Chapter 12
Well Rehabilitation

12-1. General

The analysis of well discharge records and accompanying piezometric data will often indicate whether the relief wells are functioning as intended. A decrease in well discharges with time for similar pool or river stages with rising piezometric levels between wells is usually indicative of decreasing well efficiency. A quantitative measure of the loss in efficiency is only determined by carefully conducted pumping tests as previously described. Should the pumping tests indicate a reduction in specific capacity of more than 20 percent compared to that measured at installation, a detailed study should be made of the consequences of the reduction and what remedial measures should be employed. Generally, it may be possible to restore the wells to about their original efficiency by means of rehabilitation techniques.

Rapidly developing technology in the fields of chemistry and microbiology, as they are related to wells and aquifers, could negate portions of the following rehabilitation techniques but the items covered are at least broadly covered and represent present practice. Environmental concerns (past and present chemical usage) also require that certain Federal, State, and local laws be followed and rehabilitation techniques may have to be modified to comply with these laws.

12-2. Mechanical Contamination

Plugging of relief wells by silts, clays, or other particulate media entering the filter pack either from the formation or through the top of the well is usually difficult to determine except as indicated by periodic pumping tests. If significant reductions in specific yield are noted, rehabilitation of the well is in order. Mechanical redevelopment of the well similar to that used to develop a new well should be the first step. Overpumping or pumping the well at the highest rate attainable is generally advantageous. Surging and the use of horizontal jetting devices also may produce beneficial results.

12-3. Chemical Treatment with Polyphosphates

Mechanical plugging of relief wells is corrected most often by chemical treatment with polyphosphates. These chemicals act as dispersing agents which causes silt and clay particles to repel one another and calcium, magnesium, and iron ions adhering to the particles to remain in a soluble state. The most widely used chemicals for this purpose are the glassy sodium phosphates which are inexpensive and readily available. The chemicals are usually applied in concentrations of 15 to 25 lb per 100 gal of water in combination with at least 50 ppm of chlorine (about one-half gal of 3 percent household bleach or chlorox in 100 gal of water). Phosphate solutions are mixed in a barrel or tank adjacent to the well. The material is best dissolved in small amounts in a wire basket or perforated container in agitated or swirling water. If the material is dropped directly into the tank or well, it will sink to the bottom and form a large gelatinous mass that could remain undissolved for some time. One of the most effective means of introducing the phosphate and chlorine solution into the well is by means of a horizontal jetting device. The well should then be surged vigorously prior to pumping. Three or more repetitions of injecting, surging, and pumping over a 2 to 4-hr cycle will be much more effective than a single treatment with a longer detention time.

12-4. Chemical Incrustations

If the cause of reduced well efficiency is determined to be chemical incrustation, more frequent cleaning and maintenance should be initiated. If the efficiency remains low, consideration should be given to treating the well with a strong acid solution which can chemically dissolve the incrusting materials so that they can be pumped from the well. Acids most commonly used in well rehabilitation are hydrochloric acid, sulfamic acid, and hydroxyacetic (glycolic) acid. Acid treatment should be used with caution on wooden screen wells as the acid may tend to attack the lignin in the wood and cause severe damage. Methods for acid treatment of wells are described in detail by Driscoll (1986). The methods require great care and only experienced personnel with specialized equipment should be employed. Specialized firms with experience in this field should be utilized for this purpose.

12-5. Bacterial Incrustation

Incrustation of wells by iron bacteria is best controlled by a combination of chemical and physical treatments. Many chemical treatments have been suggested and applied in practice but their success has been variable as evidenced in many cases by recolonization or regrowth in the treated wells. A strong oxidizing agent such as chlorine is widely used to limit the growth of iron bacteria. Chlorine, in the form of a gas, is used in the restoration of commercial wells; however safety and experience requirements limit its general application. A more convenient alternative is the use of hyperchlorite or other chlorine products (see Table 12-1). A discussion of procedures for the use of the various products is given by Driscoll (1986). Physical methods for control of iron bacteria are available, however sufficient research has not been accomplished to justify their use in relief wells. A survey of new techniques is presented by Hackett and Lehr in Leach and Taylor (1989).

12-6. Recommended Treatment

As clogging of well screens and filter materials is caused not only by the organic material produced by the bacteria but also by oxides and hydroxides of iron and manganese, better results are usually obtained by treating the well alternately with a chlorine compound to attack the organic material and a strong acid to dissolve the mineral deposits. Between each treatment the well is pumped to waste to ensure that chlorine and acid are not in the well at the same time. A recommended procedure using the two procedures is:

a. Inject a mixture of acid, inhibitor, and wetting agent. The addition of a chelating agent such as hydroxyactic acid may sometimes be beneficial. An inhibitor is needed only if the well screen is metal. The amount of acid should be typically one and a half to two times the volume of the well screen. If a chelating agent is not used, iron will precipitate out if the pH rises above 3. The precipitate can result in clogging; therefore the pH should be monitored throughout the acid treatment and not be allowed to rise above 3 regardless of whether a chelating agent is used.

b. Gently agitate the solution with a jetting tool at 10-min intervals for a period of 1 to 2 hr.

c. Pump out a volume of solution equal to the volume of the well.

d. Determine the pH of solution removed from the well. If the pH is more than 3, repeat steps (a) to (c).

e. Allow the acid to remain in the well for a minimum of 12 hr and then pump to waste.

f. Inject a mixture of chlorine and one or more chloric-stable surfactants (detergents and wetting agents, for example). The concentration of the chlorine should exceed 1,000 ppm.

Table 12-1
Quantities of Various Chlorine Compounds Required to Provide as Much Available Chlorine as 1 lb of Chlorine Gas[1]

Chemical	% Available Chlorine	Number of lb Equivalent to 1 lb Cl_2
Chlorine Gas	100	1.0
Calcium Hypochlorite	65	1.54
Lithium Hypochlorite	36	2.78
Sodium Hypochlorite	12.5	8.0
Trichlorisocyanuric Acid[2]	90	1.11
Sodium dichloroisocyanurate[2]	63	1.59
Potassium dichloroisocyanurate[2]	60	1.67
Chlorine Dixoide	4	25.0
Chlorine Dioxide	2	50.0

Notes:
1. From Driscoll (1986).
2. Chlorine compounds that incorporate isocyanuric acid stabilize the chlorine against degradation from sunlight. Except for storage, the advantage offered by the addition of isocyanuric acid is less valuable in water wells.

g. Gentle agitate the solution with a jetting tool at 10-min intervals every 2 hr for the first 8 hr and then at 8 hr intervals for at least 24 hr.

h. Pump out a volume of solution equal to the volume of the well.

i. Determine chlorine concentration. If the concentration is less than 10 percent of the original concentration, repeat steps f to h.

j. Perform a pumping test on the well. If the specific capacity has improved by more than 5 percent, repeat the entire procedure until the specific capacity does not improve by 5 percent.

12-7. Specialized Treatment

The USAE Waterways Experiment Station personnel, funded under a repair evaluation maintenance and restoration (REMR) work unit, developed a field procedure (Kissane and Leach 1991) for cleaning water wells that provides initial kill of the active bacteria in the well, dissolves the biomass in the screen, in the gravel pack, and some distance into the aquifer, and provides some inhibition of future growth. The procedure was developed using a patented process known as the Alford Rodgers Cullimore Concept (ARCC). The procedures in general include an initial well diagnosis performed with a prepackaged field microbiological test kit which is designed to give a qualitative indication of the types of bacterial and chemical agents at work in the wells, and a very general indication of the bacterial concentrations. The initial water chemistry is also measured prior to treatment. A treatment is then designed with the information from the tests, targeting the problematic agents with an appropriate set of chemicals. Redevelopment of the wells using the ARCC method is based on the use of blended chemicals and high temperature (BCHT) and is divided into three principle elements of treatment:

a. Shock. This phase is achieved by adding high temperature chlorinated water to the well and surrounding aquifer to "shock" kill or reduce the impact of deleterious algae and bacteria. The water is chlorinated to >700 ppm with gaseous chlorine to avoid binders found in powdered chlorine and is applied to the well as steam until the well temperature is brought above 120 deg F for massive bacteria kill. The chlorine treatment remains in the well for a specified period of time; mechanical surging is used; and pumping follows for removal of the initial loosened biomass.

b. Disrupt. This phase is achieved by the addition of chemical agents, acids and surfactants, and steam to the well and surrounding aquifer while the well is pressurized. Mechanical surging to break up organic and mineral clogging in the system is also used. The mechanical surging and chemical set time are important during this phase to achieve dissolution of the remaining biomass.

c. Disperse. This phase of treatment consists of removal of the material that has been clogging the well and aquifer. Acceptance criteria for the well are checked and further cycles are considered or a final cold chlorination treatment is applied for inhibition of any remaining bacterial colonies.