

October 18, 2013

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Re: City of Henderson, MN; Well No.1; Well Rehabilitation Recommendations
WSE Lab Report 19632, dated October 18, 2013

Analyses of water samples for the City of Henderson Well No. 1 suggest that the development and accumulation of iron oxide and carbonate scale in the active portion of the well, is likely affecting the operation and efficiency of the open borehole well. To address the identified concerns, as presented in WSE Report 19632, this well would benefit from a combined mechanical and chemical rehabilitation, followed by a pH controlled chlorination treatment for disinfection. Due to the open borehole well completion, rehabilitation should be conducted in a cautious manner, and a video survey to evaluate the integrity of the well prior to treatment is strongly encouraged. A post-rehabilitation video survey and pump test for comparison purposes may be valuable, as well. The recommended multi-phase treatment utilizes successive phases of cleaning to address the fouling present, and is outlined below.

Pretreatment: Pump Removal

Remove the permanent pump and column pipe from the well, service as needed, clean. Disassembly of the pump is recommended for effective cleaning. Following cleaning, the pump should be evaluated for corrosion and material degradation that may have occurred over time. The motor should be evaluated for excessive wear and the need for repair or replacement.

Pretreatment: Mechanical Agitation

The well should be thoroughly agitated to remove fouling that has accumulated on the casing and production zone. The agitation should utilize a stiff nylon brush, or jetted to disrupt and dislodge biological growth within the well column. The tool used should complement the inner diameter of the well in size, allowing sufficient tool material to contact the well structure and aid in removal of accumulated material.

Immediately following the pretreatment agitation efforts, it is very important to thoroughly purge the well of debris and disrupted material, beginning at the very bottom of the well and working upwards until thoroughly evacuated. Purge until visible turbidity is removed.

Evacuated material should be collected above ground and disposed of according to local and state regulations.

Chemical Treatment Phase

Following the removal of the accumulated debris within the borehole, the chemical treatment phase will be used to further clean the well column, while allowing cleaning efforts to extend into the near-well formation to open fissures and flow paths. This treatment step is designed to primarily target iron and any biological deposits within the well and the fouling potential within the near-well formation. This step should incorporate 6% phosphoric acid and 2% NW-310 biodispersant by Johnson Screens calculated on a volume equivalent to 1.5 times the standing well volume.

Based on the supplied data, the treatment should utilize the following chemicals:

Phosphoric acid (75% active)	200 gallons
NW-310 biodispersant	65 gallons
Potable Water (for blending)	250 gallons

Blend the solution above ground and add the chemicals into the bedrock portion of the well via a tremie pipe or similar delivery mechanism. Efforts to evenly distribute the solution throughout the entire well column are strongly advised. Once the solution has been introduced, begin to surge or jet the solution throughout the entire well for 6 to 8 hours. Following surging, allow the solution to remain downhole overnight. *Monitor the pH of the downhole solution and keep it at 3.0 or below during the entire treatment process.*

The following day, surge or jet the well again for 4 to 6 hours, focusing efforts on the screened sections of the well, again monitoring the pH and keeping it at 3.0 or below, adding additional hydrochloric acid if needed to maintain pH. Following surging of the treatment solution, the well should be thoroughly purged of the chemicals and disrupted material. Pump the well until the pH has returned to normal (7.0 or greater), visible turbidity is zero, and the well is pumping clear. Collect and neutralize the evacuated material above ground according to state and local regulations.

Disinfection

Following chemical treatment, the well should be disinfected. Disinfection should utilize a pH-adjusted chlorination treatment of a 250 ppm chlorine level in a pH range of 6.5 to 7.0.

The volume of the disinfection solution should be equivalent to 3 times the standing well volume. This larger volume is utilized to flood the borehole with the disinfection solution in order to increase the effectiveness of treatment, as well as increasing the treatment area. Utilization of NSF approved chlorine enhancing chemicals Johnson Screens NW-410 product, is strongly encouraged to aid in both effective disinfection as well as to increase the treatment area. Based on the supplied well data, the chlorination treatment should incorporate the following chemicals:

Sodium Hypochlorite (12% strength)	16 gallons
NW-410 chlorine enhancer	38 gallons
Potable Water (<i>approximately</i>)	7500 gallons

The disinfection solution should be blended above ground and introduced into the well by a tremie pipe or similar treatment line. Efforts should be made to disperse the disinfection solution evenly throughout the well. Once the solution is placed into the well, it should be lightly agitated with a single disc surge block or jetting tool, to supply agitation and

dispersion throughout the well column and borehole. Following agitation, check the chlorine residual within the well to ensure sufficient strength is present. If the chlorine residual has diminished below 150 ppm, add additional sodium hypochlorite to raise it to that level.

Allow the chlorine solution to remain downhole overnight. Following this period, begin evacuation of the well from the bottom, working upwards, until a minor residual (~ 50 ppm) is present and all debris has been evacuated from the well, as identified by visible turbidity. At this time, the permanent pump and column pipe can be placed back into the well and utilized to purge the remaining chlorine solution from the well.

Once disinfection efforts are completed, the well should be returned to an active operating schedule as soon as possible.

Follow up sampling of the well to evaluate cleaning efforts and to establish a new baseline could aid in establishing long term well operation and maintenance procedures. A monitoring program that includes periodic submittal of water samples to the lab to assess the iron levels and overall mineral congestion within the system would be beneficial to ensure the long-term operating efficiency of the well, and identify fouling before it reaches severe levels.

The interpretations and recommendations presented are based on an evaluation of the water samples and submitted data. The recommended treatment is based on laboratory and field evaluations of similar fouling occurrences within potable well systems. Further investigative efforts, such as a pump test, additional video surveys, or other evaluation methods may offer additional insight into the condition of the well and the degree of fouling.

If you have any questions regarding the analyses or the recommendations presented herein, please contact our office.