TOWN OF BOW, NEW HAMPSHIRE

DRINKING WATER PROTECTION COMMITTEE

Brown Hill Road Area Water Quality Study

June 2016

DRINKING WATER PROTECTION COMMITTEE MEMBERS AND ADVISORS

Chair, Cynthia Klevens, P.E., is a chemical engineer with a masters in civil and environmental engineering, and 30 years' experience in consulting and government. She has lived in Bow since 2003 and joined the committee around 2006. She works for the NH Dept of Environmental Services as the Water Treatment Engineer for the Drinking Water and Groundwater Bureau.

Past Chair, Sandy Crystall, has been a member of the committee since its inception in 2005 and served as chair from 2007 to 2015. She is a professional wetland scientist currently working for the NH Dept of Environmental Services, and has worked as an environmental scientist for the federal government and in consulting.

Member Dick Kraybill is a retired environmental consultant licensed to practice site investigations and remediation at solid and hazardous waste sites primarily throughout the northeast U.S. His work included geotechnical and hydrogeologic investigations for site development, re-use or closure. Clients included government agencies such as NHDES, the EPA, the Corps of Engineers, and DOD as well as private industrial clients.

Member Wendy Waskin is an Environmental Program Specialist with the NH Dept of Environmental Services. She has over 30 years' experience in the environmental field, 18 with the Department's Watershed Management Bureau. She also serves as the vice-chair of the Bow Conservation Commission.

Member Blake Hooper is a new attorney licensed to practice in New Hampshire. In addition to the practice of law, his prior experience includes radio production and political organizing. He studied water in the Florida Everglades during his time in Stonehill College, where he graduated with a BA in English before moving on to obtain his law degree at Washington and Lee University. He has lived in Bow all his life and is committed to serving his community.

Past member Kevin Leonard, P.E., is a civil engineering professional with 18 years' experience designing and permitting infrastructure and land development projects throughout New Hampshire. His expertise includes site design, roadways, grading, storm water management, septic systems, erosion control, and associated local, state and federal permitting. He served on the Committee through April 2016.

Town of Bow Dept. of Public Works, Noel Gourley, is a construction professional with twenty-five years' experience in commercial and residential construction, including installation of hundreds of septic and water systems. He is responsible for establishing grades and layout for numerous drainage projects for the Town of Bow, and holds certifications as a Culvert Maintainer and Green Snow Pro.

Resident Volunteer, Brandon Kernen, P.G, , is a hydrologist with 25 years' experience working for community water systems, consulting engineering firms, and the State of New Hampshire. He has a B.S. in Hydrology and Water Resources from the University of Arizona and M.S. in Civil and Environmental Engineering from Tufts University. He is a licensed professional geologist in the State of New Hampshire.

Town of Bow Community Development Director, Mathew Taylor
Town of Bow Assistant Planner, Bryan Westover
Past Town of Bow Community Development Director, William Klubben

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ACRONYMS AND DEFINITIONS

BOS	Town of Bow Board of Selectmen
BDWPC	Town of Bow Drinking Water Protection Committee
DOT	New Hampshire Department of Transportation
DPW	Town of Bow Department of Public Works
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System; a device used in the field to establish the precise location of things of interest; in our case wells and septic systems.
mg/L	Milligrams per liter; equivalent to parts per million
MCL	Maximum Contaminant Level; a regulatory limit for certain parameters that have health implications in public water supplies.
NC	Not calculated as noted on some EPA laboratory reports for hardness
ND	Not Detected
NHDES	New Hampshire Department of Environmental Services
pCi/L	Picocuries per liter
ppb	Parts per billion
ppm	Parts per million
pH	a logarithmic scale from 0 to 14 that is a measure in standard units of how acidic or basic a water is; a pH of 7 is neutral; <7 is acidic and >7 is basic.
SMCL	Secondary Maximum Contaminant Level; concentration limits of certain parameters that have aesthetic (e.g. taste, odor, visual) impacts in public water supplies.
s.u.	Standard units; a measure of pH
SC	Specific Conductance; a measure of how well a water can conduct an electrical current. It is related to the amount of total dissolved solids and the ionic strength of those dissolved solids.
TDS	Total dissolved solids
ug/L	Micrograms per liter; equivalent to parts per billion
uS/cm	Microsiemens per centimeter; the unit for specific conductance in water

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EXECUTIVE SUMMARY

Residents from the Brown Hill Road area have voiced concerns since the 1990s regarding corrosion from salt contamination of their private wells. At that time, the Town evaluated and implemented several corrective actions including reduced salt application practices and assistance with water filtration systems, where applicable. In July 2013, residents again requested review of this issue such that the Select Board assigned the Drinking Water Protection Committee (BDWPC) to work through the Community Development Director and Town Manager to perform a new water quality study. Brown Hill Road resident and Professional Geologist Brandon Kernen also volunteered his time and expertise to support this study.
The BDWPC surveyed 158 area homeowners in June 2014 regarding their well water quality, water treatment, and requested permission to sample their private wells. Half (79) of the homeowners responded and granted permission for sampling. Water samples were collected between July and September, with results mailed to each homeowner in December 2014.
The BDWPC compiled and evaluated the results and has prepared this report for presentation to the Select Board (April 26, 2016), and to Town residents (June 8, 2016).

General findings from this study are as follows:

- The sources of chloride contamination in well water in the study area include road salt drainage and softener brine from home treatment systems. Thirteen of the 79 wells (16%) exhibited chloride higher than the 250 mg/L Secondary Drinking Water Standard.
- Both low pH and high chloride contribute to water corrosivity. Twenty four of the 79 homeowners reported in the surveys that their water was corrosive. Twelve of the 24 exceeded the chloride secondary standard (that is 12 of the 13 wells >250 mg/L). Furthermore, 23 of the 24 residents reporting corrosion had pH levels less than 7.0.
- *Older (pre-1985) wells have higher chloride and lower pH*: wells known to be installed prior to the 1984 Water Well Board Construction Standards exhibited lower pH (higher acidity), compared to wells known to be constructed after these standards were adopted. This is likely because older wells were not sealed into bedrock, and therefore are more susceptible to recharge from acid rain and surface drainage including salt contamination. Average pH in pre-1985 wells was 6.0, compared to the average in newer wells which was 6.7. Average chloride concentrations older to newer were 175 and 63 mg/L respectively.
- Wells installed in 1985 and later are required to be constructed with a minimum of 20 ft of casing, of which at least 10 ft must be sealed into the bedrock. Most of the homeowners with post-1984 wells did not report corrosion issues; however, the newer wells exhibited naturally occurring contaminants *Arsenic* (30% of the samples were above the drinking water standard) and *Uranium* (18% of the samples were above the drinking water standard).
- Current chloride levels were similar, and sometimes lower, than chloride levels tested in the 1990s, suggesting that road salt loading has not increased the concentrations found in groundwater.

General recommendations from this study are:

- **Health recommendation**: Homeowners should test for stagnant lead and copper which can leach from plumbing fixtures due to water corrosiveness. This is important for prevention of lead exposure, and requires testing the first flush of water from your sink in the morning.
- Homeowners may evaluate treatment solutions for water corrosivity such as water neutralizers, and treatment for arsenic and uranium such as Point of Use (POU) filters (as opposed to whole house systems). The NH Department of Environmental Services "Be Well Informed" web tool is available for guidance on the selection of water treatment options (direct link https://xml2.des.state.nh.us/DWITool/Welcome.aspx).
- Homeowners with softeners may consider alternative, non-salt treatment technologies, and/or volume-based regeneration to reduce brine discharges.
- The Town should continue its low road salt application practices and maintain vigilance for effective alternatives. All Town public works staff have received training under the NHDES Green SnowPro guidelines which promote best practices regarding road salt application.
- The Town should sample and evaluate the feasibility of implementing an engineering solution to reduce or eliminate infiltration of salt contaminated runoff in drainage ditches especially where this problem has been noted.
- The BDWPC should continue to provide information on the importance of private well testing, well construction standards, and water treatment guidance through public information sessions, and annual "water test day" events.

1.0 INTRODUCTION

This report summarizes the investigation of residential complaints of salt and corrosive conditions in groundwater wells in the Brown Hill Road Area by the Bow Drinking Water Protection Committee (BDWPC). The investigation was performed as authorized by the Board of Selectmen in response to concerned residents in the Brown Hill area. The general area of study that was proposed by the BDWPC is shown on Figure 1-1.

1.1 Project Background and Objectives

At the July 16, 2013 meeting of the Board of Selectmen (BOS), several residents from Brown Hill Road and Bona Vista Drive voiced their concerns regarding groundwater quality in their private wells. The residents reported continued plumbing corrosion issues, as well as concerns about the costs of maintaining treatment systems and the potential loss in value of their homes. The town has received complaints from residents in this area of town since the 1990s. One of the potential causes has been attributed to the use of salt for de-icing town roads. The town has responded in certain cases by providing funding for new private wells or treatment systems.

A representative from the BDWPC attended the July 16th meeting and offered the committee's assistance in conducting a survey of current conditions. At the August 27, 2013 meeting of the Board of Selectmen, the discussion continued by reviewing a report by the Town Manager which recounted past activities that have occurred regarding the Brown Hill Road area water quality. A copy of the Town Manager's report is included as Appendix 1-1. The Board of Selectmen requested that the BDWPC work through the Town's Community Development Director and Town Manager to perform this well water quality study and report our findings and recommendations to the Town.

In the fall of 2013 the BDWPC discussed the issues and developed the following objectives for study of the Brown Hill Road area:

- Gather private well data through a homeowner survey for information regarding well and septic locations, water quality complaints, and existing treatment systems.
- Match water well driller reports on file with the state to addresses in the study area, to establish well construction characteristics such as date of installation, well depth and length of casing.
- Perform sampling of private wells focusing on parameters associated with salt in groundwater and conditions related to corrosion in plumbing.
- Compare current study investigation results with historical information from previous studies in the area.
- Assess area conditions that might contribute to salt levels and corrosivity of plumbing.
- Prepare recommendations for the Board of Selectmen and the public.

During the planning of this investigation, Brown Hill Road resident Brandon Kernen volunteered his time and expertise to support the BDWPC's objectives. Mr. Kernen is a Professional Geologist employed by the New Hampshire Department of Environmental Services (NHDES) Drinking Water and Groundwater Bureau. Based on the history and extent of the problem, Mr. Kernen sought and obtained the collaboration from the United States Environmental Protection Agency's (EPA) Region 1 (New England) office, which assisted by providing laboratory services for an expanded list of drinking water parameters. The laboratory services were provided at no cost to the town or the residents who responded to the survey. The EPA lab analyses provided additional data parameters that resulted in a significant benefit to this study.

1.2 Previous Investigations

Stearns & Wheler, LLC was contracted by the town in 1996 to investigate the potential causes of chloride contamination in private wells in the Brown Hill Road area. Their report, titled *Chloride Study, Brown Hill Road Area, Bow, New Hampshire*, dated August 1996, concluded that road salt was the most probable cause of the elevated chloride levels, especially for those wells where there was shallow depth to bedrock and were located near roadside drainage ditches. The Stearns & Wheler investigation focused on seven wells with chlorides greater than the Secondary Maximum Contaminant Level (SMCL) of 250 mg/L. However, the report included additional historical analytical data from other sources including NHDES. The Stearns & Wheler *"Executive Summary"* and a figure showing the area of the 1996 investigation are included as Appendix 1-2 of this report.

1.3 Study Area and Homeowner Participation

The study area for this investigation (Figure 1-1) was essentially an expansion of the 1996 study area, to include homes hydraulically upgradient and downgradient of the original study. This area included Brown Hill Road, Bona Vista Drive, Clement Road, Van Ger Drive, Tonga Drive, and Hampshire Hills Drive. The Hampshire Hills Drive area was undeveloped in 1996. This area encompassed all the residents who expressed concern at the July 2013 Board of Selectmen meeting.

During the course of this study, the street addresses on Clement Road were renumbered as part of a separate Town effort. This study shows the data collected by well location and not by address. Copies of original laboratory reports with current (2016) address information are on file in the Town Manager's office.

Homeowner participation was key to the success of this investigation. Surveys were mailed to 158 residential homes, of which 79 (50%) responded and authorized the BDWPC to sample and collect data from their well water. Homeowner responses to the survey also included information on existing water treatment and general water quality comments. The BDWPC has summarized the information provided by survey responses, but neither the BDWPC nor the town make any warranties or guarantees of the accuracy of the information provided by the residents or the conclusions reached in this investigation. Also, a number of homes in the study area have been sold during the course of this evaluation, such that this report may serve to provide new residents information regarding their well water quality characteristics.

A list of the tasks and timetable that the tasks were performed are summarized in Table 1-1. A brief description of the key tasks is presented below.

2.0 TECHNICAL APPROACH

2.1 Homeowner Surveys

A homeowner survey and cover letter were developed and mailed in June 2014 to the 158 residents in the area shown on Figure 1-1. The surveys provided information about the location of wells and septic systems, water quality complaints, and existing water treatment systems. Appendix 2-1 includes a blank survey form, cover letter, and a summary of the 79 survey responses.

It should be noted that the information from the survey responses was not verified independently. The details regarding water treatment and corrosion issues for each home are dependent on the accuracy of the information presented by residents.

2.2 Fieldwork

In July-August 2014 the BDWPC and Mr. Kernen conducted the field sampling of the private well supplies for the 79 residents that granted permission. A limited number of wells were re-sampled for metals in December 2014 due to a sample preservation issue during the July-August 2014 sampling event. One resident's well was missed during the sampling and the oversight was not discovered until long after all sampling had been completed. The BDWPC has offered that resident a test of their well but the analytical data for that residence is not included in this report. In addition, one of the homeowners had two wells and both were sampled. Therefore, in terms of numbers for this study, there were 79 residents who provided surveys and there were 79 wells that were sampled.

Field tasks included locating the well and the septic system on each lot using a hand held GPS unit, and collecting a water sample from each home. Figure 2-1 illustrates the approximate locations of respondents' wells within the study area. Field efforts also included an attempt to perform a geophysical survey of underlying water fractures using instrumentation on loan from the US Geological Survey, however, there were significant interferences from metallic objects along with equipment malfunctions, such that this effort was abandoned.

An additional 10% of the samples were collected as duplicates or field blanks for quality control purposes. Samples were collected from outside spigots except for one or two instances where a resident was home and granted permission to sample from the kitchen faucet. Taps were flushed for approximately one minute and then filling two sample bottles. The first sample was used to measure pH, temperature and specific conductance with field instruments and then was discarded. The second sample was capped securely, labeled, and stored in coolers with ice for delivery to the laboratory. All samples were delivered within 24 hours of collection to the laboratory. Each sample was analyzed for the analytical protocol shown in Table 2-1.

2.3 Laboratory Testing

The EPA Region 1 laboratory in Chelmsford, Massachusetts is certified for all drinking water analysis and provided services for this project at no cost to the Town, as support for the water quality investigation. Analyses were completed from July to September 2014. Laboratory testing was performed with full quality assurance and quality control protocols. Testing results were provided in electronic and hardcopy reports to Mr. Kernen at the NHDES Drinking Water and Groundwater Bureau, who designed a simple table summary format for the BDWPC's distribution to each homeowner. The specific laboratory analytical results for each address are on file in the Town Manager's office.

2.4 Homeowner Notifications

In December 2014, the BDWPC provided each homeowner with the analytical results from the sampling of their private well analyses, accompanied by a cover letter and interpretive data sheet. A sample notification package is included as Appendix 2-2.

2.5 Data Evaluation and Reporting

The BDWPC and Mr. Kernen evaluated the data from this study. The homeowner survey results and the water sampling results were cross-referenced to allow mapping of the data with geographic information system (GIS) software, ArcGIS. Potential sources of contamination and basic hydrogeological conditions affecting groundwater quality were considered.

The BDWPC has prepared this report and an associated slide presentation to document the work performed, results, conclusions and recommendations for follow-up by the Town and by individual residents. This volunteer effort is for the benefit of town officials, residents in the study area and the general public or other interested parties.

It should be noted that the BDWPC has relied on homeowner reports, historical data from previous investigations, Region 1 EPA laboratory analyses and the diligent work of committee volunteers and Bow resident Mr. Brandon Kernen in order to produce this report. However, the BDWPC makes no warrantees or guarantees concerning the results and conclusions reported herein.

3.0 RESULTS

The results of this study expand on prior studies of the Brown Hill area groundwater quality, and serve to further identify and understand the conditions contributing to plumbing corrosion complaints. This study characterized areas up and downgradient of prior studies, and included the evaluation of well construction characteristics and age, location of septic systems and storm water drainage patterns, and quantified an expanded set of water quality parameters which had not been tested previously. Major findings are summarized as follows:

3.1 Corrosive Water Complaints

Corrosive water is an aggressive or acidic water quality condition that can dissolve metals at an excessive rate from metallic plumbing and other metallic appliances in contact with the water. Two naturally occurring factors which can make groundwater corrosive are low pH (7 standard units (s.u.) or below), and low alkalinity (low dissolved inorganic carbon). The introduction of salts by human activities, especially chloride which is highly mobile in the environment, elevates the total dissolved solids (TDS) and water conductivity which further contribute to water corrosivity. Studies by Nguyen et al (2011) have shown that chloride levels accelerate galvanic lead corrosion especially at low pH levels.

Corrosion impacts include leaching of metals from household plumbing and fixtures causing taste, staining, and in the case of lead or copper leaching, also health concerns. More severe water corrosion impacts include leaks resulting in more frequent replacement of fittings, water heaters and well pumps.

NHDES' Fact Sheet WD-DWGB-3-4 (2008) describes common corrosion conditions in groundwater, which are important to address to prevent uptake of lead and copper from plumbing fixtures into the water supply. As corrosive water sits overnight in the plumbing, metals leaching can result in concentrations at or above the health standard of 15 µg/L lead, and/or 1.3 mg/L copper.

Out of the 79 homes surveyed, 30% (24) indicated that they had experienced plumbing corrosion problems including more frequent replacement of water heaters and well pumps (Table 3-1 and Figure 3-1). These responses were most frequent at residences along Brown Hill Road.

3.2 Well Construction and Geology Susceptibility to Acid Rain and Land Activities

Well construction standards have changed over time. Wells that pre-date the state's establishment of a Water Well Board (RSA 482-B) in 1984 and adoption of water well construction regulations (Administrative Rules WE 100-1000, Chapter 600) generally have less depth of casing installed into the bedrock, and were not required to seal the base of the casing into the bedrock with a drive shoe. Wells constructed *after* 1984 are subject to minimum casing regulations and have to be constructed in a manner that helped to ensure that contaminants from surficial runoff or shallow groundwater did not impact the water supply by leaking vertically down the casing into the well. Current private bedrock well construction requires that wells be constructed with a drive shoe and a minimum of 20 feet of casing of which a minimum of 10 feet must be sealed in competent bedrock (NH Administrative Rule We 100-1000). With the exception of a couple of homes in the study area that installed replacement wells, most homes rely on the original well that was installed at the time the home was constructed. Table 3-1 includes the estimated age of 65 of the 79 wells based on homeowner survey results.

Older wells that pre-date the 1984 water well regulations and are not tightly sealed into bedrock, and/or are constructed in areas with shallow bedrock, are more directly affected by land activities since they are immediately recharged by rain and snow melt events. This conclusion is supported by the information in Table 3-2 and Appendix 3-1. Of the 65 wells where the age of the well was reported, 24 were constructed in 1984 or earlier; 41 were constructed in 1985 or later. Table 3-2 shows the relative large differences in average chloride and pH in these wells. Most noteworthy is the observation that 7 of 24 older wells exceeded 250 mg/L chloride while only 1 of the 41 wells constructed in 1985 or later exceeded 250 mg/L chloride. Significant differences in pH are also noted between the pre and post 1985 wells (Table 3-2).

As summarized in Table 3-1, water samples from 23 of the 24 homes reporting corrosion show acidic pH levels below 7.0, and 12 of the 24 homes show chloride levels above the secondary standard of 250 mg/L, both conditions which contribute to water corrosivity. Figure 3-2 (chloride) and Figure 3-3 (pH) show that wells with high chloride and low pH include homes along Clement, Bona Vista, Brown Hill, and Tonga Drive.

The results of this study show a comparatively denser cluster of corrosion complaints along Brown Hill Road in the vicinity of the intersection with Bona Vista Drive. Well samples from these homes confirmed both low pH and elevated chloride. These homes are also located in an area of relatively shallow ledge (a possible bedrock outcrop is located at the intersection of Bona Vista Drive and Brown Hill Road), denser development, and most rely on wells constructed prior to 1984 when the state adopted minimum well construction standards. Drainage ditches in this area tend to have a shallow depth to bedrock (see Figure 3-1).

The combination of the shallow depth to rock, roadside ditching directly over bedrock, and possibly well construction is believed to make these wells particularly susceptible to the introduction of salt from land activities such as salt run-off and water softener brine discharges. Further, the low pH levels suggest that many of the wells in this area are also susceptible to the effects of acid rain recharge.

3.3 Well Construction and Seasonal Variability

Older wells that are not adequately protected from near surface sources of contamination may show high variations in water quality after rainfall events and/or seasonally. Ongoing water quality monitoring at 39 Brown Hill Road over the past year (Figure 3-4) shows that pH and specific conductance (an indirect measure of total dissolved solids/salt) can fluctuate rapidly with recharge events when the well casing is not effectively sealed in areas with shallow bedrock. The very low water pH (5.4 to 5.7 s.u.) in this well would be corrosive to residential plumbing even without the added salt concentrations (NHDES 2008).

3.4 Acid Rain and Water pH in Bedrock Wells

The pH of groundwater results from a complex inter-relation among a number of factors including the pH of rainfall that recharges groundwater; the geochemistry of the geologic materials in which the groundwater is found; and other variables including the introduction of contaminants and the residence time of groundwater in contact with the water bearing formation.

The pH of rain in the northeast states is acidic and typically ranges between 4 to 5 s.u. (Ayotte, J.D. et al, 2003), and therefore causes lower pH in shallow groundwater. The composition of bedrock in a given area also impacts the pH of water. Field tests of groundwater from the 79 wells in the study area showed average and median (middle number) pHs were 6.36 and 6.48 s.u.

(see Table 3-2 and Appendix 3-1) suggesting a normal distribution of the 79 results. The range of pH values was 4.63 to 8.09 s.u. (Table 3-1), with the higher range likely due to the presence of treatment system. However, the majority of wells showed very acidic pH likely influenced from acid rain recharge. The variations in the composition of bedrock in the study area is not likely to account for the depressed pH levels observed in this study.

The eastern section of the Brown Hill study area is underlain primarily by Pelitic Schist, while the west part of the study area is underlain by Concord Granite (Figure 3-5, Bennett, D. et al 2006). Both of these bedrock formations are sensitive to acid deposition, which means they do not have the capacity to rapidly neutralize precipitation (acid rain).

Generally, pH increases with increasing water age in the aquifer. Hydrolysis of silicate minerals, which are abundant in the bedrock and glacial materials of New England, is an important process that increases pH. Because these reactions do not reach equilibrium rapidly, the pH is generally highest in older groundwater (Ayotte, JD et al 2003). This implies that groundwater derived from wells that are deep and sealed with additional casing will likely exhibit a higher pH.

3.5 Salt in Groundwater

3.5.1 Specific Conductance as Surrogate for Salt

Water samples for this study were analyzed for chloride (mg/L) by a certified laboratory, and in the field for specific conductance (µS/cm) as a salt surrogate parameter. Figure 3-6 illustrates the relationship between laboratory chloride results from the 79 wells and the specific conductance results monitored in the field. The graph confirms the linear relationship between these analyses with a linear fit coefficient of $R^2 = 0.97$. This information is provided to support the use of specific conductance as a field surrogate for homeowners and future studies by the Town.

Of the 79 wells tested for chloride, the average concentration was approximately 121 mg/L and the range was <1 to 520 mg/L (Table 3-2). Thirteen of the 79 wells had chloride values >250 mg/L and 12 of the 13 residents with chloride >250 mg/L reported corrosion problems with their supply. Six of the 13 residences with elevated chloride in their water used water softeners (see Table 3-1).

The aesthetic (taste) threshold for chloride in public water supplies is 250 mg/L. Generally, people note a salty taste in water with chloride levels above 250 mg/L. Eight of the survey respondents reported a salty taste in their water. Chloride in these wells ranged from 150 to 420 mg/L. Nine residents with chloride levels ranging above 250 mg/L to as high as 520 mg/L did not report or note salty taste in their water illustrating the subjective nature of the taste threshold.

The following subsections summarize the principal sources of salt in groundwater in the Brown Hill Road study area.

3.5.2 Salt Contribution from Water Softeners

The use of cation exchange resin or “water softeners” is a very common treatment method for reducing the hardness of groundwater in private supplies. Hardness is a measure of the total calcium and magnesium in a water source, two natural minerals that, when present in high concentrations, can precipitate and cause a white scale on surfaces such as plumbing, water heaters, and other fixtures. Hardness has no adverse health effects, in fact, calcium and magnesium are essential nutrients (PennState Extension, 2015). “Hard water” has been categorized as greater than 150 mg/L of hardness (NHDES Fact Sheet WD-DWGB-3-6 Hardness; 2008).

Typical residential water softeners use an average of 10 lb of salt per week or 40 lb of salt per month (Watertech 2014). Many residential softeners are currently installed to backwash based on a timer, such as once per week, regardless of water consumption. Some local governments such as the Region of Waterloo and City of Guelph, Canada, with naturally high hardness have adopted local ordinances requiring “demand-initiated regeneration” or meter-based backwash valves, in order to reduce salt discharges to the ground (www.watersoftenerfacts.ca). This perennial brine discharge affects water corrosivity by:

- Stripping the protective calcium and magnesium minerals in the water, while increasing the highly conductive sodium;
- Creating new brine loadings to groundwater, via the septic system or dry well, whereby increasing sodium and chloride levels in the local aquifer, and,
- Driving cation exchange reactions in the subsurface by the increased cation loading, which displaces hydrogen (pH), manganese, and other cations, and must be removed again by the home softener system creating a self-contaminating cycle (Klevens and Roy, 2011).

As their name indicates, water softeners are designed and operated to remove calcium and magnesium hardness; however, many residential applications are installed to remove trace levels of iron or manganese. The Brown Hill study area similar to other well waters in the state, exhibits iron and manganese levels between 0.05 and 3 mg/L, compared to hardness levels at orders of magnitude higher at 50 to 480 mg/L (Table 3-1). Due to the higher concentrations of hardness, the softener must remove those cations *before* it can reach the lower iron or manganese contaminants, such that it must be regenerated more frequently creating more brine discharges. When hardness removal is not necessary, other, non-salt treatment technologies may be used to reduce iron or manganese more efficiently (NHDES WD-DWGB-3-8 Iron and Manganese; 2013).

Analytical results for hardness in the Brown Hill Road study area were available from 71 of the 79 wells. For unspecified reasons, the hardness results were not calculated (NC) in the 8 remaining residential well samples. The average hardness in the 71 samples was approximately 97 mg/L and the median or middle number was 81 mg/L with a range of 3 to 480 mg/L (Table 3-2). The average and median concentrations are well below the definition of the lower limit definition of a “hard” water (150 mg/L) (NHDES WD-WDGB-3-6, 2008).

Twenty two homes reported using water softeners. Hardness results were available for 14 of these homes (the other homes having an NC designation in the analytical results (Table 3-1). Hardness results from 2 of the 14 homes were only 3 mg/L suggesting that the sampled water had undergone treatment by softening. Of the remaining 12 residences using softeners, the average hardness was approximately 116 mg/L and the median was 81.5 mg/L (see Table 3-2 and Appendix 3-1) or about the same as all 71 well results for hardness. Only 4 of the 12 wells being treated with water softeners had hardness >150 mg/L suggesting that the use of water softeners with resultant brine discharges might be unnecessary and may be exacerbating chloride levels in groundwater.

3.5.3 Salt Contribution from Road Salt / Storm Water Drainage

The potential environmental impacts related to road salting have been known for decades. Since the 1990s, the Town of Bow has been aware of the impacts of road salting on groundwater resources and private well supplies. This is especially the case in the Brown Hill Road area where topography, drainage, geological conditions, well location, and well construction are factors that can adversely affect the water quality in numerous wells in the area. The drainage system along Brown Hill Road in an area of shallow depth to bedrock is believed to be a particular problem. The drainage system adjacent to Brown Hill Road varies with the topography of the road. Drainage from the intersection of Bona Vista Drive and Brown Hill Road is routed to unlined ditches (see Figure 3-7). The ditches are excavated in an area with relatively shallow ledge. During the winter, snow banks contaminated with sand/salt accrue in the ditches until warmer weather melts the snow. The salt laden runoff drains to ditches and infiltrates to the ground. Chloride concentrations in the wells sampled were generally higher in the area of the drainage ditches (Figure 3-2 Chlorides). The remaining portion of Brown Hill Road drains with the natural contour of the land to one or both sides of the roadway.

As summarized previously, in the mid-1990s, the Town retained Stearns & Wheler who investigated the conditions at the time and made recommendations in their 1996 report that focused on installing/improving roadside drainage and implementing a *"Sensible Salting Program"* (Stearns & Wheler, 1996). To that end, the Town developed a winter maintenance policy in 1997 that has been updated periodically (Bow, Town of, 2010). The policy recommends a 4:1 sand to salt mixture to minimize salt applications on town roads. The reduced salt mixture reduces the amount of salt to approximately 140 pounds per lane mile (DPW Data 2013-2014) or, 280 pounds for a two lane road such as Brown Hill. This is about one half (1/2) the amount recommended by the New Hampshire Department of Transportation (NHDOT).

During the winters of 1998 and 1999, the town investigated alternative de-icers including calcium chloride, magnesium chloride, and a product called Ice Ban, an organic liquid, supplied by SEARCO of Rome, New York (DPW File Data 1998-1999). The field applications of Ice Ban and alternate salts had mixed results and the town's winter maintenance policy has been to proceed with the reduced salt policy using a 4:1 sand to salt application ratio.

The reduced salt policy on Brown Hill Road may have had some modest impacts to salt in groundwater in the area. Where available, the current water quality results were compared to samples collected in previous studies, and suggest that chloride levels have not increased with time. Several locations actually show current chloride concentrations are lower than historical results (Table 3-1). Chloride results collected specifically along Brown Hill Road, including one on Bona Vista Drive adjacent to Brown Hill Road, between 1988 and 1996 (Stearns & Wheler, 1996) were compared to the 2014 chloride results from wells along Brown Hill Road and nearby

Bona Vista. Chloride data from 21 wells along Brown Hill was available between 1988 and 1996. Chloride data from 35 wells along Brown Hill Road (and Bona Vista) was obtained in 2014. Many of the homes listed in the Stearns & Wheler report were sampled multiple times; one well was sampled six times. Chloride in groundwater samples from these wells averaged between 264(the lowest values) and 352 mg/L (the highest values) between 1988 and 1996 (see Appendix 3-1). Groundwater in wells along Brown Hill Road (and Bona Vista Drive) averaged 140 mg/L chloride in 2014, which is about ½ of the lowest average (264 mg/L) between 1988 and 1996.

A comparison of just the 8 wells along Brown Hill Road that were sampled both in 2014 AND 1996 or earlier (see Appendix 3-1) shows that the average chloride concentration from multiple samples collected between 1988 and 1996 is about 276 mg/L versus the average chloride concentration for the same eight wells in 2014 (about 123 mg/L). Although this may seem to indicate a significant improvement in chloride concentrations over time along Brown Hill Road, it is mitigated by the observation that the lowest values of multiple samples from each of the 8 wells in 1996 and earlier is approximately 140 mg/L. That is essentially the same as the 2014 average chloride concentration (about 123 mg/L) in the same wells sampled in 2014 (see Appendix 3-1).

It is concluded that the low salt application policy of the town has probably had an overall beneficial impact on the chloride concentrations in groundwater or, at least, has not significantly increased the problem of salt in groundwater. The Town should continue to manage and reduce road salt applications by continuing training of DPW staff, following best management practices for salt application such as the Snow-Pro guidelines (UNH T^2 Center, 2016), and evaluating cost effective alternatives, if available, that provide equivalent safety for driving.

3.5.4 Other Potential Sources of Salt Contamination

This study focused on salt contributions from road salting and water softener regeneration brine as the most likely sources contributing to salt in groundwater. Two other potential sources are worth mentioning although they were not investigated during this study. The first is the application of salt on residential driveways and walkways. This may also impact groundwater quality, depending on the amount applied, the direction of the drainage, and the depth of the water table.

The second is the potential for discharges from swimming pools and hot tubs using sea water or other salts to simulate sea water. Typical sea water contains over 18,000 mg/L of chloride and other contaminants such as bromide (see www.lenntech.com/composition-seawater.htm). Residential pool draining and on site discharge of large volumes of sea water will affect local groundwater and potentially surface waters, depending on the location, volume and frequency of discharges.

3.6 Arsenic and Uranium Occurrence

Arsenic and uranium are naturally occurring drinking water contaminants that originate from the bedrock. Twenty four of the 79 wells exceeded the MCL of 10 ug/L for arsenic; 14 of the wells exceeded the MCL of 30 ug/L for uranium and a total of 10 wells exceeded both MCLs for arsenic and uranium (Table 3-1 and Appendix 3-1). The locations of these wells are shown on Figure 3-8.

All groundwater samples from the 24 homes with reported plumbing corrosion did not exhibit arsenic or uranium concentrations in excess of safe drinking water standards. However, *thirty out of the remaining fifty-five* wells where no corrosion was reported exceeded the drinking water standard for arsenic and/or standard for uranium (Figure 3-8 and Table 3-1). This is an important finding because these contaminants do not present any color, smell or taste, so homeowners may not be aware of their presence. It also supports the observation that wells with reported corrosive water conditions are probably being recharged by groundwater in the uppermost water bearing zones that receive recharge from recent precipitation, while deeper and newer wells are sealed into the bedrock and recharged from bedrock containing arsenic and uranium bearing fractures. Homeowners need to be aware that attempts to mitigate corrosion issues by drilling a new well which is deeper and more tightly sealed in bedrock may be more likely to require treatment for bedrock contaminants such as arsenic, uranium and radon.

It should also be noted that samples for this study consisted generally of raw, untreated water from the outside spigot. Many homes in the study area reported having existing treatment; however, additional information and testing is recommended to establish if existing treatment is addressing elevated arsenic and/or uranium.

3.7 Other Parameters of Concern

The original objective of this investigation focused on complaints of corrosion and the presence of salt (sodium chloride) in groundwater. However, through the efforts of local resident Brandon Kernen and the cooperation of the U.S. EPA, participating homeowners were provided with a broad list of chemical parameters in their drinking water that greatly enhanced the understanding of water quality issues in the study area. This has afforded participating residents with additional information that otherwise would not have been available.

Two other water quality parameters of general concern in New Hampshire well waters but could not be included as part of this investigation are radon, measured in picocuries per liter (pCi/L) and Total Coliform bacteria measured as presence / absence (P-A/100mL). Radon occurs naturally in bedrock wells as it is a decay product of the naturally occurring uranium. Total coliform bacteria are introduced into well water by contamination from the environment. To evaluate the occurrence of these parameters in Bow private well water, the BDWPC requested historical results of private well testing from the state water laboratory in Concord. These results are only available in aggregate form to protect homeowner privacy, but show that radon was present above the recommended levels in 74% of samples analyzed; and total coliform bacteria was present in 28% of samples analyzed (Table 3-3). The results are for wells from Bow residents tested at the state lab for calendar year 2015. Private well owners may consider this occurrence data to assess the safety of their own well supplies in terms of public health standards.

Table 3-3 also presents information regarding other analytical parameters that were tested throughout the town during 2015.

4.0 CONCLUSIONS/RECOMMENDATIONS

Based on evaluation of the data collected and results obtained in this investigation, the BDWPC offers the following conclusions and recommendations:

4.1 Conclusions

Reports of corrosion of plumbing in the Brown Hill Road area are most likely attributable to several factors working singly or in combination to impact groundwater in the study area. These factors create corrosive or "aggressive" conditions in the water because they attack the plumbing fixtures and copper piping. Water corrosiveness can present health impacts from possible lead and/or copper leaching from home plumbing and fixtures. First flush, stagnant lead and copper levels were not assessed as part of this study but, because of their health implications, are listed as one of the main recommendations for follow-up below.

The BDWPC considers that water corrosivity in the Brown Hill study area results from both natural and man-made factors:

- Low pH (<7.0) in groundwater resulting primarily from acid rain that is a primary source of recharge for wells that are not sufficiently sealed into bedrock;
- Chloride levels from the application of road salt, stormwater runoff and unlined drainage ditches; and,
- Chloride levels and increased cation exchange in soils from residential water softener brine discharges.
- Well construction (pre-1985) that, depending on location and shallow bedrock conditions, may not effectively prevent contaminants and acid rain recharge from entering the water supply and affecting water quality.

The BDWPC cannot predict, based on the information gathered, which wells might be affected more or less by the above factors. In addition, other factors influencing the water corrosiveness (e.g. the removal of natural hardness, alkalinity and total dissolved solids) were not quantified.

Homeowners experiencing corrosion issues need to be aware that constructing a replacement well that is deeper and with casing sealed further into bedrock may alleviate corrosion, but is more likely to contain bedrock contaminants such as arsenic, uranium and radon, which also require water treatment.

4.2 Recommendations

1. Homeowners should test private well water for stagnant lead and copper which may be leaching from fixtures and plumbing due to water corrosiveness. The BDWPC can provide information through the town website and public meetings to encourage testing.

2. Homeowners with acidic water (pH<7) should evaluate the benefit of installing a calcite neutralizer to raise water pH. Homeowners with severe plumbing fixture corrosion and/or having groundwater with copper or lead above recommended health standards should also consider replacement of piping and fittings with alternative plumbing materials certified for drinking water use, that are not subject to the corrosive effects of the water.

3. Homeowners with water softeners should reassess the need for treatment using brine-based softeners and cease using them if possible, and/or optimize their operation by installing volume-based regeneration controls to reduce the brine discharge. The NHDES provides an online water treatment tool called "**Be *Well* Informed Guide**" http://xml2.des.state.nh.us/DWITool/Welcome.aspx to self-evaluate private well water quality and treatment options.

4. The Town should continue to manage and reduce road salt applications by continuing training of DPW staff, following best management practices for salt application such as the Snow-Pro guidelines, and evaluating cost effective alternatives, if available, that provide equivalent safety for driving.

5. The Town should evaluate the feasibility of implementing an engineering solution, such as installation of corrugated storm water piping, to reduce or eliminate infiltration of salt contaminated runoff in the drainage ditch/culvert system in the areas between 33 and 66 Brown Hill Road. This is the area shown on Figures 3-2 and 3-7 where shallow depth to bedrock is suspected and wells with elevated chloride results is most severe. Evaluating the feasibility of lining the drainage swale adjacent to 48 Brown Hill Road is one solution recommended to prevent salt infiltration to groundwater in that location.

6. The BDWPC, working through the town and with agencies such as the NHDES and Dartmouth private well program, should continue to provide information to educate homeowners about groundwater, wells, and the protection of their water supplies. The BDWPC should continue to promote private well testing and provide information concerning the selection of efficient water treatment solutions for common groundwater issues including water corrosivity, hardness, iron, manganese, bacteria, arsenic, uranium and radon.

7. The BDWPC should make information available regarding well construction standards for new or replacement wells.

8. The BDWPC should research the potential environmental impacts and regulations of discharges, if any, from swimming pools using sea water.

In summary, the BDWPC considers that the best approach to address water complaints in groundwater in the Brown Hill Road area is to continue to minimize the amount of salt on road applications; control and reduce road salt runoff infiltration to unlined drainage ditches and culverts; and eliminate the use of water softeners with brine discharges except where analytical results demonstrate a critical need for a softener. The BDWPC should continue to provide information to residents on private well testing, and treatment technologies for iron and manganese, water corrosivity, and naturally occurring bedrock well contaminants such as arsenic, uranium and radon.

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