities where RCAP piloted their private well program, the majority of households (and, thus, the town population) rely on private wells for drinking and/or other household water use. The one exception was Sterling in which about 80% of the population uses the public water supply. Table 4 presents information on the percentage of private wells tested in each of the six participating towns based on available data. As shown, the percentages are very low—with all but Bolton registering below 10% in 2020.

**Table 4. Snapshot of Well Testing in Six Pilot Towns Prior to Program Implementation**

Town	# Private Wells Documented <sup>a</sup>	% Households w/Private Wells	2020 Population	#Private Wells Tested in 2020 <sup>g</sup>	% Private Wells Tested in 2020 <sup>h</sup>
Berlin	596	~100% <sup>f</sup>	3,158	40	6.7%
Bolton	1,464	~70% <sup>b</sup>	5,665	244	16.7%
Boxborough	953	~50% <sup>b,i</sup>	5,506	54	5.7%
Hubbardston	961	~100% <sup>c</sup>	4,328	10	1.0%
Princeton	692	~100% <sup>d</sup>	3,495	25	3.6%
Sterling	477	~20% <sup>e</sup>	7,985	11	2.3%

<sup>a</sup>Data from MA DEP: <https://eeaonline.eea.state.ma.us/portal#!/search/welldrilling>. Number of wells based on total count of unique well records and identification numbers.

<sup>b</sup>Calculated based on 2020 town population data from: <https://malegislature.gov/Redistricting/MassachusettsCensusData/CityTown> and assuming 2.7 persons per household.

<sup>c</sup>Based on Hubbardston town documents: [https://www.hubbardstonma.us/sites/g/files/vyhliif3276/f/uploads/hubbardston\\_os\\_plan\\_draft\\_update\\_8-21-19\\_1.pdf](https://www.hubbardstonma.us/sites/g/files/vyhliif3276/f/uploads/hubbardston_os_plan_draft_update_8-21-19_1.pdf).

<sup>d</sup>Based on Princeton town documents: [https://www.town.princeton.ma.us/sites/g/files/vyhliif4891/f/uploads/02\\_princeton\\_mvp\\_summary\\_of\\_findings\\_report.pdf](https://www.town.princeton.ma.us/sites/g/files/vyhliif4891/f/uploads/02_princeton_mvp_summary_of_findings_report.pdf).

<sup>e</sup>Based on Sterling town documents: <https://www.sterling-ma.gov/water-department/pages/water-system>.

<sup>f</sup>Based on Berlin town document: [https://www.townofberlin.com/sites/g/files/vyhliif4156/f/news/berlin\\_mvp\\_draft\\_report\\_08\\_12\\_20.pdf](https://www.townofberlin.com/sites/g/files/vyhliif4156/f/news/berlin_mvp_draft_report_08_12_20.pdf).

<sup>g</sup>Data from SafeWell, 2020, Personal correspondence with Dan Gaffney.

<sup>h</sup>Calculated based on data from SafeWell.

<sup>i</sup>Reports indicate that majority of population use private wells. See:

<https://boxborough.maps.arcgis.com/apps/Cascade/index.html?appid=cf2dc1482103429dbd924da5e3026e22>

## Change in Outcome Indicators

**When RCAP implemented the Program, the proportion of wells tested increased in participating towns.** RCAP collected water samples and conducted well assessments with 240 participating households. When these 240 assessments and water tests are added to those annual tests that SafeWell performs (Table 4), we see a substantial increase in the percentage of households in each of the participating towns that received a recent well assessment/water test. Although the overall percentages remain relatively low, the proportional increase is high in those towns where RCAP was piloting its program. In Berlin, MA, for example, the number of wells assessed doubled with the introduction of the Program. See Table 5.

**Table 5. Snapshot of Well Testing in Six Pilot Towns Prior to Program Implementation**

Town	#Private Wells Tested in 2020 <sup>a</sup>	% Private Wells Tested in 2020 <sup>b</sup>	#Private Wells Tested in 2021 <sup>c</sup>	% Private Wells Tested in 2021 <sup>d</sup>
Berlin	40	6.7%	80	13.4%
Bolton	244	16.7%	284	19.4%
Boxborough	54	5.7%	94	9.7%
Hubbardston	10	1.0%	50	5.2%
Princeton	25	3.6%	65	9.4%
Sterling	11	2.3%	51	10.7%

<sup>a</sup>Data from SafeWell, 2020, Personal correspondence with Dan Gaffney. <sup>b</sup>Calculated based on data from SafeWell and data from MA DEP on total number of wells by town, 2021: <https://eeaonline.eea.state.ma.us/portal#!/search/welldrilling>. Number of wells based on total count of unique well records and identification numbers.

<sup>c</sup>Calculated by adding 40 additional tests for each participating town. <sup>d</sup>Calculated based on number of private wells tested in 2021 and MA DEP data on total number of wells by town, 2021.

**There were some changes in household well safety knowledge, beliefs, and practices after their program participation.** Table C3 in Appendix C presents pre- and post-questionnaire responses to key items. Overall, there were few item-specific changes from pre- to post-assessment in terms of private

well practices, beliefs, and efficacy. Yet, results do point to some notable differences—some anticipated and others surprising.

**Well safety practices.** Participants demonstrated improved knowledge of well safety with a significantly greater percentage of participants at post-assessment noting that well water tests should be conducted annually compared to other options,  $\chi^2(1, N = 192) = 23.83, p = .000$ . Interestingly, the percentage of households indicating that they were likely or very likely to test their well water in the next 12 months decreased from pre- to post assessment,  $\chi^2(1, N = 195) = 7.12, p = .008$ . At pre-assessment, it is likely that participants were motivated to test their well water, thus their rationale for enrolling in the Program. By post-assessment, participants had received results of their water test. Those households with wells that had no contaminants may have been less motivated to seek another test in the next 12 months where at the outset of the Program they may have been motivated to learn about their well chemistry.

**Well safety beliefs.** Paired t-tests showed that participants agreed more emphatically that they know where to get water tested for health concerns at post-assessment ( $M = 3.23, SD = .679$ ) compared to pre-assessment ( $M = 2.52, SD = 1.05$ ),  $t(192) = 9.899, p < .001$ . Results from the pre-assessment ( $M = 1.90, SD = 1.02$ ) and post-assessment ( $M = 2.94, SD = .723$ ) also show that participation is associated with improved confidence in understanding of water well,  $t(190) = 14.366, p < .001$ . Interestingly, when asked about belief that well contains dangerous levels of contaminants, participants agreement scores decreased significantly from pre-assessment ( $M = 1.30, SD = .76$ ) to post-assessment ( $M = 0.98, SD = .90$ ),  $t(194) = -4.370, p < .001$ . The response categories and score range for each belief item is: 0 = strongly disagree, 1 = disagree, 2 = neutral, 3 = agree, and 4 = strongly agree. When belief items are summed to create a total score that ranges from a low of 0 to a high of 44, paired t-test analyses find that **overall, there was a significant improvement in well water safety beliefs from pre-assessment** ( $M = 27.16, SD = 3.59$ ) to post-assessment ( $M = 28.55, SD = 3.55$ ),  $t(175) = 4.90, p < .001$ . When items were summed, this item was omitted: There are long-lasting effects of drinking or bathing in contaminated well water as this item was inadvertently omitted from some of the pre-tests administered.

**Well safety knowledge.** All knowledge statements included in the pre- and post-questionnaires were true. Participants could respond to each statement by indicating that it was *absolutely false*, *likely false*, *likely true*, or *absolutely true*. At pre-assessment and post-assessment participants were more likely to know about the impact of well or property conditions on other wells in the vicinity. However, they were less knowledgeable about the source of their well water and how well depth effects water quality. To compare changes in knowledge from pre-assessment to post-assessment, false and true responses were combined to create a new dichotomous variable with a *true* or *false* response. Participants at post-assessment were more likely than those at pre-assessment to answer correctly that a poorly maintained well can impact the quality of water in other wells,  $\chi^2(1, N = 194) = 28.51, p = .000$ . However, knowledge decreased from pre-test to post-test on knowing where most well water comes from,  $\chi^2(1, N = 196) = 41.55, p = .000$ ; and the influence of well depth on safe drinking water,  $\chi^2(1, N = 196) = 39.66, p = .000$ .

### Program Outcomes Inform Stricter Well Regulations

Outcomes described above as well as additional information gathered on existing and local well regulations, well owner precautions or preventative behaviors, and well water quality point to the need for more substantial regulations that encourage testing of well water quality and well maintenance.

**Current regulations offer neither positive nor negative incentives for well water testing and maintenance.** Table 6 shows that these regulations typically cover essential areas such as well construction, design, maintenance, permits, and water quality (Bowen et al, 2019). However, none

addresses the frequency of testing nor includes provisions for required domestic well water testing at the time of property transfer or sale—a policy shown to increase well testing in other states. Further, there are no stipulations related to regular testing of wells located on and serving domestic rental property when a new lease is signed.

**Table 6. Presence of Private Well Policies at Program Outset, by Policy Type and Town**

Town	Construction	Design	Maintenance	Permits	Water Quality	Abandoning	Selling Home	Rental
Berlin								
Bolton <sup>a</sup>								
Boxborough <sup>b</sup>								
Hubbardston								
Princeton								
Sterling <sup>c</sup>								
State <sup>d</sup>								

<sup>a</sup>[https://www.townofbolton.com/sites/g/files/vyhliif2836/f/pages/well\\_regulations\\_2-13-18.pdf](https://www.townofbolton.com/sites/g/files/vyhliif2836/f/pages/well_regulations_2-13-18.pdf)

<sup>b</sup><https://www.boxborough-ma.gov/DocumentCenter/View/516/Well-Regulations-PDF>

<sup>c</sup><https://www.sterling-ma.gov/sites/g/files/vyhliif1266/f/file/file/wellregs.pdf>

<sup>d</sup><https://www.mass.gov/doc/private-well-guidelines/download>

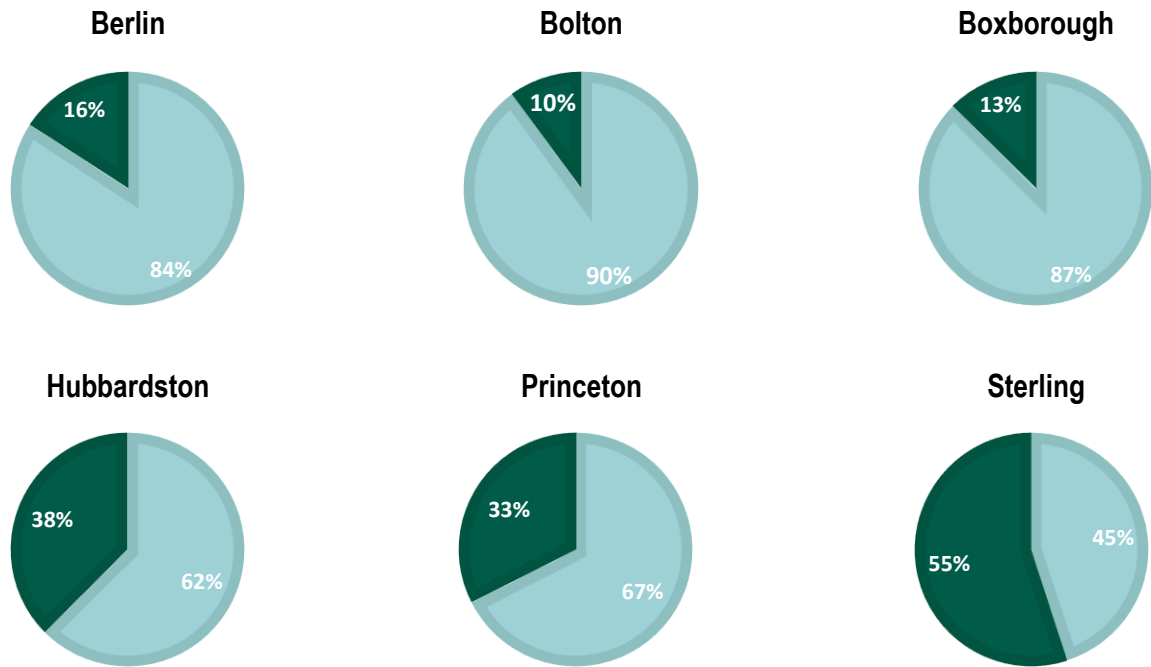
*Onsite well assessments find some well and water safety precautions in place and others absent.* The lack of regulations and regular testing is concerning as RCAP well assessments show that about three-fourths of the 240 households participating have no well drill log. Only one homeowner reported testing well water annually for contaminants. See Table 7 for town-specific numbers and percentages. Similarly, 40% of all wells assessed did not meet well construction standards.

**Table 7. Household Well Water and Onsite Analysis Findings by Town, N = 240**

	Drill Log	Annual Testing	Water Ever Disinfected	Permanent Treatment	Well Meets Construction Standards
TOWN	N (%)	N (%)	N (%)	N (%)	N (%)
Berlin	18 (45%)	0 (0%)	21 (52%)	30 (75%)	23 (58%)
Bolton	9 (23%)	0 (0%)	3 (7%)	26 (65%)	24 (60%)
Boxborough	10 (25%)	0 (0%)	2 (5%)	26 (65%)	24 (60%)
Hubbardston	13 (33%)	0 (0%)	18 (45%)	27 (68%)	18 (45%)
Princeton	4 (10%)	0 (0%)	2 (5%)	22 (55%)	23 (58%)
Sterling	8 (30%)	1 (2%)	14 (35%)	31 (78%)	30 (75%)
<b>TOTALS</b>	<b>62 (26%)</b>	<b>1 (.04%)</b>	<b>60 (25%)</b>	<b>162 (68%)</b>	<b>142 (59%)</b>

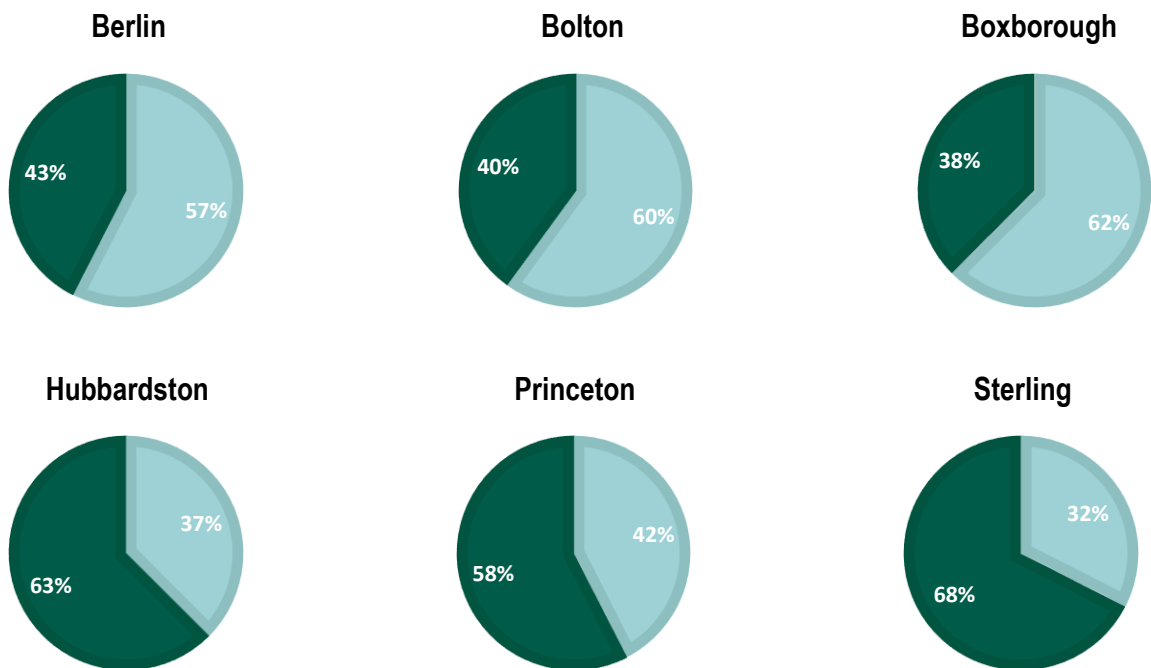
*Despite precautions, lab results find varying levels of contaminants in well water by town.* Results of the water tests conducted with 240 households found that 65 (27%) households have levels of contaminants exceeding MassDEP public drinking water health-based limits. Most commonly found contaminants included the following: Total coliform bacteria (N = 34); arsenic (N = 24); radon (N = 12); manganese above .3mg/L (N = 6); uranium (N = 5); and E. coli (N = 2). Figure 5 shows percentage of households with lab results showing contaminants exceeding MassDEP drinking water health-based limits by town. Over half of households (N = 124; 51%) had levels of contaminants exceeding primary and/or secondary standards. These standards include: PH (N = 45); manganese (N = 24); chloride (N = 11); Iron (N = 8); color (N = 3); odor (N = 2); copper (N = 1); and fluoride (N = 1). Figure 6 shows percentage of households with lab test results showing that water contaminants exceeded primary and/or secondary standards by town.

**Figure 5. Percent of Households that Have Levels of Contaminants Exceeding MassDEP Drinking Water Health-Based Limits by Town**



Key for Figures 5 and 6: ■ Contaminants within limits/standards ■ Contaminants exceed limits/standards

**Figure 6. Percent of Households that Have Levels of Contaminants Exceeding Primary and Secondary Standards by Towns**





Assuming that participating households are representative of other private well owners in their towns, RCAP may be able to estimate the number of wells likely to contain contaminants that exceed health limits. Based on data from the MassDEP well data portal that includes documentation on the number of wells by town, these estimates include the following: 95 wells in Berlin, 146 in Bolton, 123 in Boxborough, 365 in Hubbardston, 228 in Princeton, and 262 in Sterling.

***Households implemented water quality remediation and well structure repairs following participation in the Program.*** Thirty-eight homeowners (16%) indicated that they paid for well remediation after water tests found contaminants. Of these, 12 indicated that the repairs cost less than \$100; 10 that repairs cost between \$100 and \$1,000; and 14 that repairs cost \$1,000 or more. Two respondents indicated that there was no cost associated with their remediation. Another 62 (26% of 240) indicated that they plan to implement remedies to address contaminants found in their well water. Twenty-six respondents (10.8%) indicated that they paid for repairs to their well structure when assessments found problems with their well structure. Most of these homeowners (17) spent less than \$100 on repairs. Another 64 (27% of 240) homeowners indicated that they plan to implement repairs to address problems found with their well structure.

Using data from well water testing and onsite inspections, RCAP is mounting a case for statewide legislation to require testing of well water quality at the time of property sale or transfer. Working closely with stakeholders (Appendix A), RCAP drafted legislation based on these model regulations that closely parallel those required for septic systems. As of January 15, 2022, RCAP stakeholders introduced the model regulations to the MA House of Representatives' Rules Committee that then referred the regulations to the Joint Committee on Environment, Natural Resources, and Agriculture. Testimony is pending.

**More than half of households participating in the pilot Program support model regulations (N = 113; 57.3%); 28% (N = 56) were neutral on the subject—maybe because they did not understand the implications.**

## Findings Have Implications for Model Scaling and Policy Change

***The North Central MA Private Well Pilot Program was able to do the following:***

- Select six towns to participate in the program based on factors such as proportion of households that rely on domestic well water for drinking and other household purposes, geographic location, and motivation to assist in household recruitment activities.
- Recruit and enroll 240 households, 40 from each of the six towns selected, to participate in a pilot study.
- Conduct 240 onsite well inspections, and collect and test water samples from 240 households.
- Provide all households participating with a report of well assessment and water test findings.
- Deliver services that yielded satisfaction from the vast majority of participants who also said they would recommend that their friends participate in this kind of program.

***Program implementation was associated with the following outcomes:***

- Increased proportion of wells inspected and water tested in each of the pilot study towns.
- Overall significant improvement in beliefs favoring well safety.
- Some significant improvements in well safety knowledge and practices, especially with regard to knowing that well water testing should occur annually.

- Identification of additional households using well water with levels of contaminants exceeding MassDEP health-related limits; and having levels exceeding primary and/or secondary standards.
- Remediation and repair of household wells/well water supply subsequent to identification of contamination or structural defects.

***The evaluation has a few limitations that affect confidence in outcomes reported here.*** First, households that selected into the program were mostly highly educated and had incomes exceeding the MA average. Therefore, we do not know whether this program would work for different populations such as households with lower incomes. Second, the non-experimental design limits our ability to rule out other factors that might have affected changes in knowledge, beliefs, and practices from pre-assessment to post-assessment. Third, there is no central database—census count or representative sample—that includes or tracks the number and percent of households with private wells that have engaged in inspection and/or water testing. This data absence limits the accuracy of our projections on percentage of wells tested by town. We rely primarily on the reports of one lab in the region, SafeWell, to provide a kind of baseline. However, we are aware that other labs are actively conducting tests in the region; yet, these labs have been reluctant to share data on testing even in aggregate.

***Despite these limitations, there are implications for scaling the Program.*** Most important, the Program will implement on-site well inspections and assessments only in cases where household well water supply screens “positive” for contamination. This, given difficulties encountered in implementing the universal onsite well inspection and assessment (i.e., very labor intensive) and that roughly three-quarters of households did not present with levels of contaminants exceeding MassDEP health-related limits. Second, if possible, the Program will provide incentives or low-interest loans for remediation and repair of wells as needed, given that participants frequently cited cost of treatment as preventing well water testing and assessment.

***There are also several implications for policy.*** RCAP will focus on developing, advocating for, and implementing statewide model regulations that incentivize well water testing via property transfer or sale as is currently done in New Jersey and Rhode Island. Its next evaluation phase should focus on whether the implementation of model regulations results in a substantial increase in well water testing. RCAP should consider launching an awareness campaign along with model regulations given that knowledge of private well safety is still limited. Moreover, given limited data on number of well water tests conducted, any regulations or legislation should stipulate which entity will be responsible for tracking well water tests conducted at property transfer or sale. Finally, to collect representative statewide data on well water testing, consider adding a question to the MA Behavioral Risk Factor Surveillance System as is currently done in Maine.

## Citations

- Bowen, K., Krishna, T., Backer, L., Hodgins, K., Waller, L. A., & Gribble, M. O. (2019). State-level policies concerning private wells in the United States. *Water Policy*, 21(2), 428-435. <http://doi.org/10.2166/wp.2019.205>
- Commonwealth of Massachusetts. (2022). Drinking water standards and guidelines. <https://www.mass.gov/guides/drinking-water-standards-and-guidelines>.
- Copas, A. J., Lewis, J. J., Thompson, J. A., Davey, C., Baio, G., & Hargreaves, J. R. (2015). Designing a stepped wedge trial: Three main designs, carry-over effects and randomisation approaches. *Trials*, 16, 352. <https://doi.org/10.1186/s13063-015-0842-7>
- Flanagan, S. V., Marvinney, R. G., & Zheng, Y. (2015). Influences on domestic well water testing behavior in a Central Maine area with frequent groundwater arsenic occurrence. *Science of the Total Environment*, 505, 1274–1281. <https://doi.org/10.1016/j.scitotenv.2014.05.017>
- Flanagan, S. V., Spayd, S., Procopio, N., Chillrud, S. N., Braman, S., & Zheng, Y. (2016). Arsenic in private well water part 1 of 3: impact of the New Jersey Private Well Testing Act on household testing and mitigation behaviors. *Science of the Total Environment*, 562, 999–1009. <http://doi.org/10.1016/j.scitotenv.2016.03.196>
- Hemming, K., Haines, T. P., Chilton, P. J., Girling, A. J., & Lilford, R. J. (2015). The stepped wedge cluster randomised trial: rationale, design, analysis, and reporting. *BMJ*, 350, 391. <https://doi.org/10.1136/bmj.h391>
- Imgrund, K., Kreutzwiser, R., & de Loë, R. (2011). Influences on the water testing behaviors of private well owners. *Journal of Water and Health*, 9, 241–52. <http://doi.org/10.2166/wh.2011.139>
- Johnson, T.D., Belitz, K., Lombard, M.A., 2019, Domestic well locations and populations served in the contiguous U.S. for 2000 and 2010: *Science of the Total Environment*, v. 687, p. 1261-1273. <https://doi.org/10.1016/j.scitotenv.2019.06.036>
- Linsley, P., Howard, D., & Owen, S. (2015). The construction of context-mechanisms-outcomes in realistic evaluation. *Nurse Researcher*, 22(3):28–34. <http://doi.org/10.7748/nr.22.3.28.e1306>
- Massachusetts Department of Environmental Protection. (2020). Standards and guidelines for contaminants in Massachusetts drinking waters. Boston, MA: Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs. <https://www.mass.gov/doc/2020-standards-and-guidelines-for-contaminants-in-massachusetts-drinking-waters/download>.
- Munene, A., Lockyer, J., Checkley, S., & Hall, D. C. (2020). Exploring well water testing behaviour through the Health Belief Model. *Environmental Health Insights*, 14, 1–10. <https://doi.org/10.1177/1178630220910143>
- Zheng, Y., & Flanagan, S. V. (2017). The case for universal screening of private well water quality in the U.S. and testing requirements to achieve it: Evidence from arsenic. *Environmental Health Perspectives*, 125(8), 085002. <https://doi.org/10.1289/EHP629>

## Appendix A. North Central MA Private Well Program Stakeholders

Stakeholder Group	Description of Group	Roles
<b>Grant Management Team</b>		
<b>Health Foundation of Central MA</b> <i>Contact: Amie Shei, Vice President for Programs</i>	Provides grants to non-profit organizations in support of its mission to use its resources to improve the health of those who live or work in the Central MA region, with particular emphasis on vulnerable populations and unmet needs. Major grant making occurs through the Health Promotion Synergy Initiative. The Synergy Initiative provides three to five years of funding for collaborative projects that target community-identified health issues in Central MA with integrated strategies designed to improve health.	Fund or authorize the continuation or expansion of the program; Provides overarching guidance program implementation and evaluation.
<b>RCAP Solutions</b> <i>Contact: Brian Scales, Vice President &amp; Chief Capacity Officer</i>	RCAP advocates on behalf of rural communities for reasonable and fundable statewide regulations for private wells and assists local Boards of Health in establishing regulations for current contaminant protection and providing public education to private well owners and local communities.	Responsible for day-to-day implementation of the program activities that are being evaluated and will need to implement any changes; Responsible for data collection.
<b>Education Development Center, Inc.</b> <i>Contact: Kim Dash, Principal Health Evaluator</i>	Since 1958, has been a leader in designing, implementing, and evaluating powerful and innovative programs in more than 80 countries around the world. EDC's evaluators work with project teams and partners to design and conduct independent evaluations of federal, state, and community initiatives, inform product development, monitor progress, and document outcomes.	Design and oversee evaluation activities; Provide guidance to staff implementing evaluation activities; Obtain human protections approvals and oversight.
Stakeholder Group	Description of Group	Roles
<b>Leadership Team</b>		
<b>MA Department of Environmental Protection</b> <i>Contact: Joseph Cerutti, Program Coordinator</i>	Provides guidance on water quality testing for private wells and certifies laboratories that conduct well water tests for contaminants. DEP currently is conducting a statewide analysis of PFAS contamination in the public water supply as well as in private wells. North Central MA Well Water Program will align with these efforts such that our findings will inform those of the MA DEP and vice versa.	Help shape and advocate for model regulations, invited to attend regulation review meetings with local BOH.
<b>Nashoba Associated Boards of Health</b> <i>Contact: James Gareffi, Chair</i>	Regional Board of Health with 15 Member Towns: Ashburnham, Ashby, Ayer, Berlin, Bolton, Boxborough, Dunstable, Groton, Harvard, Lancaster, Littleton, Lunenburg, Pepperell, Shirley and Townsend. The Environmental Division enforces State Sanitary and Environmental Codes, Massachusetts General Laws and local regulations (including wells).	Assist with recruiting homeowners to participate in the pilot test; Provide education and outreach; Advocate for model regulations with local BOH members.
<b>Montachusett Public Health Network</b> <i>Contact: Steve Curry</i>	Regional health network that consists of the Cities of Fitchburg, Leominster and Gardner and the towns of Athol, Clinton, Hubbardston, Phillipston, Princeton, Royalston, Sterling, Templeton, Westminster, and Winchendon. Services provided by the MPHNS include but are not limited to inspectional services such as housing, food establishment, and Title 5 inspections.	Assist with recruiting homeowners to participate in the pilot test; Provide education and outreach; Advocate for model regulations with local BOH members

EVALUATION REPORT - North Central MA Private Well Program Pilot Study

Stakeholder Group	Description of Group	Roles
<b>Leadership Team, continued</b>		
<b>MA Department of Public Health, Bureau of Environmental Health</b> <i>Contact: Jan Sullivan</i>	Responds to the environmental health concerns of Massachusetts residents by studying the impact of pollutants on communities and informing the public about how to prevent or minimize their exposure to harmful pollutants. Regulatory programs enforce laws and regulations related to minimum health and sanitation standards for housing.	Shape and advocate for model regulations
<b>Massachusetts State Legislature</b> <i>Contact: Rep. Danillo Sena</i>	Danillo Sena is the member of the Massachusetts House of Representatives from the 37th Middlesex district. He was elected on June 2, 2020.	Advocate for model regulations and statewide funding program that the evaluation may recommend
<b>Massachusetts State Legislature</b> <i>Contact: Senator James Eldridge</i>	Jamie Eldridge has served as State Senator for the Middlesex and Worcester district since January 2009. Among other committee positions, he is the Senate Chair of the Clean Energy Caucus.	Advocate for model regulations and statewide funding program that the evaluation may recommend
<b>University of Illinois</b> <i>Contact: Steve Wilson, Groundwater Hydrologist</i>	Brings subject matter expertise in groundwater hydrology, extensive fieldwork and research on best practices in reaching out to and educating private well owners on benefits of well water testing; leads Illinois State Water Survey	Increase credibility and knowledge base of program and assists evaluation with expertise
<b>SafeWell</b> <i>Contact: Dan Gaffney</i>	Local company that provides well assessment and water testing services for households in Central MA as well as maintains database on private wells.	Help shape model regulations; Provide comparison data on well water testing.
Stakeholder Group	Description of Group	Roles
<b>Advisory Team</b>		
<b>Massachusetts Environmental Health Association</b> <i>Contact: Bill Murphy, Vice President</i>	An affiliate of the National Environmental Health Association, provides quality training and educational programs while also providing the opportunity for members to meet and exchange ideas and information with other professionals in the field of Public and Environmental Health.	Shape and advocate for model regulations
<b>Community Health Network of North Central MA</b> <i>Contact: Chelsey Patriss, Executive Director</i>	One of 27 community health networks across Massachusetts, created by the Department of Public Health in 1992. CHNA 9 is a partnership between the Massachusetts DPH, the Central MA Center for Healthy Communities, residents, hospitals, local service agencies, schools, faith communities, businesses, boards of health, municipalities, and other concerned citizens working together to: identify the health needs of member communities, find ways to address those needs, and improve a broad scope of health in these communities.	Assist with recruiting homeowners to participate in the pilot test; Provide education and outreach; Advocate for model regulations
<b>Northeastern University</b> <i>Contact: Kelsey Pieper, Assistant Professor</i>	Brings subject matter expertise in environmental chemistry; corrosion; drinking water quality, treatment, and infrastructure; post-disaster drinking water recovery; and public health engineering.	Increase credibility and knowledge base of program and assists evaluation with expertise
<b>Patriot Real Estate</b> <i>Contact: Paul Yorkis</i>	Provides professional real estate services to buyers throughout MA and sellers in the Boston metro area.	Help develop model regulations related to real estate transactions.

EVALUATION REPORT - North Central MA Private Well Program Pilot Study

Stakeholder Group	Description of Group	Roles
<b>Advisory Team, continued</b>		
<b>U.S. Congress</b> <i>Contact:</i> Congresswoman Lori Trahan (via Josselyn DeLeon)	Lori Ann Loureiro Trahan is an American businesswoman and politician who serves as the U.S. Representative for Massachusetts's 3rd congressional district, having been elected in November 2018.	Can advocate for federal program changes that allow for whole house filter remediation systems that the evaluation may recommend

In addition to the groups named in the table above, RCAP engaged private well households and consumers to assist with program advertisement and awareness raising as well as recruitment of other households for pilot study participation. These included the following individuals by town:

Town	Representatives
<b>Boxborough</b>	Les Fox and Mary Brolin
<b>Hubbardston</b>	Mallory Seamon and Erin Caton
<b>Sterling</b>	David Faverau and Kathie Nickerson
<b>Princeton</b>	Sherry Patch
<b>Berlin</b>	Paul Mikelk and Margaret Narowicz
<b>Bolton</b>	Kristen Zina and Jenny Jacobsen

## Appendix B. Household Pre- and Post-Questionnaires

### Household Pre-Questionnaire

[UNIQUE ID CODE] – ENTER

FIRST, A FEW QUESTIONS THAT ASK ABOUT YOUR EXPERIENCE WITH WELL WATER TESTING

1. Does the water in your home come from a private well on your property?

- Yes (go to next question)
- No (If “no”, then this message should appear: Thank you for your interest in our survey. We are mainly interested in hearing from renters and homeowners whose household water comes from a private well.)

2. Do you use your well water

		Yes	No
a.	For drinking?	1	0
b.	For other household purposes?	1	0

3. Do you know where your well is located on your property?

- Yes
- No

4. Do you have a copy of the drillers report (well log) for your household well?

- Yes
- No

5. Have you ever had a well inspection or site analysis?

- Yes (go to next question)
- No (go to Q7)

6. When did you have this inspection or site analysis?

- In the last 6 months
- About one year ago
- About 2 years ago
- About 3 years ago
- About 4 years ago
- About 5 years ago
- More than 5 years ago
- Can't remember

7. Did you know that you can test your well water for bacteria or harmful chemicals and minerals?

- Yes (go to next question)
- No (go to Q13)

**Pre-Questionnaire, continued**

**8. I learned about private well water testing from:**

	Yes	No
a. Department of Environmental Protections	1	0
b. Department of Public Health	1	0
c. Friends or relatives	1	0
d. General contractor, home builder or plumber	1	0
e. Health professional	1	0
f. Neighbor	1	0
g. RCAP	1	0
h. Search on the Internet	1	0
i. Town employee or town outreach	1	0
j. Water well contractor	1	0
k. Other: [open field]	1	0

**9. Have you ever tested your private well for bacteria or other chemicals and minerals?**

- Yes (go to next question)
- No (go to Q13)

**10. When did you last test your well water?**

- In the last 6 months
- About one year ago
- About 2 years ago
- About 3 years ago
- About 4 years ago
- About 5 years ago
- More than 5 years ago
- Can't remember

**11. What contaminants were found?**

- No contaminants
- Arsenic
- Bacteria (e.g., coliform)
- Nitrate/nitrite
- Perfluoroalkyl substances (PFAS)
- Radon
- Uranium
- Volatile organic compounds (e.g., benzene)
- Other [open field]



**12. What were the reasons for not having your well water tested? Check all that apply.**

- Water test results by previous owner were clean so I don't need to test again.
- We have lived here for a long time and no one in my household has gotten sick so the well water must be clean.
- I only drink bottled water so it doesn't matter whether or not my well water is contaminated.
- I filter my well water before I drink or cook with it so it doesn't matter whether or not my well water is contaminated.
- Testing is too expensive.
- My well water tastes good so it's probably not contaminated.
- Not a high enough priority for me.
- Land uses on surrounding properties are not likely to cause well water contamination.
- Other: [open field]

**13. Have you ever attended a workshop or educational program on water wells?**

- Yes
- No

**14. How often do you think homeowners should test their well water for contaminants?**

- Once is enough
- Every 6 months
- Every year
- Every 5 years
- Every 10 years

**15. How likely are you to test your well water for bacteria or other chemicals and minerals in the next 12 months?**

- Highly unlikely
- Somewhat unlikely
- Somewhat likely
- Highly likely

**Pre-Questionnaire, continued**

**THESE NEXT QUESTIONS ASK FOR YOUR OPINIONS ABOUT WELL WATER CONTAMINANTS AND TESTING.**

To what extent do you agree or disagree with the following statements?		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
16.	I sometimes worry about the safety of my water.	0	1	2	3	4
17.	It's best to leave my well alone unless I have a problem with it.	0	1	2	3	4
18.	It's likely that my well contains dangerous levels of contaminants.	0	1	2	3	4
19.	My chances of getting sick from contaminated well water are high.	0	1	2	3	4
20.	I would feel safe drinking water straight out of my well without any form of treatment.	0	1	2	3	4
21.	Problems I would experience from drinking and bathing in contaminated well water would last a long time.	0	1	2	3	4
22.	If I had contaminated well water, I would have a hard time selling my house.	0	1	2	3	4
23.	I know where I could go to get my water tested for health concerns.	0	1	2	3	4
24.	I feel confident in my understanding of my water well.	0	1	2	3	4
25.	Testing my well water will help find bacteria, chemicals, and minerals that could make me and others in my household sick.	0	1	2	3	4
26.	If contaminants were found in my well water through testing, then I could have the contaminants removed with a treatment system.	0	1	2	3	4
27.	Having contaminants removed from my well water will decrease my chances of getting diseases linked to those contaminants.	0	1	2	3	4

**28. Which of the following has presented or currently presents a difficulty in getting your water tested? Please check all that apply.**

- Finding a laboratory or agency to do the testing
- Remembering to do the testing
- Collecting the water sample
- Paying the cost to have the sample analyzed
- Finding a contractor who will collect the sample and arrange to have it tested
- Understanding the results of the testing
- Knowing which contaminants to test for
- Being able to afford treatment if contaminants are found
- Other: [open field]
- I have had no difficulty getting my water tested.

**Pre-Questionnaire, continued**

**THESE QUESTIONS ARE ABOUT YOUR UNDERSTANDING OF WELL WATER**

Please indicate the answer that reflects your best guess about the following statements.		Absolutely False	Likely False	Likely True	Absolutely True
29.	The deeper a well is, the safer the water is to drink.	0	1	2	3
30.	The water in most wells comes from rain/snow in the local area.	0	1	2	3
31.	A poorly maintained well can impact the quality of water in other wells in the area.	0	1	2	3
32.	What happens on neighboring properties can impact the quality of groundwater in a well.	0	1	2	3

**NOW, A FEW QUESTIONS ABOUT THINGS THAT MIGHT MAKE IT EASIER FOR YOU TO HAVE YOUR WELL WATER TESTED.**

How likely would you be to conduct well-water testing if you:		Very Unlikely	Unlikely	Neutral	Likely	Very Likely
33.	Had a do-it-yourself home testing kit	0	1	2	3	4
34.	Were offered a home delivery sampling service	0	1	2	3	4
35.	Knew more about well water testing options	0	1	2	3	4
36.	Knew about well water treatment options	0	1	2	3	4
37.	Could get my well water tested for free	0	1	2	3	4
38.	Could get a loan to cover the cost of well-water treatment	0	1	2	3	4
39.	Knew that there were contaminants in my area	0	1	2	3	4
40.	Received well water testing reminders	0	1	2	3	4

**FINALLY, WE WOULD APPRECIATE SOME INFORMATION ABOUT YOUR HOUSEHOLD TO HELP US CATEGORIZE SURVEY RESPONSES.**

**41. In what town do you live?**

- Berlin
- Bolton
- Boxborough
- Hubbardston
- Princeton
- Sterling

42. What are the highest levels of education that the adult members of the household have completed? Please check all that apply.

- Some formal schooling
- High school diploma or equivalent
- Apprenticeship or trades certificate
- Completed some college
- Associate degree
- Bachelor degree
- Master's degree
- Doctoral or professional (e.g., MD, JD) degree
- Prefer not to answer

43. What was your total household income before taxes during the past 12 months?

- Less than \$25,000
- \$25,000 to \$34,999
- \$35,000 to \$49,999
- \$50,000 to \$74,999
- \$75,000 to \$99,999
- \$100,000 to \$149,999
- \$150,000 or more
- Prefer not to answer

**THANK YOU!**

## Household Post-Questionnaire

[UNIQUE ID CODE] – ASSIGNED

FIRST, A FEW QUESTIONS THAT ASK ABOUT YOUR EXPERIENCE WITH WELL WATER TESTING

**1. Do you use your well water**

		Yes	No
a.	For drinking?	1	0
b.	For other household purposes?	1	0

**2. Do you know where your well is located on your property?**

- Yes
- No

**3. How often do you think homeowners should test their well water for contaminants?**

- Once is enough
- Every 6 months
- Every year
- Every 5 years
- Every 10 years

**4. How likely are you to test your well water for bacteria or other chemicals and minerals in the next 12 months?**

- Highly unlikely
- Somewhat unlikely
- Somewhat likely
- Highly likely

**5. What contaminants surfaced in the recent well test that RCAP Solutions conducted?**

- No contaminants
- Arsenic
- Bacteria (e.g., coliform)
- Nitrate/nitrite
- Perfluoroalkyl substances (PFAS)
- Radon
- Uranium
- Volatile organic compounds (e.g., benzene)
- Other [open field]

**6. Have you implemented any remedies to address the contaminants found in your well water?**

- Yes
- No [skip to question 8]
- No contaminants [skip to question 9]

**7. How much did the remediation cost?**

- Less than \$100
- \$100 to \$499
- \$500 to \$999
- \$1,000 to \$5,000
- \$5,000 to \$9,999
- \$10,000 to \$14,999
- \$15,000 or more

**8. Do you plan to implement any remedies to address contaminants found in your well water?**

- Yes
- No

**9. Have you implemented any repairs to address problems with your well structure?**

- Yes
- No *[skip to question 11]*
- No problems found *[skip to question 12]*

**10. How much did the repairs cost?**

- Less than \$100
- \$100 to \$499
- \$500 to \$999
- \$1,000 to \$5,000
- \$5,000 to \$9,999
- \$10,000 to \$14,999
- \$15,000 or more

**11. Do you plan to implement any repairs to address problems found with your well structure?**

- Yes
- No

**Post-Questionnaire, continued**

**THESE NEXT QUESTIONS ASK FOR YOUR OPINIONS ABOUT WELL WATER CONTAMINANTS AND TESTING.**

To what extent do you agree or disagree with the following statements?		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4
12.	I sometimes worry about the safety of my water.	0	1	2	3	4
13.	It's best to leave my well alone unless I have a problem with it.	0	1	2	3	4
14.	It's likely that my well contains dangerous levels of contaminants.	0	1	2	3	4
15.	My chances of getting sick from contaminated well water are high.	0	1	2	3	4
16.	I would feel safe drinking water straight out of my well without any form of treatment.	0	1	2	3	4
17.	Problems I would experience from drinking and bathing in contaminated well water would last a long time.	0	1	2	3	4
18.	If I had contaminated well water, I would have a hard time selling my house.	0	1	2	3	4
19.	I know where I could go to get my water tested for health concerns.	0	1	2	3	4
20.	I feel confident in my understanding of my water well.	0	1	2	3	4
21.	Testing my well water will help find bacteria, chemicals, and minerals that could make me and others in my household sick.	0	1	2	3	4
22.	If contaminants were found in my well water through testing, then I could have the contaminants removed with a treatment system.	0	1	2	3	4
23.	Having contaminants removed from my well water will decrease my chances of getting diseases linked to those contaminants.	0	1	2	3	4

**THESE QUESTIONS ARE ABOUT YOUR UNDERSTANDING OF WELL WATER**

Please indicate the answer that reflects your best guess about the following statements.		Absolutely False	Likely False	Likely True	Absolutely True
		0	1	2	3
24.	The deeper a well is, the safer the water is to drink.	0	1	2	3
25.	The water in most wells comes from rain/snow in the local area.	0	1	2	3
26.	A poorly maintained well can impact the quality of water in other wells in the area.	0	1	2	3
27.	What happens on neighboring properties can impact the quality of groundwater in a well.	0	1	2	3

**Post-Questionnaire, continued**

**NOW, A FEW QUESTIONS ABOUT THINGS THAT MIGHT MAKE IT EASIER FOR YOU TO HAVE YOUR WELL WATER TESTED.**

How likely would you be to conduct well-water testing EVERY YEAR if you:		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
28.	Had a do-it-yourself home testing kit	0	1	2	3	4
29.	Were offered a home delivery sampling service	0	1	2	3	4
30.	Knew more about well water testing options	0	1	2	3	4
31.	Knew about well water treatment options	0	1	2	3	4
32.	Could get my well water tested for free	0	1	2	3	4
32.	Could get a loan to cover the cost of well-water treatment	0	1	2	3	4
34.	Knew that there were contaminants in my area	0	1	2	3	4
35.	Received well water testing reminders	0	1	2	3	4

**36. Would you be in favor of a state regulation that requires homeowners to test private well water prior to selling their house?**

I would be very much opposed

I would be opposed

I would be neutral

I would be in favor

I would be very much in favor

**FINALLY, WE WOULD APPRECIATE YOUR FEEDBACK ON THE WELL TESTING EXPERIENCE.**

**37. Overall, how satisfied were you with the well testing services that RCAP Solutions provided?**

- Satisfied
- Somewhat satisfied
- Neutral
- Somewhat dissatisfied
- Dissatisfied

**38. Overall, how satisfied were you with the well assessment/site analysis that RCAP Solutions provided?**

- Satisfied
- Somewhat satisfied
- Neutral
- Somewhat dissatisfied
- Dissatisfied



**Post-Questionnaire, continued**

**39. How likely are you to recommend private well water testing to your friends and neighbors?**

- Definitely recommend
- Probably recommend
- Neutral on the subject
- Probably not recommend
- Definitely not recommend

**40. How likely are you to recommend private well water assessment/site analysis to your friends and neighbors?**

- Definitely recommend
- Probably recommend
- Neutral on the subject
- Probably not recommend
- Definitely not recommend

To what extent to you agree or disagree with the following statements:		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>41.</b>	Water test results were easy to understand.	0	1	2	3	4
<b>42.</b>	Site analysis results were easy to understand	0	1	2	3	4
<b>43.</b>	Advice was provided on how to fix my well or de-contaminate it.	0	1	2	3	4
<b>44.</b>	I received water test and site analysis results quickly.	0	1	2	3	4
<b>45.</b>	Someone explained the water test and site analysis results to me.	0	1	2	3	4
<b>46.</b>	Someone provided recommendations to me based on my well water test and site analysis results.	0	1	2	3	4
<b>47.</b>	It was easy to get an appointment for a well water test and site analysis.	0	1	2	3	4

**THANK YOU!**

## Appendix C. Additional Tables

**Table C1. Number of Households by Town Interested and Participating in Pilot Program**

Town	Households that Request Assessment	Households Registered for Assessment	On-site Assessments Conducted	Households w/Water Test Results from Lab
Berlin	54	40	40	40
Bolton	64	40	40	40
Boxborough	52	40	40	40
Hubbardston	52	40	40	40
Princeton	142	40	40	40
Sterling	68	40	40	40
<b>TOTALS</b>	<b>432</b>	<b>240</b>	<b>240</b>	<b>240</b>

**Table C2. Percentage of Households Satisfied with Pilot Program, by Town, N = 194**

TOWN	Satisfied with Private Well Water Testing		Satisfied with On-site Well Assessment		Likely to Recommend Water Testing to Friend		Likely to Recommend On-site Assessment to Friend	
	N	%	N	%	N	%	N	%
Berlin	29	100	27	93.0	27	93.0	27	93.0
Bolton	27	90.0	27	90.0	26	86.7	25	83.3
Boxborough	35	87.5	18	45.0	36	90.0	36	90.0
Hubbardston	31	79.5	31	79.5	30	76.9	28	71.8
Princeton	21	75.0	22	78.6	24	85.7	23	82.1
Sterling	27	96.4	27	96.4	24	85.7	25	89.3
<b>TOTALS</b>	<b>179</b>	<b>92.3</b>	<b>152</b>	<b>78.4</b>	<b>167</b>	<b>86.0</b>	<b>164</b>	<b>84.5</b>

Satisfied = those indicating that they were *satisfied* (vs. *somewhat satisfied, neutral, somewhat dissatisfied, and dissatisfied*) ; Likely = those indicating that they would *definitely* or *probably* recommend.

**Table C3. Pre/Post Item Response, N = 240 (Pre-test); N = 197 (Post-test)**

Item	Pre-Household Assessment		Post-Household Assessment	
	N	%	N	%
<b>Practices: Number and Percent Indicating YES</b>				
Use well-water for drinking	229	95.4	181	91.9
Use well-water for other household purposes	221	92.1	171	86.8
Know where well is located	235	97.9	195	99.0
Know to test well water annually	84	35.0	100	50.8
Likely/very likely to test well water in next 12 months	165	68.7	111	56.3
<b>Beliefs: Number and Percent Indicating That they Agree/Strongly Agree with the Following Statements</b>				
Worry about safety of water	159	66.3	110	55.8
Believe it is best to leave well alone unless there is a problem	77	32.1	63	32.0
Believe that well contains dangerous levels of contaminants	13	5.4	12	6.1
Believe chances of getting sick from contaminated well water are high	62	25.8	54	27.4
Feel safe drinking untreated well water	100	41.7	95	48.2
Believe there are long-lasting effects of drinking/bathing in contaminated well water*	76	31.7	137	69.5
Believe they would have a hard time selling house if had contaminated well water	205	85.4	179	90.9
Know where to go to get water tested for health concerns.	145	60.5	178	90.4
Feel confident in understanding of water well.	69	28.8	157	79.7
Believe that testing well water will help find contaminants that could make household members sick.	227	94.6	193	98.0
Think that if contaminants are found in well water, then could be removed with a treatment system.	217	90.4	175	88.8
Believe that having contaminants removed from well water will decrease chances of getting diseases linked to contaminants.	226	94.1	191	97.0
<b>Knowledge: Number and Percent Responding True/Absolutely True to the Following Statements</b>				
The deeper the well is, the safer the water is to drink.	132	55.0	84	42.6
The water in most wells comes from rain/snow in the local area.	101	42.1	80	40.6
A poorly maintained well can impact the quality of water in other wells in the area.	179	74.6	162	82.2
What happens on neighboring properties can impact the quality of groundwater in a well.	235	98.0	191	97.0
<b>Number and Percent Indicating That They Are Likely /Very Likely to Test Well Water Every Year If:</b>				
Had a do-it-yourself home testing kit	212	88.4	171	86.8
Were offered a home delivery sampling service	208	86.7	163	82.7
Knew more about well water testing options	194	80.8	138	70.0
Knew about well water treatment options	194	80.8	141	71.6
Could get my well water tested for free	232	96.7	179	90.9
Could get a loan to cover the cost of well-water treatment	109	45.5	84	42.6
Knew that there were contaminants in my area	224	93.4	185	93.9
Received well water testing reminders	188	78.4	135	68.5

\*Note: This item was inadvertently removed from the pre-assessment for some towns so no comparison of means was conducted.

**Table C4. Pre/Post Differences in Household Private Well Belief Scores by Item, N = 197**

Variable	N	Pre-Assessment		Post-Assessment		t-test
		M	SD	M	SD	
Worry about safety of water	193	2.55	1.06	2.45	1.02	-1.404
Believe it is best to leave well alone unless there is a problem	195	2.00	.98	1.89	1.02	-1.260
Believe that well contains dangerous levels of contaminants	195	1.30	.76	.98	.9	-4.370 ***
Believe chances of getting sick from contaminated well water are high	193	1.81	1.05	1.64	1.2	-1.649
Feel safe drinking untreated well water	196	2.12	1.17	2.22	1.27	1.304
Believe there are long-lasting effects of drinking/bathing in contaminated well water	74	2.86	.689	2.80	.776	-0.760
Believe they would have a hard time selling house if had contaminated well water	195	3.24	.752	3.22	.778	-0.314
Know where to go to get water tested for health concerns.	193	2.52	1.05	3.23	.679	9.899 ***
Feel confident in understanding of water well.	191	1.90	1.02	2.94	.723	14.366 ***
Believe that testing well water will help find contaminants that could make household members sick.	195	3.31	.61	3.43	.573	2.136
Think that, if contaminants are found in well water, then they could be removed with a treatment system.	195	3.12	.570	3.16	.629	.776
Believe that having contaminants removed from well water will decrease chances of getting diseases linked to contaminants.	193	3.23	.513	3.33	.572	1.831

\*\*\*p = .000