Appendix C
Experience Basis and Maintenance Treatment Example

C-1. Case Histories of Well Maintenance Activities

Case histories are illustrative of possible problems and how they were handled elsewhere. A number of water supply system case histories are summarized in Smith (1992), Borch, Smith, and Noble (1993), and Cullimore (1993) among others. These are illustrative of the worldwide distribution of problems of wells, and, in particular, those associated with Fe, Mn, and S biofouling, and how they have been addressed. Several other geotechnical and environmental-studies case histories are summarized in Smith (1995) and Alford and Cullimore (1999) and are the basis for the following.

(1) Problems associated with wells are largely the same all over the world.

(2) Lack of planning and adequate response to deterioration problems of wells results in reduced performance of wells and water collection and distribution systems.

(3) The economic impacts of this deterioration can be significant, but are only now being quantified adequately in the water supply setting (e.g., Sutherland, Howsam, and Morris 1994), but hardly at all in the HTRW remediation field. For water supply wells, Sutherland, Howsam, and Morris (1994) estimate that 40% of wells worldwide are operating inefficiently. It is estimated that $100 million is annually spent on well and well pump rehabilitation in North America.

(4) Preventive actions useful in limiting the effects of biofouling (as documented in open literature) have not been widely applied in the planning of ground water supply and control projects to date.

(5) Design and operations poorly matched to the aquifer being pumped (e.g., choice of corrodible materials or excessive pumping) aggravate environmental well deterioration causes.

(6) Adverse well deterioration effects on the reliability of ground water quality samples have been documented.

(7) Wells operating under vacuum and anaerobically exhibit fewer clogging symptoms.

(8) Injection of biocides has largely been ineffectual in solving the immediate well problems. They almost always fail to prevent a recurrence of problems, although recurrence of performance decline may be significantly delayed.

(9) Where attention to microbial fouling potential (or the symptoms of such fouling) results in the institution of a preventive maintenance program, biofouling-related problems can be controlled (see additional case histories summarized in this section). However, programs have to be revised in response to experience with a well field over time.

(10) New well construction may serve to temporarily avoid recurrence of a problem. However, current experience is demonstrating that clogging, biofouling, and Fe/Mn/S transformations may extend several meters away from wells with existing problems. The performance problems of the former wells cannot be considered solved with new construction. The problems are likely to recur with the new wells unless a maintenance program is implemented.

C-2. Maintenance Treatment for Wells: Basic Procedure

The procedure described below is an invasive maintenance treatment procedure that has proven to be generally effective in stemming biofouling-related decline of well system performance on HTRW sites. Note that some well situations will not require Steps 1 and 2, but most do at some point. An approach similar to this has been approved at a Superfund site location in New Hampshire.

1. Detach and remove the installed well pump and other equipment such as water-level gauge transducers. Set aside, service, or replace components as needed, and clean in preparation for re-installation. NOTE: It is better to remove the pump in most situations; however, if the well pump is on the bottom, or if the well is specially equipped, the pumping system can be used for circulation.

2. Brush casing and screen and bail or pump out to remove settled and surface-attached debris in the well. Brushes should be properly sized and designed to abrade surface deposits, but not to score or gouge casing or screen materials. These are often specially shop-fabricated for specific well applications.

3. (Optional): Conduct a downhole TV survey to assess damage or material changes. Conduct the survey before brushing is started.

4. Mix a solution for treatment in clean (sediment-free) chemical-resistant tanks: In a volume of clean (potable) water three times that of the calculated volume of the well screen (including the gravel pack volume often makes for an excessively large treatment volume), add sufficient nonphosphorus anionic wetting agent to make a 1% solution and mix, add sufficient industrial-grade glacial (87%+) acetic acid sufficient to make a 12% solution (range 10 to15 %), and amend with sufficient clean, industrial grade sulfamic acid to adjust the pH to < 2 (mix well to dissolve). Oxalic or citric acids can be used in place of acetic acid for heavy iron oxide encrustation in waters with less than about 120 to150 mg/L total hardness. Adjust pH as needed by adding acid. NSF International listed products are available for some of these applications.

NOTES:

Always add acids to water and not vice-versa. While relatively safe to handle, all the chemicals specified can cause chemical burns of skin, eyes, and respiratory tissues if mishandled. Anyone handling well treatment chemicals should have specific training for this purpose, and equipment should be supplied to minimize the potential for accidental spills or human exposure.

Both acetic acid and sulfamic acid are readily available from conventional chemical supply sources. While costly in relation to some acid products, acetic acid has the advantage of having some disinfection properties, is not highly reactive with metals and metal oxides (in contrast to mineral acids), and is the best detergent acid. Sulfamic acid is inexpensive and a readily transportable and storable solid. Both acetic and sulfamic acids are Class 55 detergents (nonhazardous), which adds flexibility in transport.

Highly concentrated acetic acid solutions freeze below about 12^{o} C (~ 55^{o} F) and should be kept above this temperature prior to mixing. Dilute treatment solutions have much lower freezing temperatures far below most ambient ground water temperatures. Where this may be critical (as in application under very cold surface conditions into near-freezing ground water), those conducting treatment should calculate the freezing points of dilute solutions. Hot water can be mixed with acetic acid to avoid freezing, or more dilute solutions can be used.

Constant rate pumping tests and slug tests (in which an instantaneous charge of water or a solid object is introduced into a well)

All surfaces potentially in contact with cleaning solution should be nonreactive with its components. Chemical-resistant hose, stainless steel, PVC, and high density polyethylene (HDPE) plastics in tanks, fittings, and pumps will provide good service.

5. After batch mixing, tremie into the screen zone by gravity from the bottom up across the screen surface. Apply very slowly (~ 10 gpm (~ 0.0379 cu m/min)) through a 1- to 2-in. (2.54- to 5.08-cm) -diameter pipe made of nonreactive materials.

6. Surge in place and leave overnight (12 to 24 hr). Do not leave in place more than a weekend.

NOTE: Surge tool and applications of conventional ground water technology for well development surging apply to HTRW well cleaning. For example, surge blocks should have size and weight to permit a 1- to 2-ft/sec (0.3- to 0.6- m/sec) fall.

VARIATION (pump in place): Remove the well cap, disengage pitless adapter, and pull up pumping discharge assembly to surface. Use a reversible friction pump puller to move the pump slowly up and down to provide a surging action. Pump at a low rate during surging, recirculating back down the well (monitor pH - treatment is finished if pH rises above about 5 or if water clears). Note: Watch for lockup and stop immediately if it occurs.

7. If satellite wells are installed around a pumping or injection well for treatment application (highly recommended), treat each 2- to 4-in (5.08- to 10.16-cm) -diameter well with a solution as in step 4, but six times the satellite well's screen diameter. Surge in place and leave overnight (see step 6).

8. For both the target and satellite wells, sound wells to determine depth and safety to insert development tools. Surge and pump to containment and necessary pretreatment prior to release to water/wastewater treatment. Release water should pass through the site's remediation treatment facility prior to release to the open environment.

NOTES:

Know the specific release and treatment requirements of the jurisdiction, project, and site.

Check pH and treat as needed to within 1 pH of background (pH 6.5 to 8.5 for wastewater treatment plants).

Tanks for containment should be sufficient in size to handle the expected discharge water volume requiring treatment without shutting down development. The system for neutralizing should permit continuous and not batch treatment.

If site remedial treatment is digestive, expect a radical increase in BOD and COD. Expect and plan for pretreatment for a large increase in mineral and encrustation-debris solids content.

9. Continue surging until a set standard for clarity is met (standard set realistically based on site experience. Some standards used are < 5 NTU turbidity, < 5 ppm sediment, and a predetermined percent recovery of specific capacity. Sound wells periodically and remove accumulated debris. Examine to determine the nature of solids (filter pack? formation?). If excessive filter pack is brought in, examine with downhole TV to determine if a screen or casing breach has occurred.

NOTE: This can be a lengthy process, especially if wells were not developed sufficiently when installed, or during remediation attempts. Frequent maintenance treatments should reduce the necessary development time considerably.

10. Reassemble, install, and test the pump and in-well instrumentation and return to service.

11. Benchmark biofouling and performance indicators using methods suggested.

12. Clean and make necessary repairs to treatment equipment.

C-3. Treatments for Heavily Impacted Wells

a. While the intended scope of this EP is the maintenance of well system performance, it is recognized that O&M personnel will usually find themselves in the situation of rehabilitating wells and systems that have deteriorated in performance. Rehabilitative treatments have many similarities to maintenance treatments such as the example outlined in paragraph C-2. Such treatments are summarized in Driscoll (1986), Borch, Smith, and Noble (1993), Cullimore (1993), Smith (1995). One such treatment summarized in Alford and Cullimore (1999) focuses on HTRW remediation applications.

b. Rehabilitation treatments outlined in these publications typically can be applied using adaptations of conventional ground water technology equipment. In addition, well rehabilitation has a number of specialty tool, equipment, supply, and service vendors. An attempt has been made to offer information on and Internet links to sites on well rehabilitation from the "Groundwater Science" website <http://www.groundwatersystems.com>.