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Gravel Packing Water Wells

by

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Gravel Packing Water Wells

by Harmon F. Smith*

THE rice industry gave rise to the idea of gravel packing † of water wells, as much as 50 years ago. In Arkansas and Kansas irrigation wells were being gravel-packed for the rice industry as early as the turn of the century.

Popularity of the practice has continued to grow and got a big boost with the advent of reverse rotary drilling. The gravel packing of drilled wells using an outer casing, of reverse rotary drilled wells or of ordinary rotary drilled wells has met with equal success.

Two general types of gravel packing are used — the uniform grain-size pack and the graded grain-size pack. The former has in recent years been widely accepted, especially when manufactured screens are used, in which the opening sizes can -be controlled.

In the case of a graded pack the formation material may invade the gravel pack at the gravel formation interface, producing a more impervious mixture than would be obtained with the less well-graded mixture formed by the formation material and a uniform grain-size gravel pack material. This would account for the higher permeability claimed for uniform grain-size gravel packs.

The Bureau of Reclamation [1] in its laboratory tests on protective filters for hydraulic structures found that: (1) the uniform grain-size pack had practically no segregation during placement; (2) there was negligible settlement during operation, and (3) under the same conditions the capacity to conduct water was greater than that of the graded pack.

These — especially the lack of segregation—are important advantages. Segregation, or stratification of sizes, takes place where a nonuniform grain-size material falls through water. The larger particles move more rapidly than the finer particles, causing pockets of fine material to form between the formation and the screen. These fine sand pockets can be washed through the screen, causing well failure.

To prevent segregation of the graded pack during placement some type of special equipment is needed. The tremie or ordinary 4-inch pipe, filled with pack material and allowed to settle four or five feet at each retraction, is an accepted custom. On the other hand the uniform grain-size pack can be shoveled in from the top of the well with good results. Only the uniform grain-size pack will be considered in this article.

Lack of availability is the big disadvantage of the uniform grain-size pack. The material often must be processed on the site as the size needed is not readily available from local sources. The most important physical property of uniform grain-size material is its particle size as represented by the mean grain diameter which is approximately represented by the 50 percent grain size. To prevent the movement of formation material it is necessary to provide a pack material in which its 50 percent grain size bears a definite relationship to the 50 percent grain size of the formation material.

The Bureau of Reclamation in its laboratory tests concluded that the grain-size ratio (ratio of the 50 percent size of the pack material to the 50 percent size of the formation material) must be between the limits of five to ten.[1] Other research studies have given similar results.

The Soil Conservation Service of the U. S. Department of Agriculture in its laboratory tests on the effect of well screens and gravel envelopes on flow of sands into wells found very little sand movement with ratios of 3.6 to 8.75 for coarse formation material and ratios of 3.8 to 6.4 for fine formation material.[2]

The U. S. Waterways Experiment Station concluded [3] that *a* fine material will not wash through a filter material if the 15 percent size of the filter material is less than five times as large as the 85 percent size of the fine base material. They reaffirmed this conclusion in their field and laboratory investigation of design criteria for drainage well.[4]

Not all water-bearing formations require gravel packing. However any formation can be successfully gravel-packed. Bennison states that, generally speaking, formation materials, whose effective size is more than 0;10 inch and whose uniformity coefficient is more than 2.0 do not require gravel treatment.[5]

Probably the three most common reasons for gravel packing are: (1) to increase the specific capacity of the well, (2) to minimize sand flow through the screen in fine formations, and (3) to aid in the construction of the well.

For the past two years the Illinois State Water Survey has been gathering information on the sieve analysis of both the formation and the gravel pack used in the construction of new wells. We now have data on about 20 wells. Wherever possible, interference measurements were made in a nearby well during the pumping test of the gravel-packed well. The well effectiveness was then calculated from these data. "Well effectiveness" was defined as the ratio of the calculated drawdown,

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† The term "gravel packing" as used in this article refers to the placing of gravel adjacent to the well screen or to gravel that has been placed adjacent to the well screen. This pack also sometimes is referred to as "gravel treatment," "gravel envelope," "gravel filter. " and similar terms.

based on the observation well data ;" to the actual drawdown. Results of these studies showed that the gravel pack need not be extremely coarse but must have a definite relationship to the formation material.

Figure A shows a typical sieve analysis curve of a water-bearing formation in Illinois. It can be classified as medium sand. The other curve is that of the gravel pack used. It can be classified as very coarse sand to fine gravel. . The 50 percent grain size of the formation material is 0.38 millimeter, and that of the gravel pack material is 1.8 millimeters, or a size ratio of gravel pack to formation of 4.8. For brevity, let us call this ratio of 50 percent sizes the "gravel-pack ratio."

When the gravel-pack ratios were of the order of four to five, wells had effectiveness of from 90 to 120 percent. Wells with smaller ratios had somewhat less effectiveness. Wells that had ratios of from seven to ten were considerably less effective. One well with a ratio of about ten had an effectiveness of only 32 percent. When ratios were much above ten the wells produced considerable amounts of sand. A well that had a ratio of 20 produced so much sand that it was a complete failure. The results of this field study coincide very closely with that of the laboratory studies previously mentioned and show that the ratios of four to five are very satisfactory.

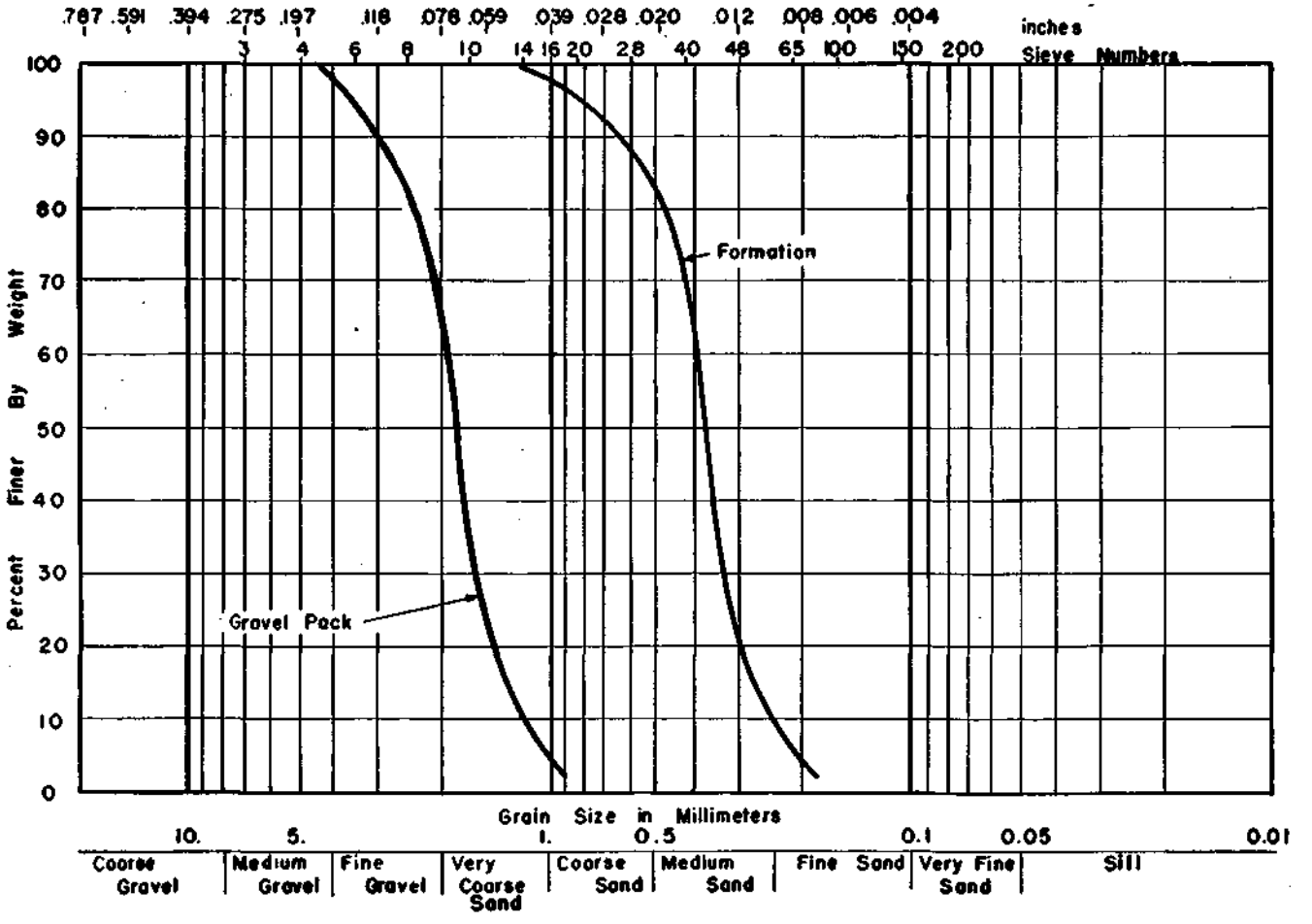
The formation need not have a small uniformity coefficient to be effective when treated with uniform gravel pack. In one case the formation uniformity coefficient was 8.3 and the well was gravel-packed with material having a uniformity coefficient of 1.5. The gravel-pack ratio was 5.1. This well produced no sand.

As mentioned previously the pack need not be of large grain size. One well where the formation graded from medium to coarse sand and which was built with a gravel-pack ratio of five, and in which the grain diameter of the gravel was ⅛-inch, produced 2100 gallons per minute with a 10-foot drawdown or a specific capacity of 210 gallons per foot.

The grain sizes of the formation must be determined before a successful gravel pack can be chosen. The best method of determining these sizes is by sieving the sample with a standard set of sieves using a shaking machine. Many of the screen manufacturers have this service available. Some contractors have their own sieve sets.

This operation is quite laborious and requires considerable time in drying the sample before sieving can be made. Due to the lack of equipment and the. time involved, many of the drillers try to estimate the grain size of the formation material and use whatever material is available for the pack. To aid drillers who do not have sieving facilities available, a pictorial method for estimating grain size of formation and gravel pack has been devised.

Figure A

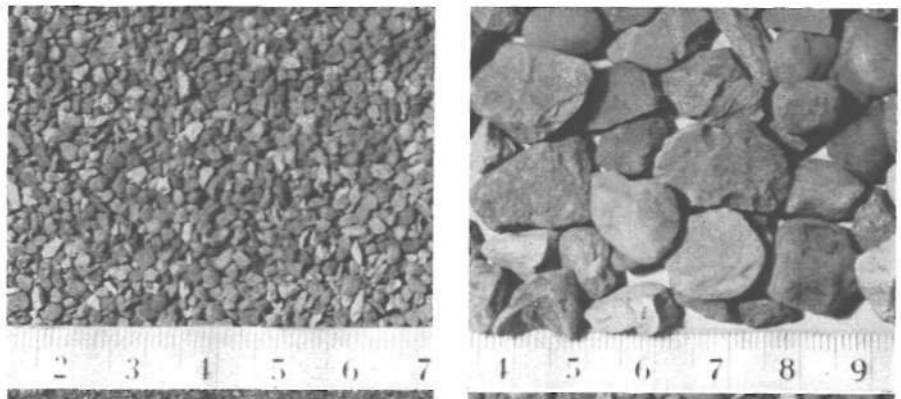


1/16 = 0.062
1/8 0.125

Left: Formation — very coarse sand; 1.0 to 2.0 mm.; 0.039 to 0.079 in.

Right: Gravel Pack — medium gravel; 4.0 to 8.0 mm.; 0.157 to 0.315 in.

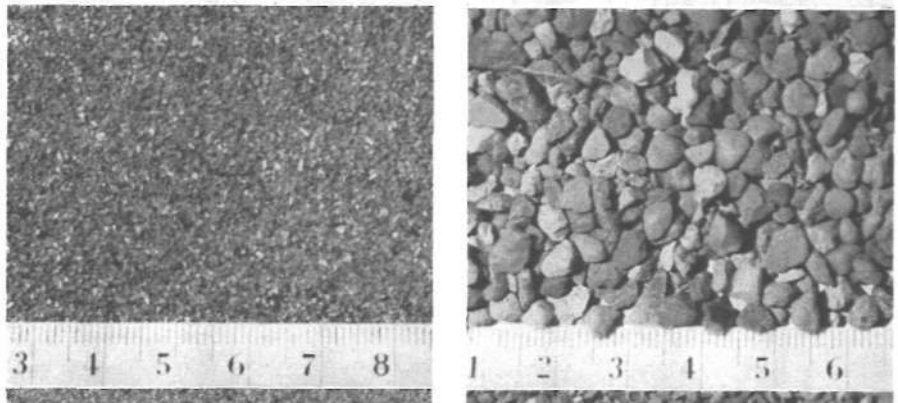
Screen Opening 0.160.



Left: Formation — Coarse Sand; 0.50 to 1.00 mm.; 0.020 to 0.039 in.

Right: Gravel Pack — fine gravel; 2.0 to 4.0 mm.; 0.079 to 0.157 in.

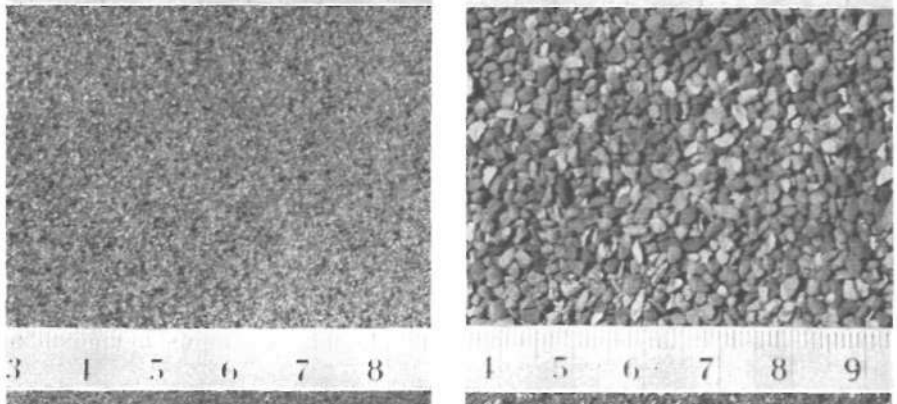
Screen Opening 0.080 in.



Left: Formation — medium sand; 0.25 to 0.50 mm.; 0.010 to 0.020 in.

Right: Gravel Pack — very coarse sand; 1.0 to 2.0 mm.; 0.039 to 0.079 in.

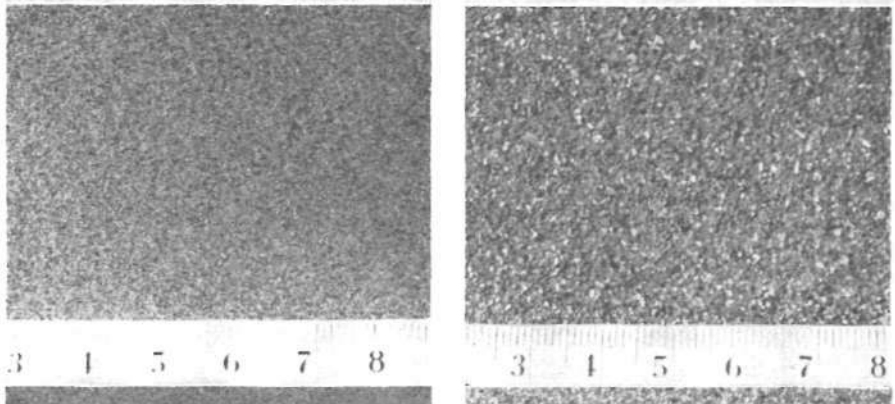
Screen Opening 0.040 in.



Left: Formation—fine sand; 0.10 to 0.25 mm.; 0.004 to 0.010 in.

Right: Gravel Pack—coarse sand; 0.5 to 1.0 mm.; 0.020 to 0.039 in.

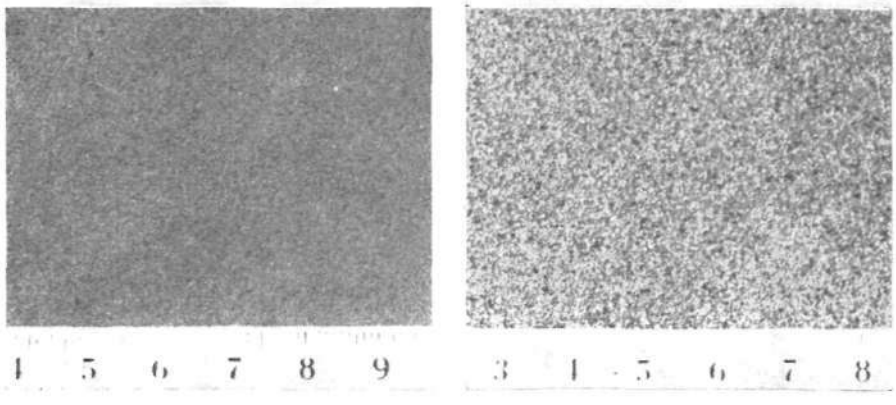
Screen Opening 0.020 in.



Left: Formation—very fine sand; 0.05 to 0.10 mm.; 0.002 to 0.004 in.

Right: Gravel Pack — medium sand; 0.25 to 0.50 mm.; 0.010 to 0.020 in.

Screen Opening 0.010 in.



(All pictured measures are in centimeters)

By comparing the formation material and the gravel-pack material with the photographs, which are actual size, satisfactory correlation can be had. For each formation illustrated these photographs show the appropriate gravel pack. The screen is then chosen that has openings of such a size that at least 90 percent of the gravel pack will be retained. Screen opening sizes for each set of conditions are suggested. In case of doubt, use a finer gravel, rather than a more coarse one.

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