

SPECIFIC YIELD OF THE  
DENVER BASIN AQUIFERS

Colorado Division of Water Resources

October 24, 1985

Technical Appendix B

## SPECIFIC YIELD OF THE DENVER BASIN AQUIFERS

### Definition of Specific Yield

Specific yield means the ratio of the volume of water which can be drained by gravity from a saturated volume of aquifer material divided by that volume of material and expressed as a percentage.

### Parameters Impacting Specific Yield

There are a number of factors which will impact the value of specific yield for an aquifer. For the Dawson, Denver, Arapahoe and Laramie-Fox Hills, the aquifer materials are often described as sandstones or siltstones. For those type of sedimentary deposits the specific yield value is a function of: the size of the individual sand or silt grains, the grain size distribution, the cementation between grains and the compaction of the aquifer materials.

The amount of water which can be drained by gravity from a sandstone or siltstone is a function of how much the water table is lowered and over what period of time does the drainage occur. The specific yield value will increase as the water table lowers and it will also increase as the length of time, since drainage began, increases. The appropriate value for specific yield is thus time and space dependent, in addition to being a function of those geologic or physical parameters discussed in the previous paragraph.

### Procedures for Determining Specific Yield

One method used to determine the average specific yield value is to conduct a long term pump test of the aquifer under water table conditions. The advantage of that method is that it determines an average value for the entire perforated interval of the well and, thus, accounts for the vertical variability of specific yield. Unfortunately, most of the Denver Basin Aquifers are still under artesian conditions. Under those conditions, an aquifer test will only yield the confined storage coefficient and not the unconfined value of specific yield. Where unconfined aquifer tests have been made, they have been for short periods of time and the time delayed release from storage may cause the calculated specific yield to be low. To obtain good aquifer test data it is desirable to use one or more observation wells but this increases the cost.

The most common method to determine specific yield for the Denver Basin Aquifers is to obtain undisturbed core samples and then conduct laboratory tests on those samples. The procedures for obtaining the cores, preparing them for laboratory testing, doing the lab tests and reporting the results is referenced in Rule 8.D. of the Statewide Nontributary Rules which were the subject of the formal hearing on October 8, 9 and 10, 1985. The 1985 Annual Book of ASTM Standards Volume 04.08 contains documentation on pages 363 thru 369 on the testing procedures and is referred to as Designation D2325.

Using laboratory test data for specific yield presents the problem of extrapolating values in both the vertical and horizontal directions to obtain the appropriate value of specific yield for the area of land under consideration. The interpretation of resistivity, spontaneous potential (SP) and other geophysical logs together with the laboratory test of core samples to obtain a weighted average value of specific yield for the aquifer at the site specific well location is a common practice.

It would be plausible to have a methodology or procedure which would allow direct determination of the appropriate specific yield value at a well. Dr. Dave McWhorter did an extensive review of the available literature. His report, entitled "Specific Yield by Geophysical Logging, Potential for the Denver Basin", was published by the Colorado Water Resources Institute at Colorado State University in July of 1984. In that publication he concludes that there might be three separate geophysical logging techniques which should be evaluated to see if they could be used to directly measure specific yield. Of these, he recommended the nuclear magnetic log technique but suggested that a careful evaluation program including the use of cores and laboratory tests was needed to determine the utility of the method.

Since Dr. McWhorter's report was published, there has been one well logged in the Denver Basin with the nuclear magnetic geophysical tool. Undisturbed core samples were collected and laboratory tests conducted. The Specific Yield readings from the nuclear magnetic geophysical log were recalibrated to yield results compatible with the laboratory data. Further experience with the methodology and checking the logs against laboratory data is needed before this procedure can be accepted as a method to obtain accurate site specific data for specific yield.

#### Available Specific Yield Data:

The only available specific yield data for the Denver Basin Aquifers are reported in the publications entitled "Colorado Ground Water Basic Data Report No. 15, Hydrogeologic Data of the Denver Basin, Table 9" published by the U.S. Geological Survey in cooperation with the Denver Board of Water Commissioners and the Colorado Water Conservation Board in 1964 or "Hydraulic Characteristics of the Principal Bedrock Aquifers in the Denver Basin, Colorado" by S.G. Robson of the U.S. Geological Survey published in 1983 as Hydraulic Atlas Series HA-659. Additional laboratory tests of undisturbed samples have been made by ground water consultants, but at the time of this writing those data are not on file in the State Engineer's Office.

The data in Basic Data Report No. 15 and HA-659 were obtained by laboratory testing of core samples, most of which were collected at the outcrops of the respective aquifers. Mr. Robson made a special effort to obtain the cores described in HA-659 from newly exposed aquifer materials. Specific Yield samples were collected in recently excavated road cuts or at building sites. This effort was made to minimize the possibility of weathering. The data have

been analyzed and the following table summarizes the results:

<u>Aquifer</u>	<u>No. of Samples</u>	<u>Average* Specific Yield</u>	<u>Average Porosity</u>
Dawson	20	15.8	31.8
Denver	10	13.8	31.8
Arapahoe	24	17.5	29.9
Laramie-Fox Hills	29	20.4	31.5

\*Samples with porosities greater than 45 percent were discarded as not being representative of the bedrock aquifers in the Denver Basin.

The above tabulation summarizes the analyses of all the data. Further detailed studies of the data from Basic Data Report No. 15 revealed that a number of samples were collected at a single outcrop site to represent the variation in specific yield across the total aquifer thickness. For example, at the Arapahoe Formation outcrop in the SE1/4 of Section 24, T4S, R70W of the 6th P.M, 9 core samples were collected and tested in the laboratory. One of the samples had a porosity in excess of 45 percent and was considered to be non-representative. The mean value of specific yield for the remaining 8 samples was 16.03 percent.

The data for the Laramie-Fox Hills Aquifer appear to have been collected from that part of the formation represented by the massive sandstones. Permits for nontributary water will be issued to allow production of the siltstones in the lower part of the Fox Hills Aquifer. Considering that the aquifer is at considerable depth below the land surface, often in excess of 1500 feet, this would increase compaction considerably. Both of these factors were considered by the State Engineer when he selected the average specific yield as 15 percent.

The value of 20 percent for the Dawson Formation is consistent with the values assigned by the State Engineer and the Water Court in decrees over the past 15 years. The Dawson is the formation closest to the land surface and, therefore, should have less compaction.

#### Discussion of Appropriate Value for Specific Yield with Ground Water Consultants:

The State Engineer met with engineers, geologists and ground water consultants four times during 1984. The purpose of those meetings was to discuss issues relative to the use of the Denver Basin Aquifers. A variety of topics were discussed at the meetings, but at two separate meetings discussion centered on the appropriate values of specific yield to be used in evaluating well permits. The values proposed in Rule 6 were supported by a majority of the 25 to 30 professionals who attended those meetings.

Utilization of these average values for each aquifer throughout the Denver Basin will allow uniformity in the issuance of well permits between adjacent property owners and will minimize the need for individuals to obtain site specific data by collecting core samples and running laboratory tests. The values appear to be reasonable and should be considered as the appropriate presumptive value, absent site specific data.

#### Site Specific Data

The proposed rules allow an individual to obtain site specific data of values for specific yield. The State Engineer shall consider those values when evaluating the allowable average annual amount of withdrawal for a well or from beneath a particular parcel of land. The criteria for obtaining site specific data acceptable to the State Engineer can be found in Rule 8.D. of the Statewide Rules for Use of Nontributary Groundwater.

This provision allowing the applicant to obtain site specific data for specific yield will allow an applicant or permittee to obtain a permit to withdraw the full amount of water from beneath their property.