Chapter 11
Malfunctioning of Wells and Reduction in Efficiency

11-1. General

Relief wells may not function as intended and may also be subject to reduced efficiency with time. Failure of relief wells to function as intended can be attributed to a number of causes. Deficiencies in design can usually be assessed during initial operation of the well system. Based on piezometric and well flow data, an assessment of the effectiveness of the well system can be made and if considered inadequate, additional relief wells may be installed. Relief wells may malfunction for a variety of reasons including vandalism, breakage, or excessive deformation of the well screens due to ground movements, corrosion or erosion of the well screen, and a gradual loss in efficiency with time. The reduced efficiency generally determined as a percentage loss in specific capacity based on the specific capacity determined from pumping tests at the time of installation is a measure of increased well losses, which in turn result in higher landside heads. Thus, reduced well efficiency will result in hydrostatic heads larger than those anticipated in the design. The major causes of reduced specific capacity with time are (a) mechanical, (b) chemical, and (c) biological.

11-2. Mechanical

Most relief wells undergo some loss in specific capacity probably due to the slow movement of foundation fines into the filter pack with a corresponding reduction in permeability. The process occurs more commonly in cases of poorly designed filter packs, improper screen and filter pack placement, or insufficient well development. Generally, the major cause of reduced efficiency by mechanical processes is the introduction of fines into the well by backflooding of muddy surface waters. Normally, backflooding can be prevented by the use of check valves at the well outlet; however if not properly designed and maintained, the valves may not function as intended. The introduction of fines into the well and surrounding filter pack under backflow conditions can result in serious clogging which will result in reduced specific capacities.

11-3. Chemical

Chemical incrustation of the well screen, filter pack, and surrounding formation soils can be a major factor in specific capacity reduction with time. Chemical deposits forming within the screen openings reduce their effective open area and cause increased head losses. Deposits in the filter pack and surrounding soils reduce their permeability and also increase head losses. The occurrence of chemical incrustation is determined chiefly by water quality. The type and amount of dissolved minerals and gases in the water entering the well determine the tendency to deposit mineral matter as incrustations. The major forms of chemical incrustation include: (a) incrustation from precipitation of calcium and magnesium carbonates or their sulfates, and (b) incrustation from precipitation of iron and manganese compounds, primarily their hydroxides or hydrated oxides.

a. Causes of carbonate incrustations. Chemical incrustation usually results from the precipitation of calcium carbonates from the ground water of the well. Calcium carbonate can be carried in solution in proportion to the amount of dissolved carbon dioxide in the ground water. For a well discharging from a confined aquifer, the hydrostatic pressure adjacent to the well is reduced to provide the gradient necessary for the well to flow. The reduction in pressure causes a release of carbon dioxide which in turn results in precipitation of some of the calcium carbonate. The precipitation tends to be concentrated at the well screen and surrounding filter pack where the maximum pressure reduction occurs. Magnesium bicarbonate may change to magnesium carbonate in the same manner; however incrustation from this source is seldom a problem as precipitation occurs only at very high levels of carbonate concentration.

b. Causes of iron and manganese incrustation. Many ground waters contain iron and manganese ions if the pH is about 5 or less. Reduction of pressure due to well flow can disturb the chemical equilibrium of the ground water and result in the deposition of insoluble iron and manganese hydroxides. The hydroxides initially have the consistency of a gel but eventually harden into scale deposits. Further oxidation of the hydroxides results in the formation of ferrous, ferric, or manganese oxides. Ferric oxide is a reddish brown deposit similar to rust, whereas the ferrous oxide has the consistency of a black sludge. Manganese oxide is usually black or dark brown in color. The iron and manganese deposits are usually found with calcium carbonate and magnesium carbonate scale.

11-4. Biological Incrustation

a. Iron bacteria are a major source of well screen and gravel pack contamination. They consist of organisms that have the ability to assimilate dissolved iron which they oxidize or reduce to ferrous or ferric ions for energy. The ions are precipitated as hydrated ferric hydroxide on or in their mucilaginous sheaths. The precipitation of the iron and rapid growth of the bacteria can quickly reduce well efficiency. Iron bacteria problems in ground water and wells are recognized throughout the world and are responsible for costly well maintenance and rehabilitation.

b. Despite the widespread familiarity with iron bacteria problems in wells, relatively little is known about their growth requirements. One reason for the lack of research on iron bacteria is that these organisms are difficult to culture for experimental study and that pure cultures of many of these organisms have never been obtained. Available information on the nature and occurrence of iron-precipitating bacteria in ground water is summarized by Hackett and Lehr in Leach and Taylor (1989).

c. In order to determine which genus of iron bacteria is contained in a particular water sample, a system of classification based on the physical form of these organisms has been employed by the water well industry (Driscoll 1986). The three general forms recognized are:

(1) *Siderocapsa*. This organism consists of numerous short rods surrounded by a mucoid capsule. The deposit surrounding the capsule is hydrous ferric oxide, a rust-brown precipitate.

(2) *Gallionella*. This organism is composed of twisted stalks or bands resembling a ribbon or chain. A bean-shaped bacterial cell, which is the only living part of the organism, is found at the end of the stalk.

(3) Filamentous Group. This filamentous group consists of four genera: Chrenothrix, Sphaerotilus, Clonothrix, and Leptothrix. The organisms are structurally characterized by filaments which are composed of series of cells enclosed in a sheath. The sheaths are commonly covered with a slime layer. Both the sheath and slime layers or these organisms typically become encrusted with ferric hydrate resulting in large masses of filamentous growth and iron deposits.

d. Identification. The presence of iron bacteria is usually indicated by brownish red stains in well collector pipes or ditches. Television and photographic surveys can pinpoint the locations of screen incrustation, and samples of the incrustations can be obtained by a small bucket-shaped container. Samples can be sent to the USAE Waterways Experiment Station, or a private firm familiar with iron bacteria for identification. Identification is best accomplished by scanning electron or transmission electron microscopy and phase contrast techniques. Correct identification is necessary for selection of an appropriate treatment method.

e. Prevention. It is not clear whether iron bacteria exist in ground water before well construction takes place, or whether they are introduced into the aquifer from the foundation soils or in mix water during well construction. Evidence exists that iron bacteria may be carried from well to well on drill rods and other equipment and therefore every effort should be made to avoid introducing iron bacteria into a well during installation, maintenance, or rehabilitation operations. After completion of operations on a well, all drilling equipment, tools, bits and pumps, should be thoroughly disinfected by washing with a chlorine solution (100 ppm) before initiating work on another well.