Case Study
Increased Well Efficiency, Extended Lifetime and Reduced Maintenance through Selection of Stainless Steel Casing and Well Screen - Sun City and Sun City West, Arizona

Executive Summary

A study of 34 public supply wells in Sun City and Sun City West, Arizona showed that corrosion of metallic components and surfaces of steel well screen was the primary cause of well performance problems. Substantial accumulations of scale, sand invasion, and declining production rates were observed in many of the wells. These problems appear to have been exacerbated by the relationship between the physical, chemical and biological components of the well environments. Scale accumulation from corrosion by-products often reduces the open area of well screens, and lowers a well's production capacity and efficiency. The useful life of water wells in Arizona typically ranges from 40 to 50 years. The use of corrosion resistant materials such as stainless steel could increase this to 100 years or more.

Background

The Arizona-American Water Company (AAWC) operates 34 potable water supply wells in the well fields located in the Sun City and Sun City West area. AAWC retained the consulting services of Clear Creek Associates to evaluate the performance of the well fields and prepare recommendations to optimize the longevity and cost-efficiency of the two water systems.

Groundwater Conditions

The two well fields are situated within the Salt River Valley where the majority of the groundwater is stored in the basin-fill sediments whose thickness is reported to extend to more than 11,000 feet. Three hydrogeologic units (upper, middle and lower) comprise the principal aquifers in the Salt River Valley fill. Approximately one-half of the groundwater production in the valley is produced from the upper and lower aquifers; the other half is produced from the middle aquifer.

Historical water-level data in the vicinity of the well fields indicates that the depth to groundwater was generally about 200 to 400 feet below ground level. In the southern and central portions of Sun City from 1991 to 1998, local water levels rose from 10 to 20 feet. In contrast, during that same period, water levels declined from 10 to 20 feet in northern Sun City. In Sun City West, water levels from 1991 to 1998 were stable in the west and declined 10 feet in the east.

Well Construction

Approximately 70 percent of the Sun City and Sun City West wells are more than 40 years old. Twenty of the wells were drilled by the cable-tool method and 14 wells were drilled by the rotary method to an average depth of approximately 1,000 feet. Well casing diameters range from 14 to 20 inches. The majority (approximately 2/3) of the wells were completed with Mill's Knife perforations. Continuous wire-wrapped screens were installed in 5 wells; 7 wells have louvered screen; 7 wells have saw-cut perforations, and 1 well has torch-cut openings. Nine of the wells had partial liners installed. Overall, the general condition of the wells was described as fair to poor.

Scaling and Corrosion

Physical, chemical, and biological conditions have the potential for combined effects that can significantly affect the performance and efficiency of water wells. The most common results of these conditions are scale deposits and/or biological films (biofilm) on well casings, screens, pumps, and pump columns.

Visual and laboratory analyses of scale samples collected from the Sun City and Sun City West wells were found to have relatively high silica concentrations (10 percent silica or more). It was postulated that the high silica content was due to entrapped silt or fine sand within the biofilm on the interior of the well casing and screen.

Water quality results for 27 of the wells showed a Langlier index of – 0.43. Negative Langlier index values are indicative of corrosive water chemistry. Based on these results, it was determined that groundwater in the Sun City and Sun City West wells was slightly corrosive, although extensive corrosion of the metal well casing and screen material was not anticipated.

Iron oxide and iron hydroxide are familiar types of mineral encrustation that form scale deposits. Other types of scale include calcite and gypsum. In the oxidized state, iron scale deposits are red to brown in color, whereas in the reduced state they are typically black. Iron scale was the principal type of deposit in the Sun City and Sun City West wells; however, the iron scale did not appear to be the result of direct mineral incrustation.

Iron-related bacteria in the groundwater were identified in most of the wells that were sampled. The analytical results showed that sheathed or stalked bacteria were observed in the scale samples, and that the samples contained more than 10 percent organics. Bacterial sheaths facilitate the structure of biofilms, and promote biological organisms beneath the surface of biofilms.

When scale deposits and/or biofilm develop within the screened intervals of a well, a common effect is for the apertures to become plugged. When this occurs, a well will often experience both reduced production capacity and diminished specific capacity. As nutrients in the groundwater are continually drawn to the well by pumping, the bacterial growth is promoted.

Well Life-Cycle Economic Analysis for Alternative Construction Materials

For the purposes of the study, the useful life of a typical water well was evaluated in terms of its rate of efficiency loss and its structural integrity. The useful life of a well was considered to be over when its operation and maintenance (O&M) costs and reliability no longer justify its continued use. At that time, the well would normally be replaced with a new well with greater production capacity, higher efficiency, and/or more structural reliability. The two primary attributes considered were the rate of efficiency loss and useful economical life.

The 75-year life-cycle cost analysis for this assessment compared the construction and operation costs for wells completed with different casing and screen materials. The cost analysis was based on a 1,210-foot deep well completed with 18-inch diameter blank casing and louvered well screen.

Generalized Well Design

The generalized well design included low carbon steel for the upper blank casing where corrosion and scale accumulation were not anticipated. As added protection for the low carbon steel, the design provided an annular seal of cement grout and/or bentonite. For the lower portion of the well, there were three alternatives considered for the blank casing and well screen. They were: a) Type 304 stainless steel (SS), b) high strength low alloy (HSLA), or c) low carbon steel (LCS). For the LCS alternative only, a dielectric coupling was included to connect the low carbon steel upper casing to the lower casing and screen composed of SS screen. Based on these assumptions, the design consisted of 700 feet of 18-inch blank casing, 500 feet of 18-inch well screen, and a 10-foot sump below the screen.

Well Life-Cycle Cost Analysis

Drilling and Construction. Drilling and construction cost estimates were based on actual bid prices for existing wells in the two water systems. Unit prices for casing and well screen were provided by Roscoe Moss Company. The analysis showed that the estimated construction costs for the wells were as follows:

- Low carbon steel $315,000
- HSLA $338,000
- Stainless steel $415,000

General Assumptions. The economic analysis included a variety of costs related to the design, construction, and operation of the wells. A partial listing of the assumptions is presented below:

- 75-year operational period
- 25-year economic life for LCS
- 50-year economic life for HSLA
- 75-year economic life for SS
- Wells operate 45 percent of time (on annual average)
- Cost to abandon/demolish existing well = $125,000
- Hydrogeologic and engineering services included in design costs
- Initial specific capacity = 25 gpm/ft
- Uniform decline in static water level
- Pump efficiency = 78 percent
- Pumps last 10 years in new wells

Specific Capacity. The economic analysis considered that during a well's lifetime there would be a gradual decline in specific capacity as the screen openings were corroded and clogged. It was assumed that when the specific capacity declined by 25 percent, the well would be redeveloped and that the specific capacity would improve by 90 percent. The frequency of the redevelopment for the various materials was as follows: LCS (5 years), HSLA (7.5 years), and SS (15 years).

Well Maintenance. Over the 75-year analysis period, it was assumed that based on the above frequencies for redevelopment, the number of well cleanings would be as follows: LCS wells (12 times); HSLA wells (9 times); and SS wells (4 times). The estimated cleaning costs were $18,000 per event. The cost to replace a pump and motor was estimated to range from $12,000 to $35,000.

Findings

- The life-cycle economic analysis showed that over a 75-year period, the total dollar cost of a LCS well would be $1,290,000 more than the total dollar cost of a SS well.
- The annual cost savings provided by stainless steel would average about $17,200 per year.
- The cost savings of SS wells would repay their additional installation cost in only 5.8 years (compared to LCS wells).
- SS wells may last substantially longer than 75 years (potentially 100 years or more) due to the corrosion resistance of stainless steel.

Summary

Based on the results of this assessment, it was recommended that in the future new wells added to the water systems should be constructed with stainless steel. The initial cost of stainless steel would be recovered through the savings that would be realized from the increases in well efficiency and the decreases in the frequency of well cleaning.

References

Clear Creek Associates, PLC, 2003, "Sun City and Sun City West Well Field Analysis, Surprise, Arizona".