Artificial Recharge of a Brackish Water Well

By D. J. CEDERSTROM
Geologist
U. S. Geological Survey

ARTIFICIAL recharge of wells with cold water in winter, for use in the following hot summer months, has now become an accepted and economically proven practice at several industrial plants in the United States. Cold water is generally obtained from municipal systems in the winter, allowed to flow down wells into underground strata, and is pumped out again during the succeeding summer months. The cold water gains only moderately in heat content while in storage.

A number of industrial concerns in Virginia draw upon well-water supplies for part or all of their water requirements. The water is used for general purposes and industrial processing, but increasing demands are being made for water for cooling purposes, in connection with air-conditioning equipment, for chilling milk, and for maintaining low temperatures on condensers and generators. Where the chemical quality is satisfactory and sufficient quantities are present, ground water is preferred to surface water for cooling purposes because in summer the temperature of the ground water (which is about the same temperature as the average annual air temperature) is lower than that of water from streams.

Deep wells that supply private and industrial consumers in eastern Virginia have previously been discussed in this magazine.[1]

In considering the desirability of encouraging the practice of artificial recharge in the industrial Hampton Roads area in eastern Virginia, the fact was immediately realized that those areas that might benefit most from artificial recharge are underlain by strata saturated with brackish water.[2] Few deep wells exist in the Norfolk-Newport News region, and those that do exist yield water ranging in chloride content from a few hundred to more than 1,000 parts per million. Water of such mineral content, even where diluted with fresh water, is not entirely desirable for air conditioning because of its corrosiveness, and for other purposes it might be quite unsatisfactory.

However, it occurred to the writer that if fresh water were poured down a well that tapped sandy beds saturated with brackish water complete mixing of the fresh water with the brackish water might not occur, so that a large part of the fresh water might be recovered with little or no increase in mineral content.

Accordingly, steps were taken to try to carry out such an experiment as part of the program of investigations of ground-water resources carried on by the U. S. Geological Survey in coöperation with the Virginia Geological Survey. Several idle wells in operating condition exist at Camp Peary, near Williamsburg and, as detailed information on them was at hand, the Public Works Department of the Fifth Naval District was requested to allow the proposed experiment to be carried out there. The response was immediate and every possible facility was furnished by the Navy for making the test run.

Camp Peary, which was used during World War II as a training station for Naval Construction Battalions (Seabees), was supplied for about eight months with water from twelve wells, between 400 and 500 feet deep. The water obtained ranged in chloride content from 260 to 400 parts per million and, although potable, was somewhat more mineralized than was considered desirable, and a surface-water supply was made available as soon as practicable. Surface water was brought in from nearby Waller Pond. The Federal Works Agency and the city of Williamsburg (which now controls the water supply of Waller Pond) released such water from the pond as was necessary for the experiment, and a water meter was loaned by the Newport News Water Commission.

RECHARGE

The Camp Peary well selected for the test is known locally as D-3. It is 472 feet deep and eight inches in diameter. Cook 40-slot screen is placed opposite medium-textured sand strata at 430 to 440 feet and 450 to 475 feet below the surface. This well yielded 305 gallons of water a minute with a drawdown of 62 feet. The most important factor in the selection of the well was that the water level stands seventy feet below the surface (the elevation of the pump base is eighty-four feet above sea level), making it possible to build up a considerable pressure head at the well and induce rapid recharge of the water-bearing formation. The chloride content of the water originally yielded by this well is 340 parts per million.

Pipe connections were completed and recharging was begun on April 4, 1946. Water from the mains was allowed to flow directly through the turbine pump and into the well casing under a pressure of about thirty-five pounds per square inch. The pump turbines rotated backwards at a high rate of speed during this operation. To avoid the possibility of generation of electrical charges, with danger to operators and equipment, the shaft leading from the pump head to the electric motor was disconnected.

Recharge water was under pressure down to the lower outlet of the turbine column. From that point on, water spilled into an "open" well casing, and water passing downward into the ground was only under such pressure as was caused by the piling up of water in the well casing, a pressure head measured by the difference between the static level and the level of the water in the well during recharge.

The water level in the recharge well gradually rose and about May 17 water began flowing out at the pump base at the top of the casing. At that time, the amount of water flowing into the well had fallen from 250,000 gallons a day (on April 5, the second day of recharging) to about 200,000 gallons a day. Water-level observations in nearby wells showed conclusively that recharge was not being retarded by the creation of high artesian pressure but rather that recharge was failing in the recharge well itself. In other words, simple clogging was indicated.

The recharge well was then pumped in an effort to eliminate or decrease clogging. On May 1 the well was given a three-minute run; the water discharged was fiery red at first but cleared and became colorless by the end of that brief run. It seemed apparent that, in setting up the recharge experiment, cognizance had not been taken of the iron rust accumulated in the mains. When the mains were opened and water flowed to the well at a much higher rate than it ordinarily moved in the mains, this accumulation was swept into the well and lodged in the screen and adjacent sediments.

However, only a slight beneficial result was noted from this and succeeding brief

(Continued on the other side)

---

[1] D. J. Cederstrom, "Deep Wells in the Virginia Coastal Plain," THE COMMONWEALTH, April, 1943, p. 20.

[2] Cederstrom, *Chloride in Ground Water in the Coastal Plain of Virginia.* Virginia Geological Survey Bulletin 58, 1943.

This paper was released by the author for publication with the permission of the director of the U. S. Geological Survey and the state geologist of Virginia.—THE EDITOR.

Recharge of Well

(Continued from the other side)

pumping operations. It is concluded that packing of sand grains in the vicinity of the well screen took place as the well was recharged, and the diminution in recharge rate may be ascribed in larger part to this effect than to clogging due to the introduction of foreign material. The sand in the formations here is of medium, rather uniform texture; such sand would be more difficult to stabilize than a coarse sand or gravel composed of grains of different sizes. It is believed that this should be taken into account in the selection or construction of wells for recharge purposes.

According to the meter, 17.3 million gallons of water was recharged in the period from April 4 to June 28. However, some waste of water occurred and about 30,000 gallons was pumped out during the brief pumping periods mentioned above, so that probably slightly less than 17 million gallons was actually added to the underground reservoir.

Discharge

The recharged well was pumped during the period July 2 through September 21 in order to determine the extent to which the fresh recharge water had mixed with the slightly brackish ground water. Pumping took place in two periods, from July 2 through July 25 and from August 4 through September 21. The break in continuous pumping was caused by the breakdown of the electric motor.

Discharge began at about 325,000 gallons a day and rose to almost 365,000 gallons a day in about five days. Discharge had increased to 380,000 gallons a day by the end of the first pumping period, July 25. From August 4 to September 21, the rate of discharge increased very slightly.

At first, the water discharged contained only as much chloride, 10 or 12 parts per million, as the fresh recharge water, but during the latter part of the first pumping period, when 8.4 million gallons (an amount of water equivalent to about half the total amount recharged) had been pumped, the chloride content of the water discharged had increased to 20 parts per million. Thus, at the end of the first pumping period the proportion of ground water in the water discharged was not quite 3 percent.

In the second pumping period, the chloride content of the water discharged began to rise, and by the time a total of 12.6 million gallons of water had been discharged (an amount equivalent to about 75 percent of the total amount recharged) the chloride content was 98 parts per million and the water was a mixture of one-fourth ground water and three-fourths recharge water. When 17 million gallons had been pumped, an amount equivalent to the total amount of recharge, the chloride content of the water discharged was 220 parts per million. This water was a mixture of about 60 percent ground water and 40 percent fresh water. When about 25 million gallons of water had been discharged the chloride had risen to 340 parts per million and the water was almost entirely ground water.

The pumping data immediately suggest that, where fresh water is to be stored in sediments saturated with brackish water, the proper operating technique will be to add an excess amount of water the first year. Discharge of only the fresh portion of this excess recharge water will leave behind a buffer zone of fresh and brackish water. After recharging in the second and succeeding years it may then be possible to pump a quantity of fresh water equal to the total quantity recharged.

Summary

The test run at Camp Peary indicates that the storage of fresh water under ground in *sandy* sediments saturated with brackish water is practicable. The following significant facts were brought out by the test:

1. About 50 percent of the amount of water recharged in this experiment was uncontaminated when pumped out. By allowing a portion of the first run to remain in the ground, it will be possible to pump back almost all the water recharged in later runs, the proportion of recovery depending on the chloride content that can be tolerated.
2. Some clogging of the recharge well is generally to be expected, except where the sediments are coarse-grained and where the well was highly developed when it was constructed.
3. Foreign material from mains should be prevented from entering the well.
4. Restoring the permeability of a clogged well is difficult; surging for a period of many hours or even days may be necessary. It may be impracticable to do this to any degree of completeness during a recharge run, and it may be found necessary to recharge through two or more wells and to pump all of these sufficiently to redevelop them when the water is being recovered.
5. An observation well near the recharge well will be of considerable value; a graph of the water level in the observation well will indicate the extent to which recharge is taking place and indicate whether any decrease in the rate of recharge is due to clogging or the building up of head in the area.

Factors to be considered if artificial recharge is to be carried out are:

1. Economic justification; the desirability of water colder than that furnished by public supplies during summer months or by existing wells; the desirability of storing water for certain drier seasons, periods of heavy demand, or emergency use.
2. Favorable water rates; because the cost of artificial recharge is substantial, it may be necessary in many instances that water used for the operation be obtained at a cheaper rate than usual. This can doubtless be arranged in most cities if the water is purchased for recharging in periods of heavy rainfall and during off-peak hours. As the practice of artificial recharge of wells used for cooling purposes lowers the demand on city systems during hot, dry periods, when facilities may be taxed to the utmost, favorable rates may be granted more readily than if the water were put to its end use at the time of purchase.
3. Where ground water, either fresh or brackish, is already used successfully for cooling in the summer, artificial recharge will be practicable only if the efficiency of the cooling system is substantially increased by this practice. At Hopewell, Virginia, chemical processes are measurably more efficient where only a small lowering in temperature occurs. There fresh-water wells normally yielding water at a temperature of 60° F. are recharged during the winter. A heat gain of 35 percent is reported to occur in the cold recharged water; that is, the process is 65 percent efficient.
4. Where ground water cannot be used at all for cooling because of its corrosiveness or for some other reason based on chemical quality, it will probably be more economical in many places to use artificially recharged water during the summer months than to use the tepid water supplied by most city systems during this period.

Reprinted from THE COMMONWEALTH for December, 1947

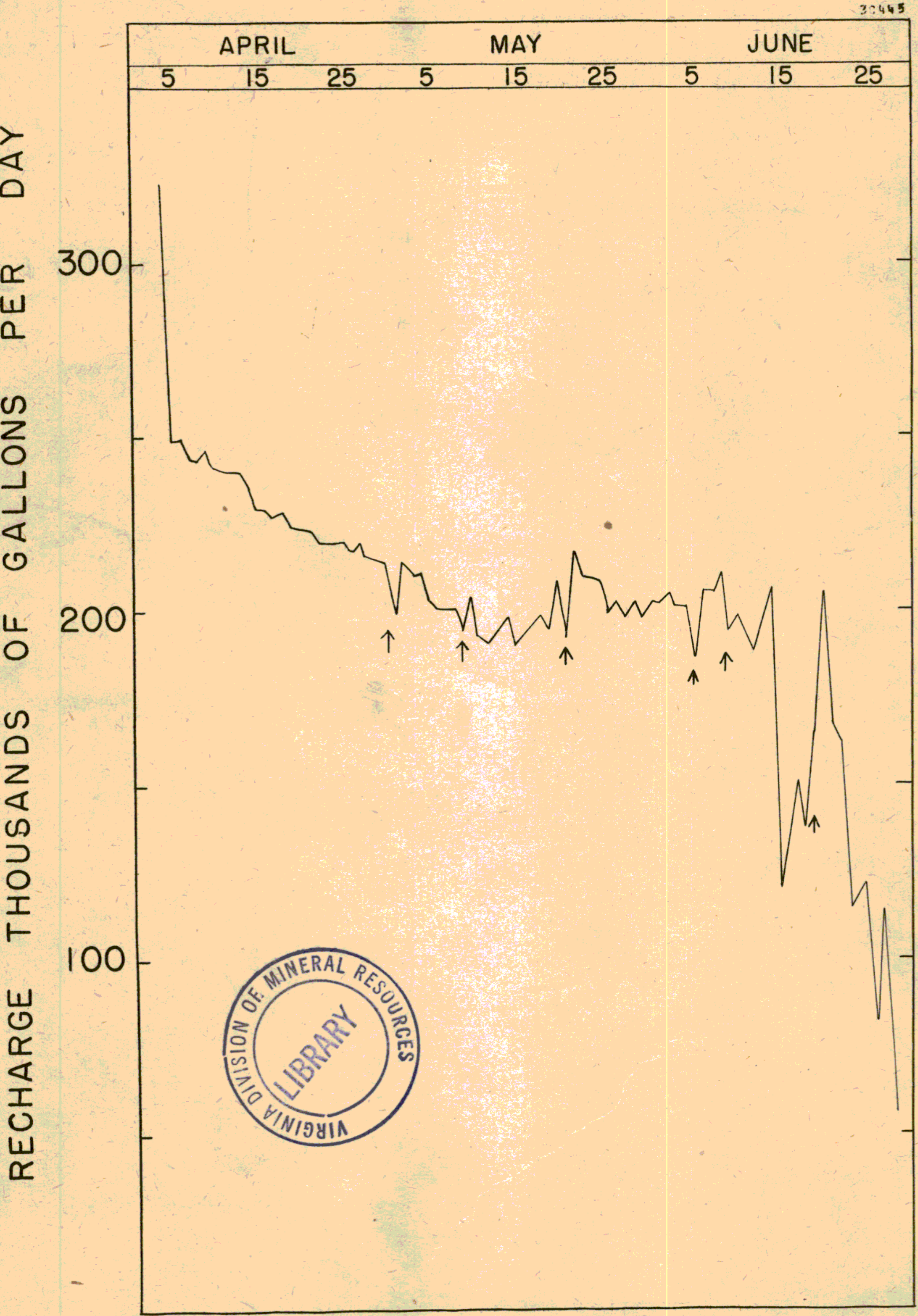

Figure I — Cederstrom — Artificial recharge

copy 1

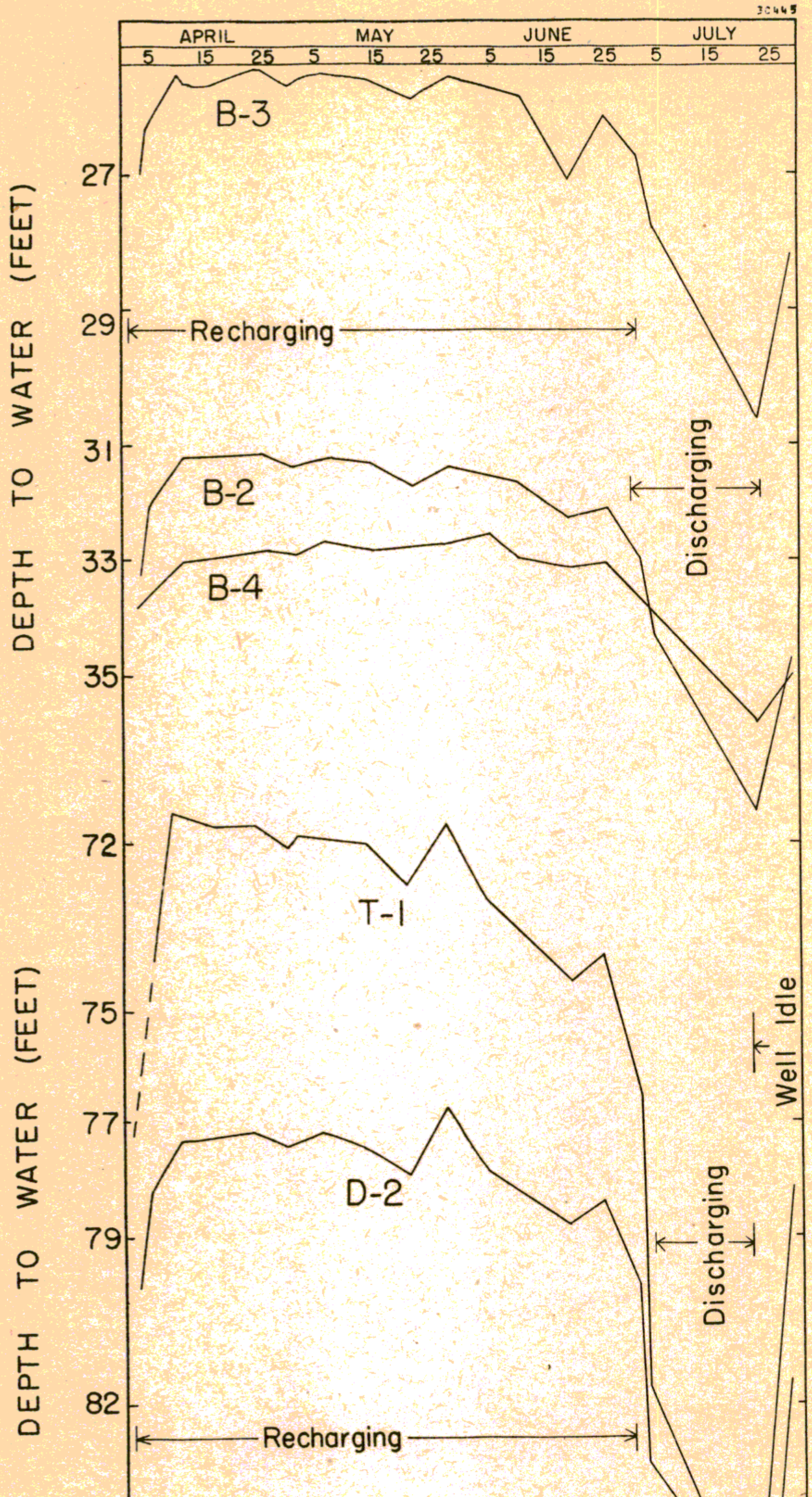

Figure 2 — Cederstrom — Artificial recharge

copy 1

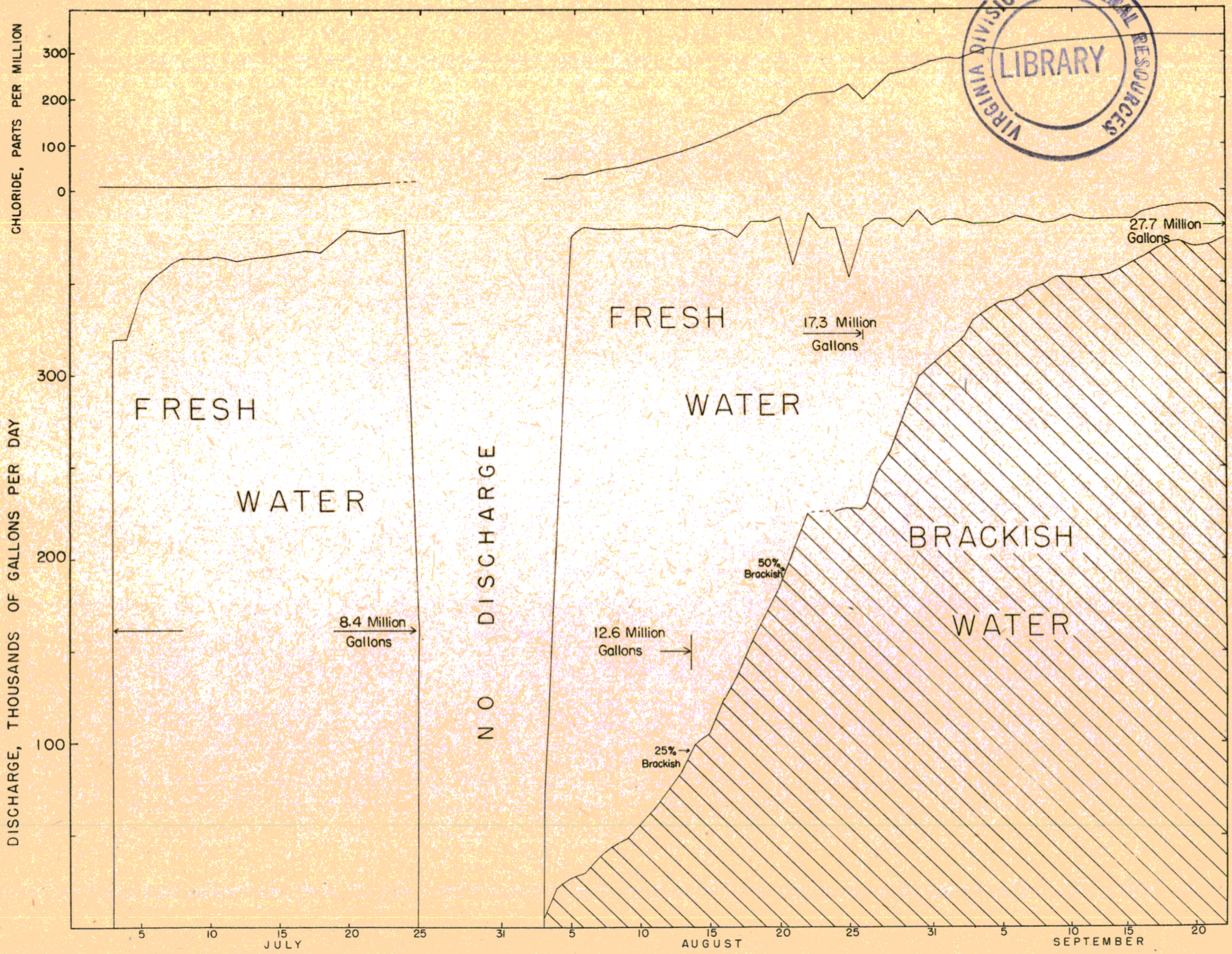

Figure 3 – Cederstrom – Artificial recharge

copy 1

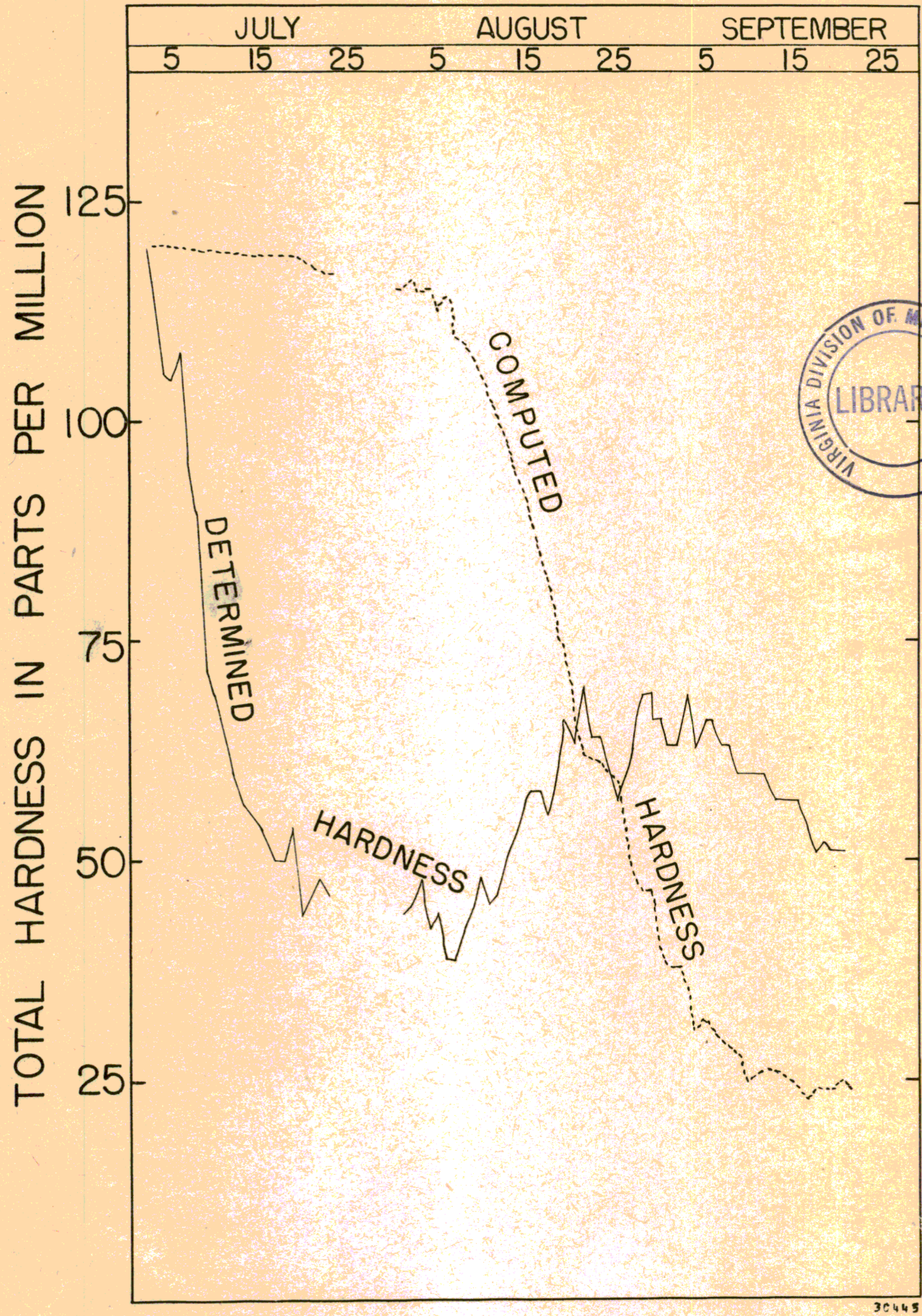

Figure 4 — Cederstrom — Artificial recharge

copy 1 (no c. 2)