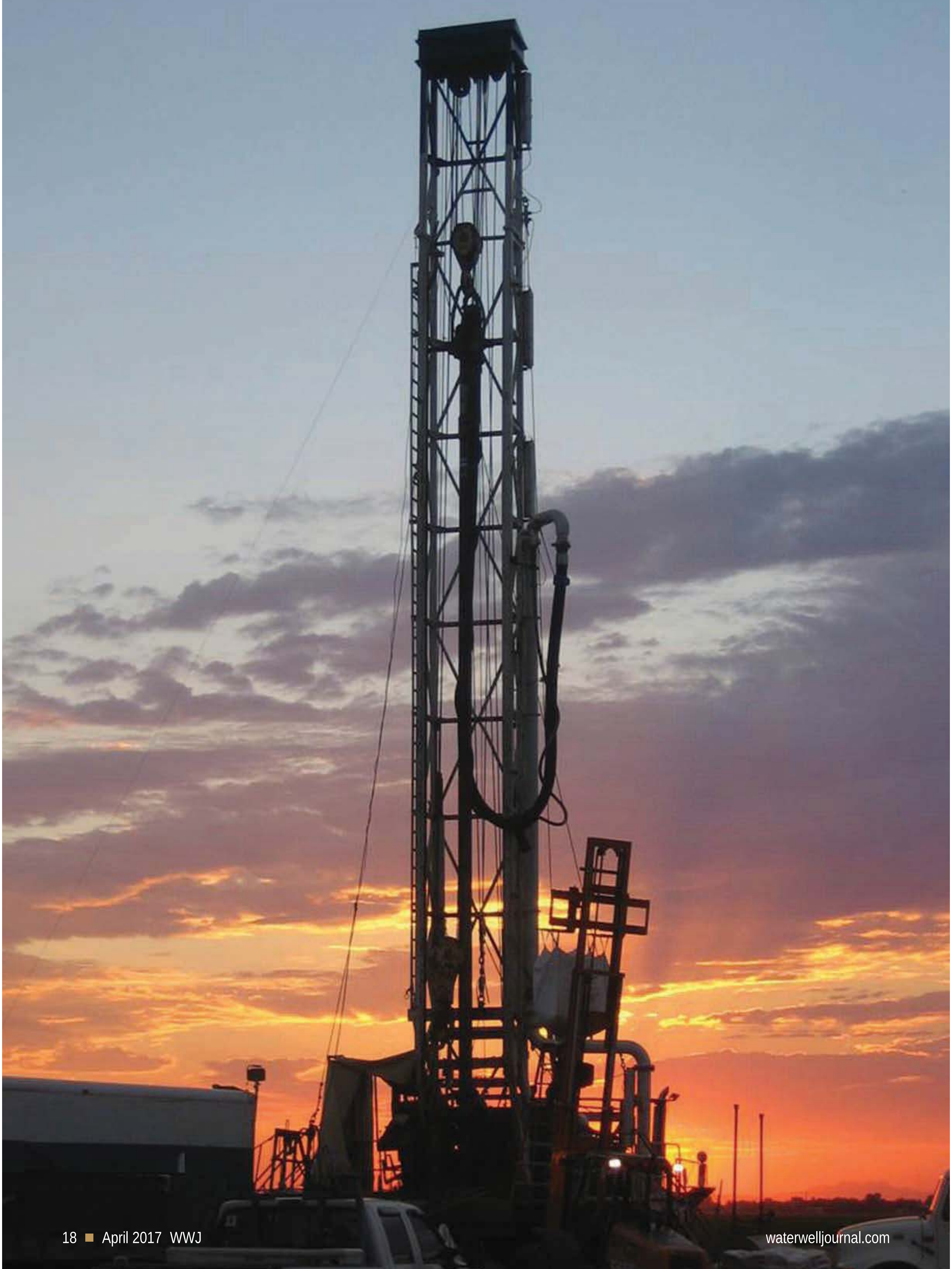

Life-Cycle Economic Analysis of Water Wells

Proper well design addressing current and future costs can save owners money.

By Marvin F. Glotfelty, PG

The design of a water well should reflect a consideration of its cost during the entire life of the well, typically from 25 years to more than 100 years.

Too often, well designs are focused only on limiting the capital cost of the well installation without regard to the operational expenses occurring during future years of the well's use. A well with the lowest construction cost will not necessarily provide the best overall value during future years of operation.

Both initial costs (during the well construction) and future costs (during operation of the well) will be impacted by the well's design and the construction materials incorporated into that design. All the materials and methods used for the construction of a water well will impact its life-cycle cost, but one of the predominant elements of any well design is the type of steel selected for the well screen.

Steel Well Casing Alternatives

Large-diameter water supply wells commonly require the strength of steel casing and screen, so polyvinyl chloride (PVC) is not typically used in deeper large-diameter wells. Three types of steel commonly are used for well screen:

- Low-carbon steel (LCS) (ASTM Standard A53)
- High strength low alloy (HSLA) steel (ASTM Standard A606 Type 4)
- Stainless steel (SS) (ASTM Standard A778 Type 304L).

LCS is the least expensive of these steel types, and also the least resistant to corrosion. HSLA steel is more expensive than LCS, and it provides a higher level of corrosion resistance to extend the life of the well. SS is the most corrosion resistant of the three steel types, but also the most expensive.

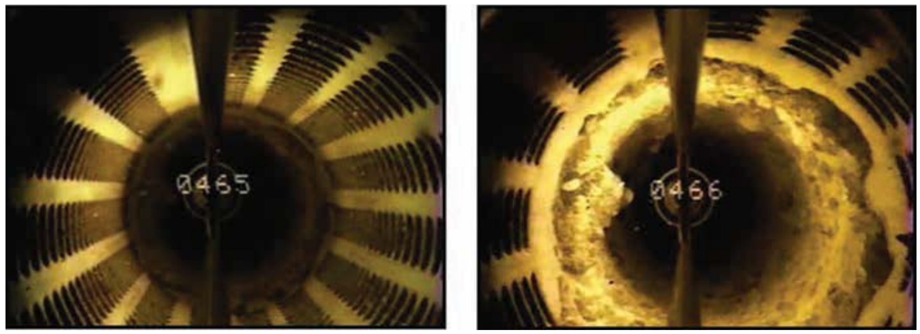

Figure 1. Scale growth on different steel types.

In addition to their differences in cost and corrosion resistance, LCS, HSLA, and SS well screens vary in their susceptibility to becoming clogged over time. Naturally occurring microbes in the subsurface cause the accumulation of scale or biofilm that clogs screen slots, and these microbes seem to favor LCS and HSLA over the SS—likely due to differences in the metal composition.

The variability in scale growth is well documented, but each well is in a unique subsurface environment. So it is difficult to make a valid comparison between the amounts of scale accumulation in individual wells at different locations.

However, the design of a well in the El Paso, Texas area allowed us to directly compare scale growth on LCS vs. SS, within a single well. The well has alternating sections of LCS blank casing and SS louvered well screen at different depths, as shown in Figure 1. The intervals of the well with SS louvered screen have minimal scale accumulation (465-foot image shown on the left), whereas intervals of LCS blank casing just a few inches away have significant accumulations of scale (466-foot image shown on the right).

Get More Detail

Want even more information? Go to the *Water Well Journal* website to view an expanded version of author Marvin Glotfelty's life-cycle economic analysis at *www.WaterWellJournal.com*.

The economic impact of steel water well screen alternatives was conducted from two perspectives to evaluate both past and future conditions. First, a review of historical water well construction costs was evaluated for the three steel well types during past years. Second, a life-cycle well cost comparison was also conducted to evaluate the future cumulative costs (present-value costs for year 2011) for the three well types during a 75-year life-cycle period.

Historical Water Well Costs

A significant database of Arizona water wells was assembled to provide a meaningful look at the fluctuations of historical well construction costs. The actual low-bid construction costs for 70 wells in Arizona were accumulated. These were similar-sized wells with 16- to 18-inch-diameter casings, and depths of generally about 1000 to 1500 feet. The database of Arizona wells

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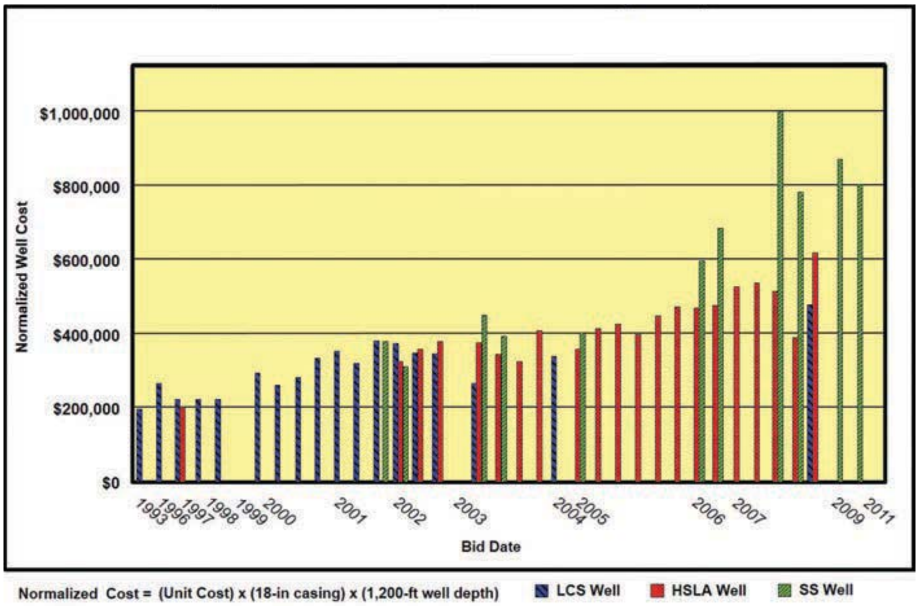

Figure 2. Normalized historical well costs for 18-inch-diameter, 1200-foot-deep wells.

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represents the work of eight different drilling companies and five different hydrogeologic consulting firms, so it reflects a broad diversity of well design and construction sources. The wells were installed during the 18-year period between 1993 and 2011.

The historical well costs for 16- and 18-inch-diameter well casing increased for all three types of steel with a noticeable rise of costs in 2005, in response to the worldwide economic growth and demand for construction materials at that time.

The cost of LCS well casing increased from about $20 per linear foot in 1993 to $75 per foot in 2009. HSLA casing increased from about $70 per linear foot in 2001 to $125 per foot in 2011. SS well casing increased from about $150 per linear foot in 2001 to $375 per foot by 2006.

Although individual material costs are insightful for assessment of past economic trends, the most meaningful view of historical well installation costs is provided by the entire cost of well installations. Comparison of well costs from different time periods is complicated by the various depths and dimensions of wells drilled over the years. Even though similarly designed wells were selected for inclusion in our database, the variability in their depths and casing diameters require us to address those size and depth discrepancies. To resolve this, an overall "unit cost" for each well was determined using the formula:

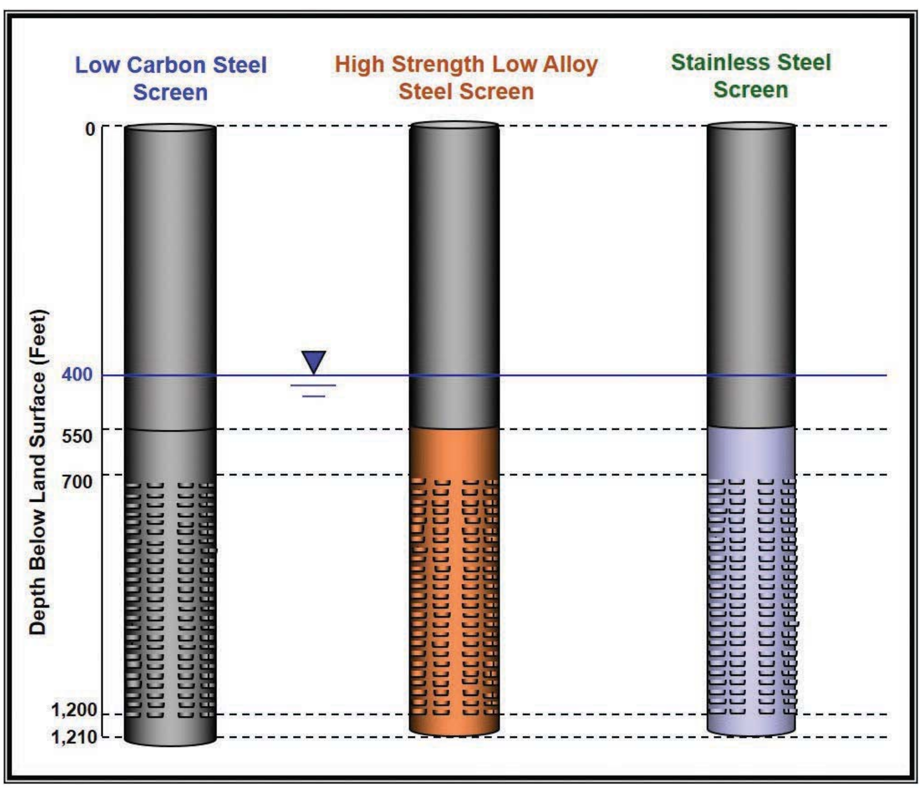
$$\text{Unit cost} = \frac{\text{Total well cost}}{(\text{Well diameter in inches}) \times (\text{Well depth in feet})}$$

Unit costs for the wells were then normalized to "typical" dimensions for wells in the Phoenix, Arizona municipal area so that the historical data would be comparable for different time periods. An 18-inch well diameter and 1200-foot depth are typical for municipal wells in the Phoenix area, and those dimensions are also common for industrial and agricultural wells in the region.

Figure 2 shows the normalized costs of wells between 1993 and 2011. A 1200-foot-deep well with an 18-inch diameter cost about $200,000 back in 1993, but that same well would cost about $500,000 in 2008. Similarly, although both HSLA and SS wells had estimated costs under $400,000 back in 2002, their estimated costs had increased by 2008 to about $600,000 and $800,000, respectively.

Life-Cycle Well Cost Comparison

Although the normalized costs shown in Figure 2 are representative of well installations from previous years, current well construction data were used for the life-cycle well cost comparison. The well construction costs were estimated for identical wells, with their only difference being LCS, HSLA, or SS well screens (Figure 3).



All wells are 18-inch diameter and have LCS upper casing, with louvered well screen of various steel types.

Figure 3. Life-cycle well screen comparison.

The cost estimate for each well type was based on actual construction costs for a dozen similarly designed wells drilled during the five years prior to this analysis (2007 to 2011). The 2011 present-value costs (rounded) for the three types of well were:

Cost of LCS screened well
= $512,300

Cost of HSLA steel screened well
= $567,000

Cost of SS screened well
= $776,400

On the day these hypothetical wells are constructed, the SS well will exceed the LCS or HSLA well costs by more than $200,000. So the question is: Will the more expensive SS well pay for itself during the subsequent years of its use? That question can be answered by a life-cycle economic analysis.

We were able to conduct a comprehensive life-cycle economic analysis because the City of Phoenix shared their wellfield operations data for this analysis. Well operational conditions that were assumed for this economic analysis (such as the longevity of each well type, well cleaning frequencies, and pump equipment replacement schedules) were based on actual empirical data from the City Water Services Department.

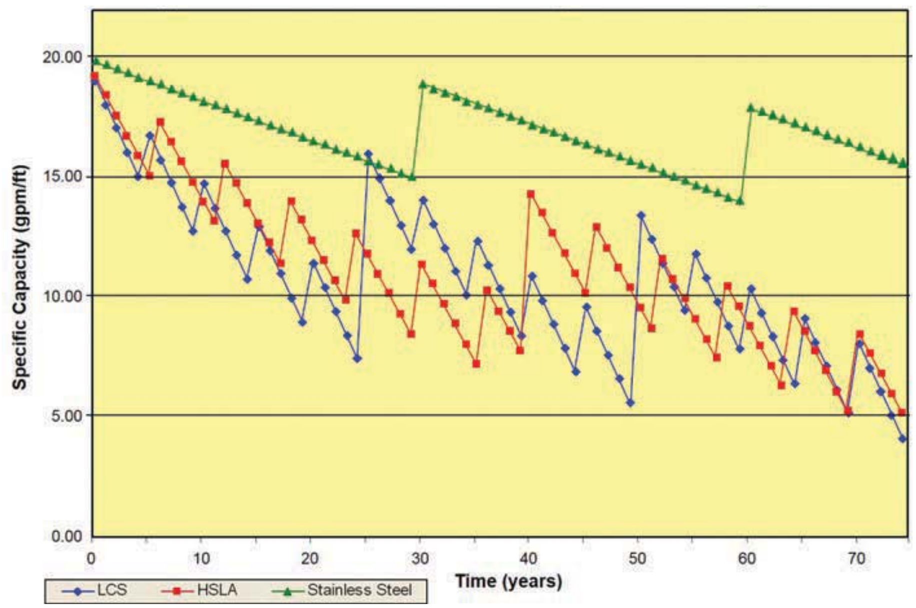


Figure 4. Efficiency loss during a 75-year well life cycle.

Phoenix is the sixth largest municipality in the United States and is located in the arid Southwest where forward-thinking and cost-efficient water management is paramount to the city's continued growth and vitality. The city recognizes the importance of proper management and stewardship of its water resources in such a manner as to ensure a safe, reliable, and sustainable water supply for its citizens.

The well operation conditions (water table depth, pump and motor efficiency, etc.) for all three well types are considered to be identical, with the exception of differing well life expectancies and variable cleaning frequencies needed to address the different rates of scale growth.

The well clogging/cleaning cycles and well replacement schedules during the 75-year life-cycle period of this analysis are shown in Figure 4. We assume the LCS well to last 25 years, whereas the HSLA well lasts 40 years and the SS well has a 75-year life (Figure 4).

Accumulation of scale on the LCS well screen was considered to cause a 25% decrease in its efficiency (specific capacity, or gpm/ft) every five years, which was improved after each well cleaning. The HSLA well took six years for a 25% loss of specific capacity to occur, and the SS well could be operated for a 30-year period before scale incrustation on its screen would cause a 25% drop in specific capacity (Figure 4).

The life-cycle costs for the three respective well types are itemized in Table 1. During the 75-year period of this life-cycle economic analysis, we summed the aggregate costs for well installations and additional construction costs, consultant costs (both hydrogeologists and engineers), operations and maintenance costs, well cleaning costs, pump and motor replacement costs, and electrical energy costs for operation of

Low-Carbon Steel Well Screen	High Strength Low Alloy Steel Well Screen	Stainless Steel Well Screen
Well Installation Costs $512,314 x 3 wells = $1,536,942	**Well Installation Costs** $566,974 x 2 wells = $1,133,948	**Well Installation Costs** $776,362 x 1 well = $776,362
Additional Construction Costs $256,000 x 3 wells = $768,000	**Additional Construction Costs** $256,000 x 2 wells = $512,000	**Additional Construction Costs** $256,000 x 1 well = $256,000
Consulting Costs $470,000 x 3 wells = $1,410,000	**Consulting Costs** $470,000 x 2 wells = $940,000	**Consulting Costs** $470,000 x 1 well = $470,000
Well Cleaning Costs 12 cleaning events = $840,000 (includes pump removal/reinstall)	**Well Cleaning Costs** 13 cleaning events = $880,000 (includes pump removal/reinstall)	**Well Cleaning Costs** 2 cleaning events = $200,000 (includes pump removal/reinstall)
O&M Labor Costs $36K/year x 72 yrs= $2,592,000	**O&M Labor Costs** $36K/year x 73 yrs= $2,682,000	**O&M Labor Costs** $36K/year x 74 yrs= $2,664,000
Pump/Motor Replacement Costs 9 events x $103K each = $927,000	**Pump/Motor Replacement Costs** 8 events x $103K each = $824,000	**Pump/Motor Replacement Costs** 8 events x $103K each = $824,000
Electrical Costs = $7,644,622	**Electrical Costs** = $7,591,306	**Electrical Costs** = $7,233,448

Table 1. Life-cycle economic analysis costs.

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pump equipment.

When all the individual costs listed in Table 1 are added up, the cumulative 75-year costs for the LCS, HSLA, and SS wells turn out to be $15.7 million, $14.5 million, and $12.4 million, respectively.

Even though the initial construction cost of the SS well was more than $200,000 higher than the other two well types, at the end of its useful economic life the SS well resulted in a cost savings of about $3.3 million compared to the LCS well and a savings of more than $2 million compared to the HSLA well. By simplistically dividing the cumulative cost by the 75 years in the life-cycle period, this means compared to the less expensive LCS or HSLA wells, the additional construction cost of the SS well will be repaid in only about six to seven and a half years.

The specific costs presented for this life-cycle economic analysis are applicable only to the city of Phoenix water supply system, and different wells may have different results. However, the overriding message of this analysis is all wells would benefit from designs based on comprehensive life-cycle costs rather than a low-bid mentality focused solely on the initial capital costs to construct the well.

A proper well design that addresses both current and future costs throughout the life of the well can in some cases save the well owner millions of dollars. WWJ

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Marvin Glotfelty, PG, is a principal hydrogeologist with Clear Creek Associates in Scottsdale, Arizona. He was the 2012 NGWA Foundation McEllhiney Lecturer and spoke on the topic "Life-Cycle Economic Analysis of Water Wells—Considerations for Design and Construction."