RECHARGING THE OGALLALA FORMATION USING SHALLOW HOLES

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INTRODUCTION

The Ogallala aquifer, an immense unconfined aquifer underlying parts of Texas, New Mexico, Oklahoma, Colorado, and Kansas, has been the scene for many artificial recharge studies. The extent of the Ogallala can best be visualized from Figure 1. The primary reason for the multitude of efforts, particularily in the High Plains of Texas, is the existing evidence that natural recharge will not sustain the aquifer in this geographical area. Virtually all the water used in this region is derived from the Ogallala and this can best be illustrated by the statistic, irrigation wells within the High Plains of Texas. In 1970, there were 65,214 wells supplying water for the irrigation of 5.5 million acres [*New*, 1970].

The southern bed of the Ogallala is hydrologically isolated from all outside areas of recharge requiring all natural recharge in this area to originate from precipitation falling on the lands immediately above the aquifer. Figure 2 illustrates this isolation showing the Pecos and Canadian river canyons and the eastern escarpment. Since the Southern High Plains is considered a simi-arid region with limited and highly erratic rainfall, poorly

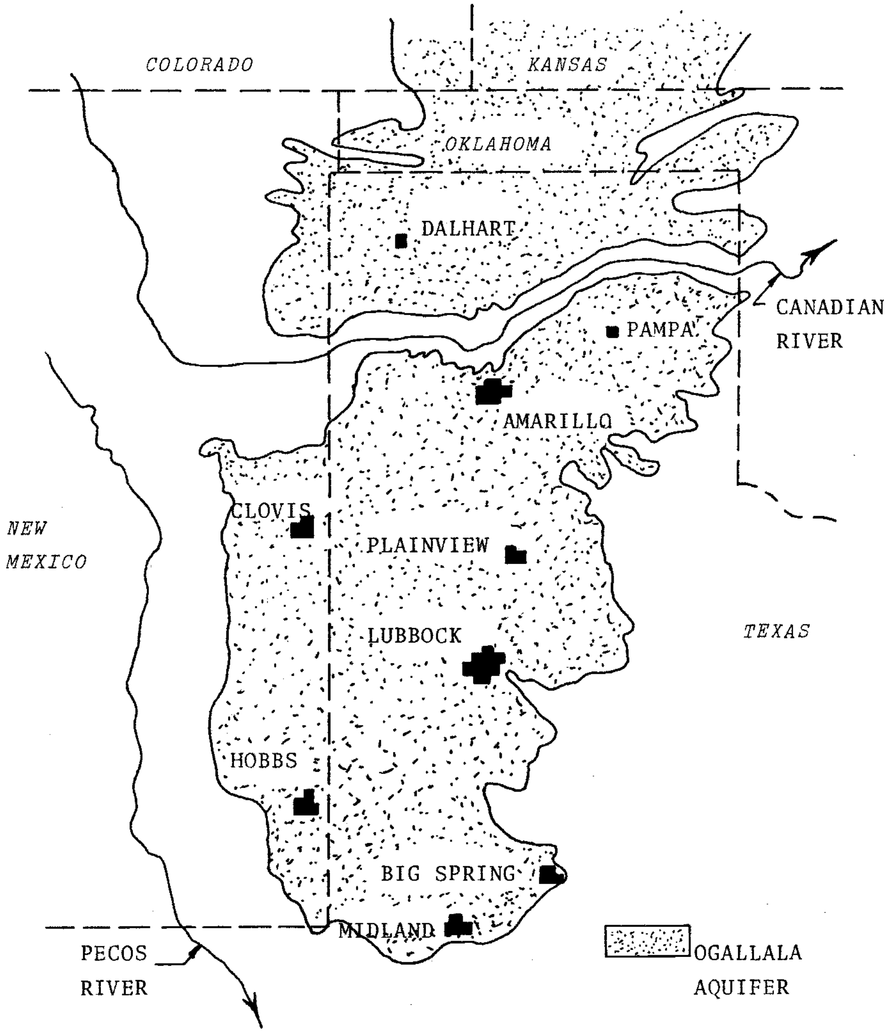


Figure 1. Location map of the Ogallala aquifer in the Texas High Plains.

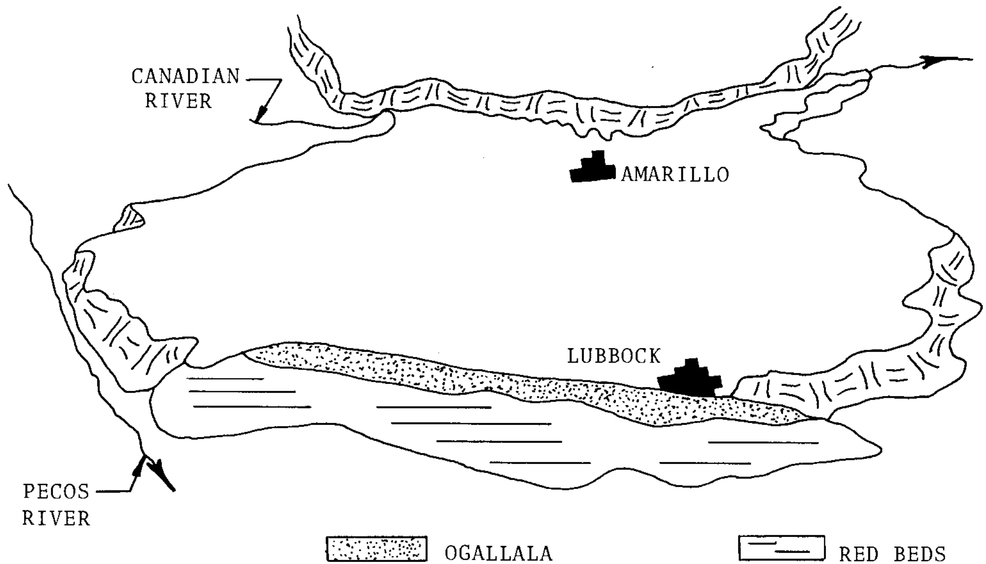


Figure 2. Three-dimensional sketch of the Southern High Plains showing the aquifers hydrologic isolation.

established drainage nets, and limited lakes and reservoirs, there exists only a limited opportunity for natural recharge.

The actual volume of natural recharge has been estimated by several reports and investigations [*Cronin*, 1969; *Havens*, 1966] as less than a 1-inch increase in water level elevation per year. Contrasting this with the volume of water withdrawn manifast in water level declines of 2-3 feet, it can be seen that withdrawal is many times greater than estimated natural recharge [*Signor*, 1968; *The Texas Water Plan*, 1968]. In order to preserve the economic utility of the aquifer, it appears that artificial recharge affords the only means of establishing at least a pseudo-balance between withdrawals and the natural recharge into the Ogallala.

DEVELOPMENT

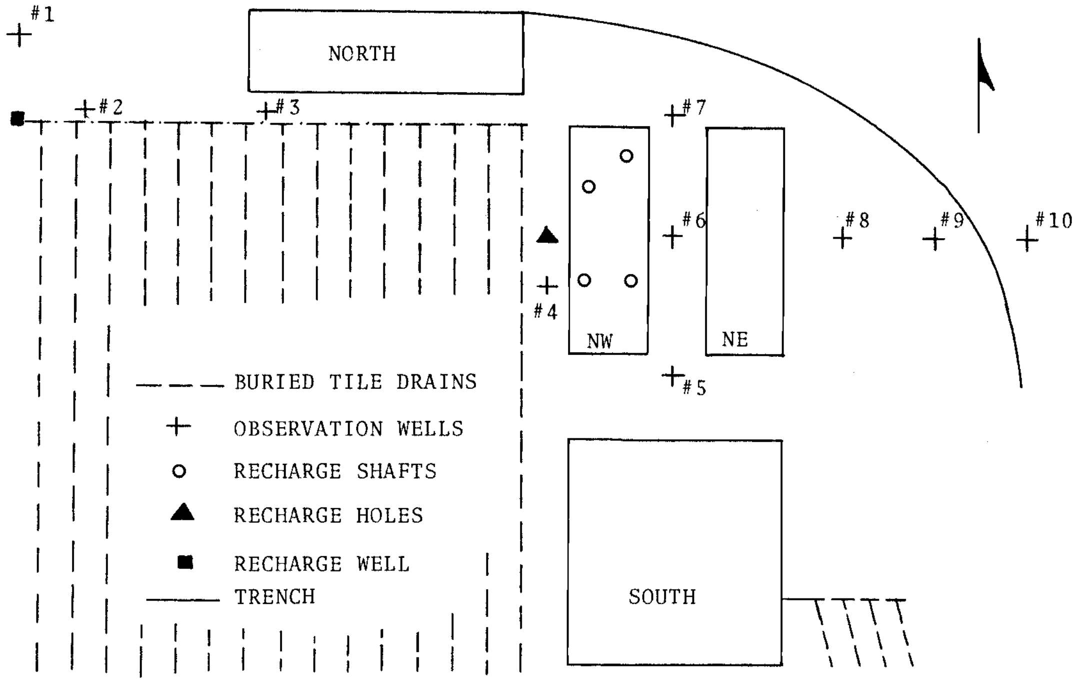
Artificial groundwater recharge efforts utilize various methods which include multiple-purpose wells, shafts, pits, trenches, spreading, and modifications of these methods. All of these methods have been subject to research and investigations by various federal, state, and private research organizations [*Clyma*, 1966; *Dvoracek*, 1964-65; *Dvoracek and Peterson*, 1970; *Dvoracek and Wheaton*, 1968; *Dvoracek and Wheaton*, 1969; *Hauser*, 1967; *Signor*, 1968 (Sep); *Signor*, 1968(Dec), *Valliant*, 1962]. All of the efforts have experienced success in at least an isolated area, however, not one method has been deemed regionally successful. The prime reason for this failure is the extreme heterogenity or variability which exists within the aquifer itself.

During the course of one recent investigation, a rather unique way of recharging the Ogallala was found. In January, 1969, a network of ten 5-inch observation wells were being installed in the Groundwater Recharge area on the Texas Tech University farm. At one of the proposed well sites, the well driller, using the hydraulic-rotary method, lost circulation at a depth of approximately 30 feet. Being unable to reestablish circulation at this site, the site was abandoned and a new site 5 feet south was selected. At approximately the 40 foot depth, loss of circulation was again experienced. Moving to a new location 50 feet south of the second site, an observation well was drilled to a depth of 150 feet. Figure 3 shows the location of the holes and the entire recharge area.

Due to a lack of water for recharge at this time, the holes were capped to maintain their initial condition. In early May, 1969, surface runoff water became available and an initial attempt to recharge through the holes used a 2-inch plastic tube inserted to the bottom of the first hole. The size of the pipe was inadequate to permit filling the hole with water. To permit increases in the recharge rates and also to prevent collapse of the hole, a 30 foot joint of 4-inch aluminum irrigation pipe was placed in the hole as shown in Figure 4. Water was pumped into the hole and permitted to freefall into the hole. During this period of recharge, the second hole experienced a cave-in at a point below the surface.

RESULTS

The initial recharge for a period of 12 days in early May, 1969 was 2.5 acre-feet of water at rates ranging from 120 gpm at the start of recharge to 60 gpm at the termination of the period. The 120 gpm rate was relatively short, approximately 1 day, after which the 60 gpm rate was relatively constant. The recharge period was broken for short periods due to maintenance of equipment.



Scale: 1" = 150'

Figure 3. Topographic map of the Agricultural Engineering Department, Texas Tech University recharge area.

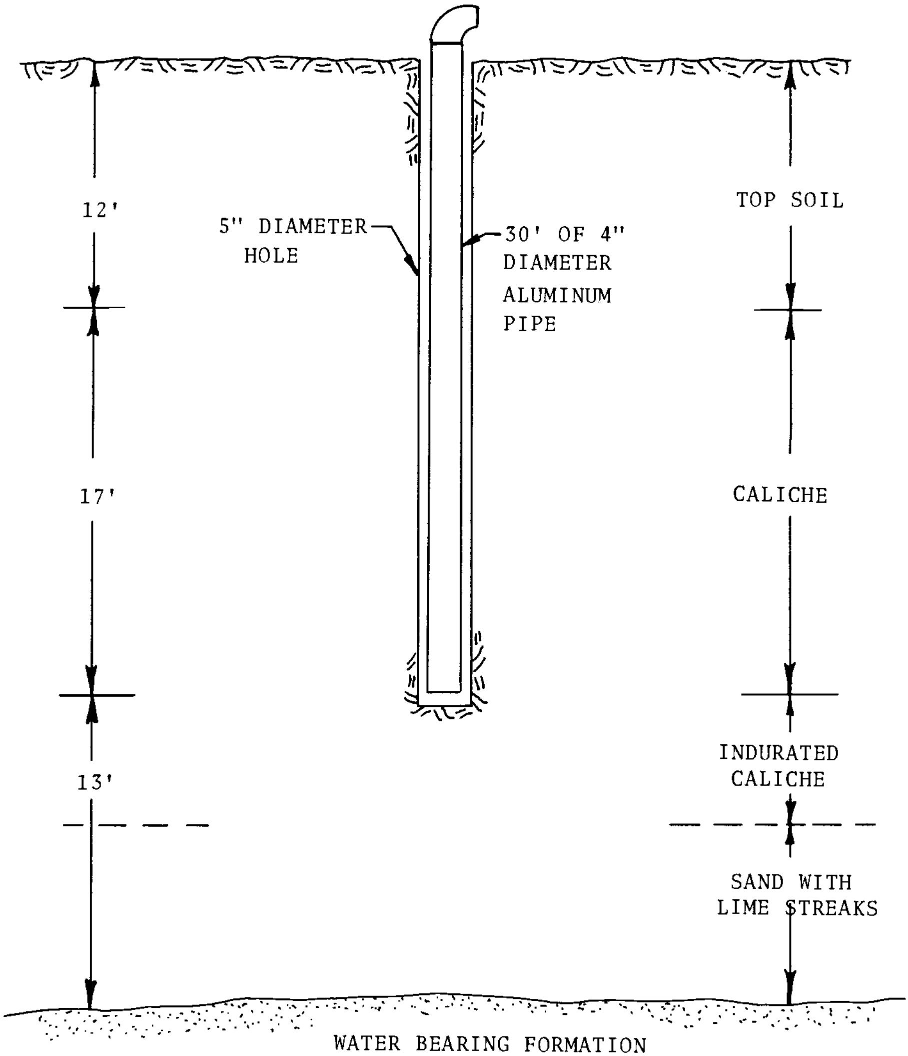


Figure 4. Schematic of the initial hole recharge facility.

Approximately 1 month later, a second test was conducted covering a period of 3 days and a total recharge of 1.2 acre-feet. A decline in rate from 140 gpm to 90 gpm was observed and a water level increase of 3.9 feet was observed in observation well no. 4. It became evident during this attempt that a cavity was present at the bottom of the hole being recharged. The cavity size was estimated to have a volume of approximately 60 cubic feet. A cavity of sufficient size to include both holes was found to exist at the relatively shallow depth of 4 feet.

Ten days after the second test, recharge was again practiced. A slight increase in rate of recharge was observed with rates ranging from 140 gpm to 100 gpm. During a 4 day period, 2.1 acre-feet were recharged to the formation resulting in a 4.7 foot rise in water level elevation in observation well no. 4. Two months passed before the water level returned to its original position.

Approximately 2 months of extremely dry conditions preceded the next recharge in late August, 1969. This period permitted the most extensive recharge period as 4.4 acre-feet were recharged with the rate ranging from 160 to 120 gpm. After 12 days, the water level in observation well no. 4 had risen 11.1 feet. All other wells in the observation well network exhibited water level increases approximately proportional to their distance from point of recharge. All of the increase could not be attributed to hole recharge as pits and a multiple-purpose well were also recharging during this period. Therefore the decay of groundwater could not be monitored as desired. An 8 day recharge period was possible in mid-September, 1969 permitting recharge of 2.7 acre-feet through the hole with a corresponding net increase in water level of 11.2 feet in well no. 4. The rates were consistent with those of the previous period. During the period between August 26 - September 26, the water level rise in well no. 4 amounted to over 22 feet.

In late October, 1969, 1.1 acre-feet were recharged with the rate increasing to a high of 170 gpm reducing to 120 gpm. Evidence supported the contention that an increase in the size of the bottom cavity had occurred. The upper cavity also reached proportions making a structural failure of the surface imminent. Excavation of a 1 foot thick surface layer exposed an irregular cavity approximately 8 X 4 X 5 feet in dimension. To prevent further cavitation at the surface, a 1-foot diameter pipe was inserted around the hole and anchored into the hard caliche layer.

An instrument was developed to permit photographing the cavity. After many attempts, a sufficient number of photos were obtained to allow for the preparation of a representative mosaic. Analysis of the mosaic indicated a southeast direction and an upward dip of 40 degrees existed. The depth of the cavity at the terminus of the hole is approximately 3 feet with a total length of 12 feet. Figure 5 represents a schematic of the cavity and location of both holes.

In February, 1970, the second hole was re-excavated with a hand auger and cased similar to the first hole. This hole did not appear to pass through the cavity of the first but did appear to possess a cavity 5 feet below the first. This however remains unconfirmed as the hole was to small to permit passage of the photographic equipment.

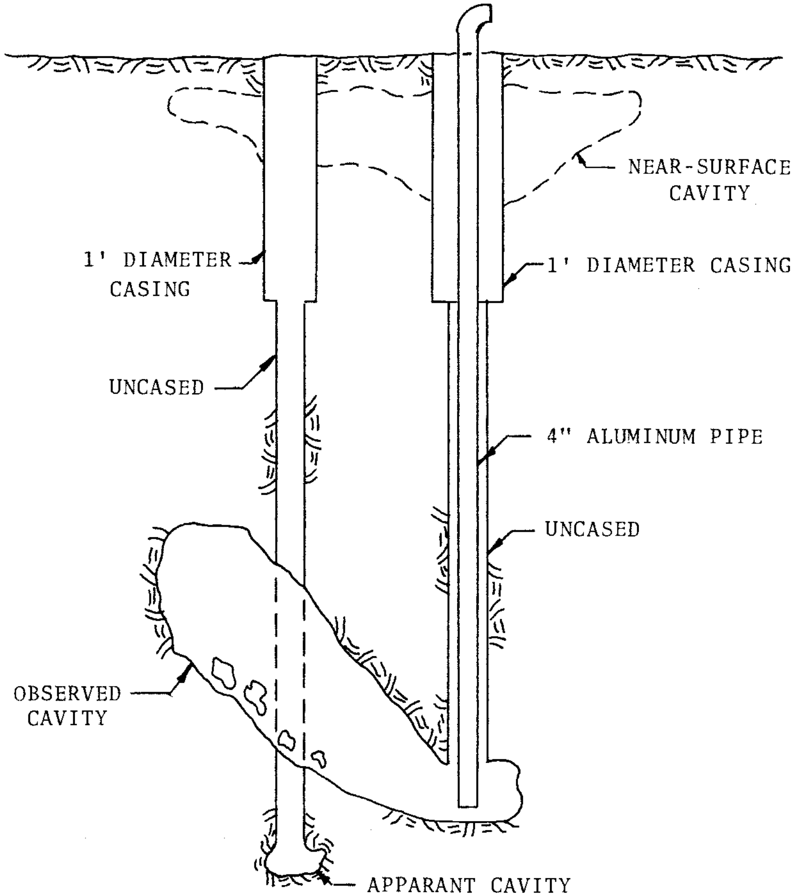


Figure 5. Schematic of cavity at base of hole, March, 1970.

The initial recharge period in 1970 and after re-excavation of the second hole was of relatively short duration. One observation significant to note was the reduction in recharge rates to 140 gpm maximum with a sustained rate of 100 gpm. The reason for the decline is attributed to the clay material which fell into the cavities during redrilling. A recharge period in early April, 1970 presented a tremendous increase in the initial rate, 220 gpm, with a sustaining rate of 120 gpm. Apparently a shift in materials occurred during the previous period and this was supported by photographs of the cavity after this recharge period.

Another significant period of recharge occurred during mid May, 1970. The initial rate of recharge was 260 gpm with a sustained rate of 155 pgm. During this 26 day period of recharge (May 13 - June 9), a total of 12.7 acre-feet were recharged into the formation. Water levels were significantly raised due to this extended recharge period. Photographs of the cavity revealed further enlargement and displacements within the cavity.

Table I summarizes the recharge efforts within the small diameter hole. As can be noted, rates varied as well as water levels however both are quite significant for the various recharge periods. It should also be noted that all recharge was accomplished using surface runoff waters characteristically high in sediment content.

SUMMARY AND CONCLUSIONS

During the past two years more than 28 acre-feet of surface runoff water have been recharged through the shallow hole with increases in recharge

TABLE I - HOLE RECHARGE - TEXAS TECH UNIVERSITY

Period of Recharge	Rate of Recharge (gpm)	Volume of Recharge (acre-feet)	Water Level in Observation Well #4 (feet)
5-5 to 5-17-69	120[a] / 60[b]	2.5	3182.99[c] / 3189.99[d]
6-3 to 6-6-69	140 / 90	1.2	3187.49 / 3191.69
6-16 to 6-20-69	140 / 100	2.1	3187.89 / 3192.59
8-26 to 9-6-69	160 / 120	4.4	3182.39 / 3193.49
9-18 to 9-26-69	160 / 120	2.7	3196.09 / 3207.29
10-25 to 10-27-69	170 / 120	1.1	3199.69 / 3205.09
3-9 to 3-10-70	140 / 100	0.5	3189.25 / 3190.83
4-6 to 4-9-70	220 / 120	0.8	3188.48 / 3190.03
5-13 to 6-9-70	260 / 155	12.7	3189.62 / 3204.86

[a] Upper number represents maximum

[b] Lower number represents sustained

[c] Upper number represents beginning

[d] Lower number represents end of recharge

rates for each subsequent recharge period. There remain several unanswered questions. One, where did the volume of earthen material which constituted the upper and lower cavities go? It is possible that a cavity of some form existed prior to recharge however the upper cavity had to be developed during recharge. Perhaps of greater significance is why the material did not plug the formation surrounding the hole? Another source of earthen material was the sediment carried in the recharge waters which carried concentrations to 200 ppm.

As previously stated, the rate of recharge has shown a steady increase rather than an expected decline. The prime factor which seems to influence the rate is the degree of saturation of the formation surrounding the hole. It is felt that a condition of soil piping [*Cedergren*, 1967] may be responsible for the increasing rates and disposition of the cavity material. Soil piping, however, may be hard to support as channel sizes increase, sediments from the channel must also be displaced.

A phenomena more unexpected than the surprisingly high rates occurred after the re-excavation of the second hole. When recharge commences, the water within both holes rises simultaneously however the level in the second hole stabilizes at a level lower than in the first. This difference in level seems to correspond with the rate of recharge as the difference is 2.5 feet at 200 gpm but only 1.5 feet at 150 gpm. An explanation for this phenomena has not been attained to date.

In conclusion, hole recharge has proven to be a very effective and economical method of recharge in the area of the test. The big question remaining is "Can this success be duplicated in other areas?" Efforts to obtain at least a partial answer were made as eight additional holes in two areas were drilled. However, an exceptionally dry fall and winter has precluded even one recharge effort in the new locations.

If a positive answer could be attained to the above question, an efficient and economical method of artificial recharge will have been discovered. Indications are that this may be possible but must be the subject of increased research efforts.

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