IPA

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Report Of
Freshwater Injection-Recovery Study
Palm Beach County

The 1972 Legislature passed Senate Bill 1154 which included appropriations of $150,000 to evaluate subsurface storage of fresh water in the State of Florida. In summary, the appropriations bill authorized and directed the Department of Natural Resources to conduct feasibility studies, plan, and execute programs for storage of surplus surface water in aquifers for reclamation and use. The injection-recovery project in Palm Beach County was initiated as a result of this bill.

This report contains a summary of the drilling and testing of a deep injection well in northeast Palm Beach County. The well is located on the south side of Structure S-46 on the C-19 Canal of the Central and Southern Florida Flood Control District, at its intersection with State Road 706 (Figures 1 and 2).

The purpose of this investigation was to determine the feasibility of injecting and storing large volumes of fresh water into saline water contained in the upper part of the Floridan aquifer, and to determine the potential recoverability

the injection well was drilled and tested to locate the injection zone, followed by construction of the monitor well. The monitor well is located about 500 feet from the injection well to record the effect of the injected water on the aquifer system.

The injection well is constructed with 12-inch diameter casing to 990 feet and open hole penetrating the Floridan aquifer to a depth of 1280 feet. The monitor well has the same construction except the well diameter is five inches. Construction of the wells is shown in Figure 3.

Between February 1975 and October 1976, four cyclic injection and recovery tests were made. A cycle consisted of injecting a measured quantity of fresh water into the deep saline aquifer and, after a storage period, recovering the water by natural artesian flow. The recovery phase of each cycle was terminated when the chloride content of the recovered water reached 250 milligrams per liter (mg/l), the upper limit recommended for drinking water by the U.S. Public Health Service.

During injection, the fresh water forms an underground bubble in the heavier, saltier water of the artesian aquifer. Repeated injection cycles expand the fresh water bubble, thereby increasing the percentage of recovered fresh water.

Table 1 shows the results of the injection-recovery cycles. Percentage recovery of injected water is in terms of mixed water with chloride content less than 250 mg/l. No

recovery of fresh water from cycle 1 indicated that all of the injected water was blending and creating a mixed zone, or zone of transition, made up of fresh water and saline water of the Floridan aquifer. Fresh water recovery occurred in cycle 2 and increased in cycles 3 and 4. This increase in recovery indicated that the mixed zone had been established between the fresh water and saline water and a fresh water bubble was being formed and enlarged, resulting in higher recovery with each additional cycle. It should also be noted that the fresh water was stored for 30 days in both cycles and the recovery in cycle 3 was four times greater than in cycle 2.

It can be noted in Table 1 that the amount of water injected in cycle 3 was three times greater than in cycle 2. The storage period was 30 days in both cycles and the recovery of fresh water in cycle 3 was four times greater than in cycle 2.

It should also be noted that the amount of water injected in cycle 4 was one-third that injected in cycle 3. Although the storage period in cycle 4 was 120 days (4 times that of cycles 2 and 3), the percentage recovery of injected water that was recovered in cycle 4 was about twice as much as recovered in cycle 3 and eight times greater than that of cycle 2. The injection phase of cycle 4 was intended to be the same quantity as in cycle 3, approximately 300 million gallons. However, the amount was never achieved due to lack

of funding and personnel. Nevertheless, the data from the recovery phase of cycle 4 showed the highest percentage recovery of fresh water (<250 mg/l chloride) than any of the previous cycles.

With increased use of the aquifer we anticipate that ultimately a very large percentage of the fresh water may be recovered. Full scale use of the aquifer could permit large amounts of water to be pumped underground when surface supplies are plentiful and stored for later use.

Table 1 - Results of Injection-Recovery Tests

Cycle Number	1	2	3	4
Quantity Injected, million gallons	20.5	100	306	102
Storage Period, days	15	30	30	120
Quantity Recovered, million gallons*	0	4.7	55.5	36.1
Percent Recovery	0	4.7	18.0	35.2
Injection Rate	2000	2000	2000	2000
Recovery Rate	1000	1000	1000	1000

* Recovery was terminated when the chloride content of the recovered water reached 250 mg/l.

Results of the deep well injection-recovery program at the Palm Beach County Site are summarized below.

1. Completion of construction of one injection well and one monitor well.
2. A receiving zone has been located below 1000 feet in the upper part of the Floridan aquifer which will accept large quantities of injected surface water.
3. The receiving zone is separated from overlying shallow fresh water aquifer by an extensive confining layer precluding upward migration of injected water.

4. Large volumes can be injected under moderate pressure into the receiving zone. Injection rates can be maintained for long periods.
5. Recovery of fresh water is increased by cyclic injection.
6. Testing indicated that fresh water can be recovered after 120 days storage period. It is anticipated that longer storage periods would have little effect on amount recovered.
7. Fresh water can be recovered under the present well design at an average rate of 1.5 million gallons per day (1000 gpm) by natural artesian flow.

Utilization of injection facility in Palm Beach County

The Governing Board of the Loxahatchee River Environmental Control District considers deep well injection as an extremely viable tool for the management of water resources in the Loxahatchee River Basin.

Deep well injection is considered along with other alternatives for supplying fresh water to the northwest Fork of the Loxahatchee River to help maintain a desirable fresh water saline water balance for prevention of stress to the biologic system and to prevent excessive saltwater intrusion during dry periods when little or no flow is released from

Central and Southern Florida Flood Control District's C-18 Canal to the river system. The fresh water requirement for the northwest Fork is 50 CFS, or 32 MGD.

During the wet season the discharge of fresh water through the S-46 Structure on the C-18 Canal averages about 150 CFS (100 MGD). Surplus fresh water discharged during this period could be pumped into the Floridan aquifer through injection wells and be available during dry periods. At the present time the discharge is lost to tidewater.

Based on the results of the present well design, 3 MGD can be injected continuously. A well field, consisting of 20 wells adequately spaced could inject 60 MGD into the Floridan aquifer during the rainy season and store it for use during the dry periods. Injection would take place June through September, a four month period. Total injected volume would be 7200 million gallons. Assuming a recovery efficiency of 50%, or 3600 million gallons, at a rate of 1.5 MGD by each well, this could produce 30 MGD by 20 wells for a four month period.

Pumping costs for injection for the existing well are $50.00/day or $1500/month. Pumping costs for 20 wells would be $1000/day or $30,000/month or $120,000 for the four month period. The costs per million gallons of injected water per well would be about $17.00. The cost per million gallons per well for recovered water would be about $34.00, assuming

50% recovery efficiency. Recovery is by natural artesian flow.

The major costs would be for the initial construction of the injection wells. Construction for one well and pump would be $185,000, or $3,700,000 for 20 wells.

Cost estimate for desalinization of Floridan aquifer water in Palm Beach County

A desalinization facility is being constructed near the Palm Beach - Martin County line, about five miles from the injection facility, to supply water for a condominium complex. Saline water for this facility will be withdrawn from the Floridan aquifer through a 1200-foot well. Saline aquifer water (1500 ppm chloride) withdrawn from this well is comparable to native saline water in the aquifer at the Jupiter injection site. Estimated desalinization cost is $1.50 per thousand gallons of water.

Advantages of deep well injection to surface water storage

Advantages include storage of water close to the point of need (thus maximizing delivery efficiency), elimination of evapotranspiration losses, lowered construction costs, stable temperatures, no recovery costs due to recovery by artesian flow, and no requirements for large areas of land. Deep well injection would salvage water now lost to the ocean or by evapotranspiration, increase the potential fresh water supply, and reduce the demand on the existing sources in

Tentative conclusions

The results of the study indicate that deep well injection, storage, and recovery of fresh water is successful at this project site. With continued use of the aquifer, we feel that large enough amounts of fresh water may be recovered to augment existing supplies and offset projected water deficiencies in the area.

Total funds expended in this feasibility study, including the current injection-recovery cycle, will amount to $310,000. Construction costs for the injection well, monitor well, and pump facility were $250,000. Testing costs were $60,000. Of the total amount, $40,000 was contributed by Palm Beach County and $20,000 by the Florida Sugar Cane League.

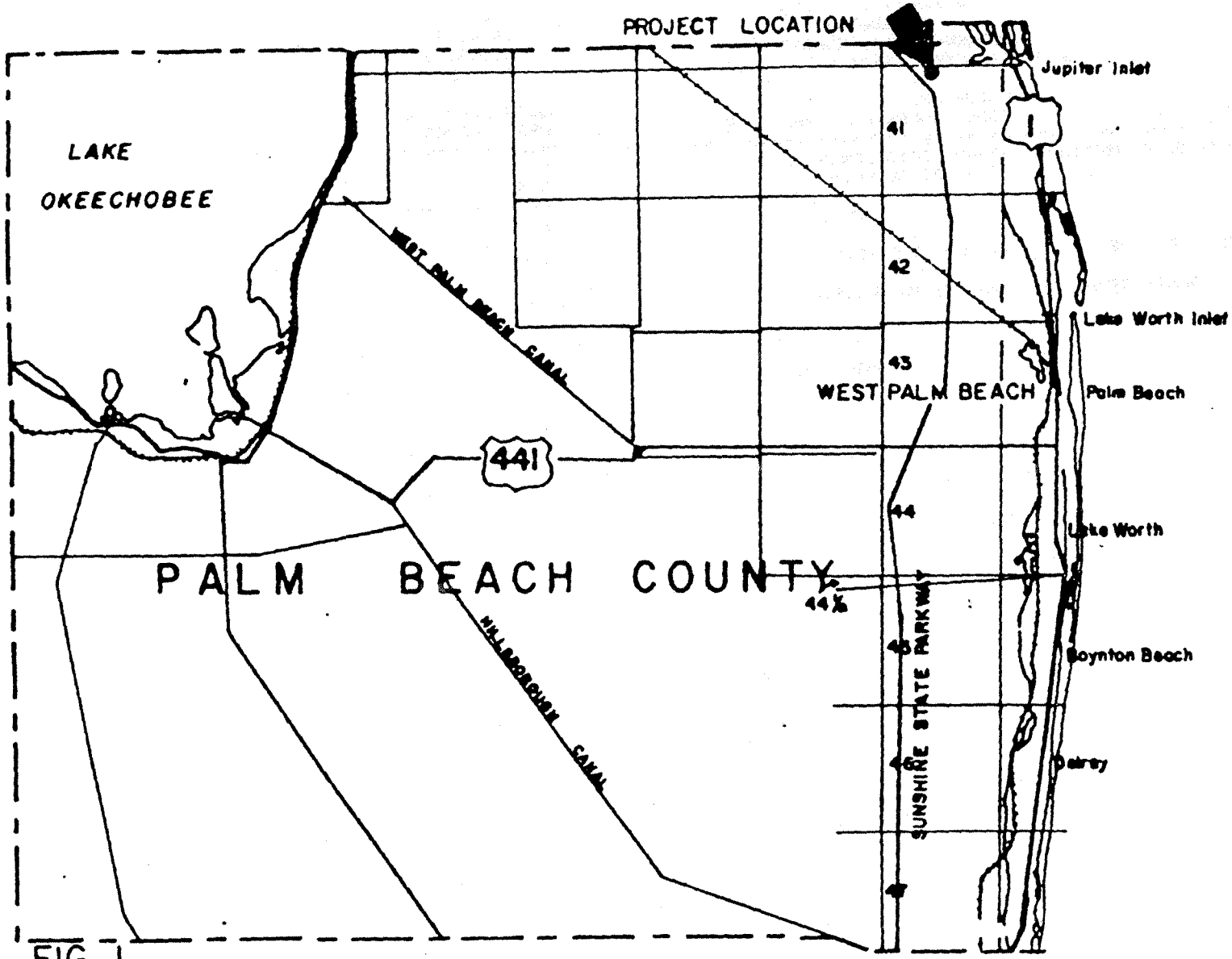
PROJECT LOCATION
Jupiter Inlet
LAKE
OKEECHOBEE
41
42
43
WEST PALM BEACH CANAL
WEST PALM BEACH
Lake Worth Inlet
Palm Beach
441
44
Lake Worth
PALM BEACH COUNTY
44½
45
Boynton Beach
SUNSHINE STATE PARKWAY
HILLSBOROUGH CANAL
46
Delray
47

FIG. 1

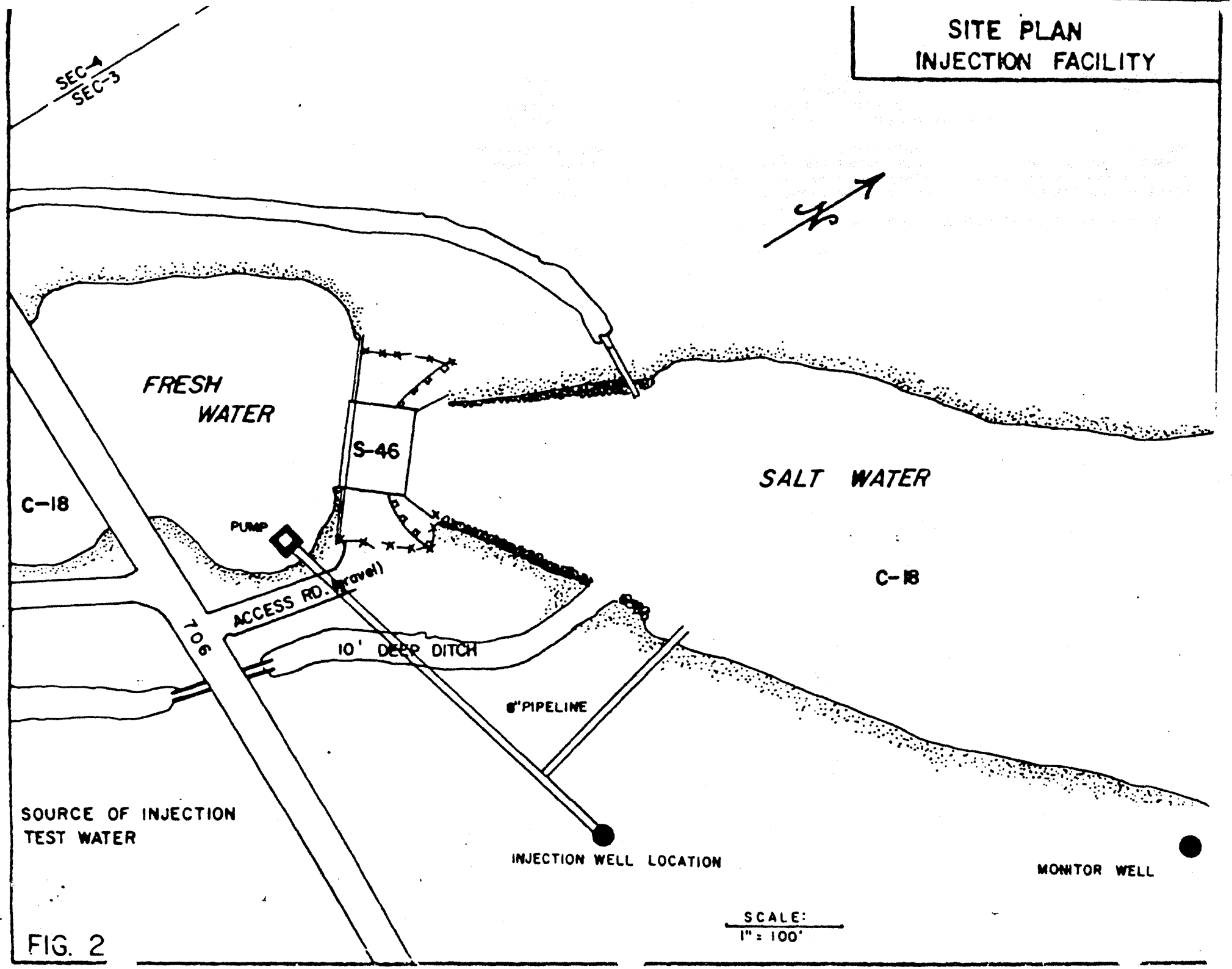
SITE PLAN
INJECTION FACILITY
SEC-4
SEC-3
FRESH
WATER
S-46
SALT WATER
C-18
PUMP
ACCESS RD. (gravel)
706
10' DEEP DITCH
8"PIPELINE
C-18
SOURCE OF INJECTION
TEST WATER
INJECTION WELL LOCATION
MONITOR WELL
SCALE:
1" = 100'

FIG. 2

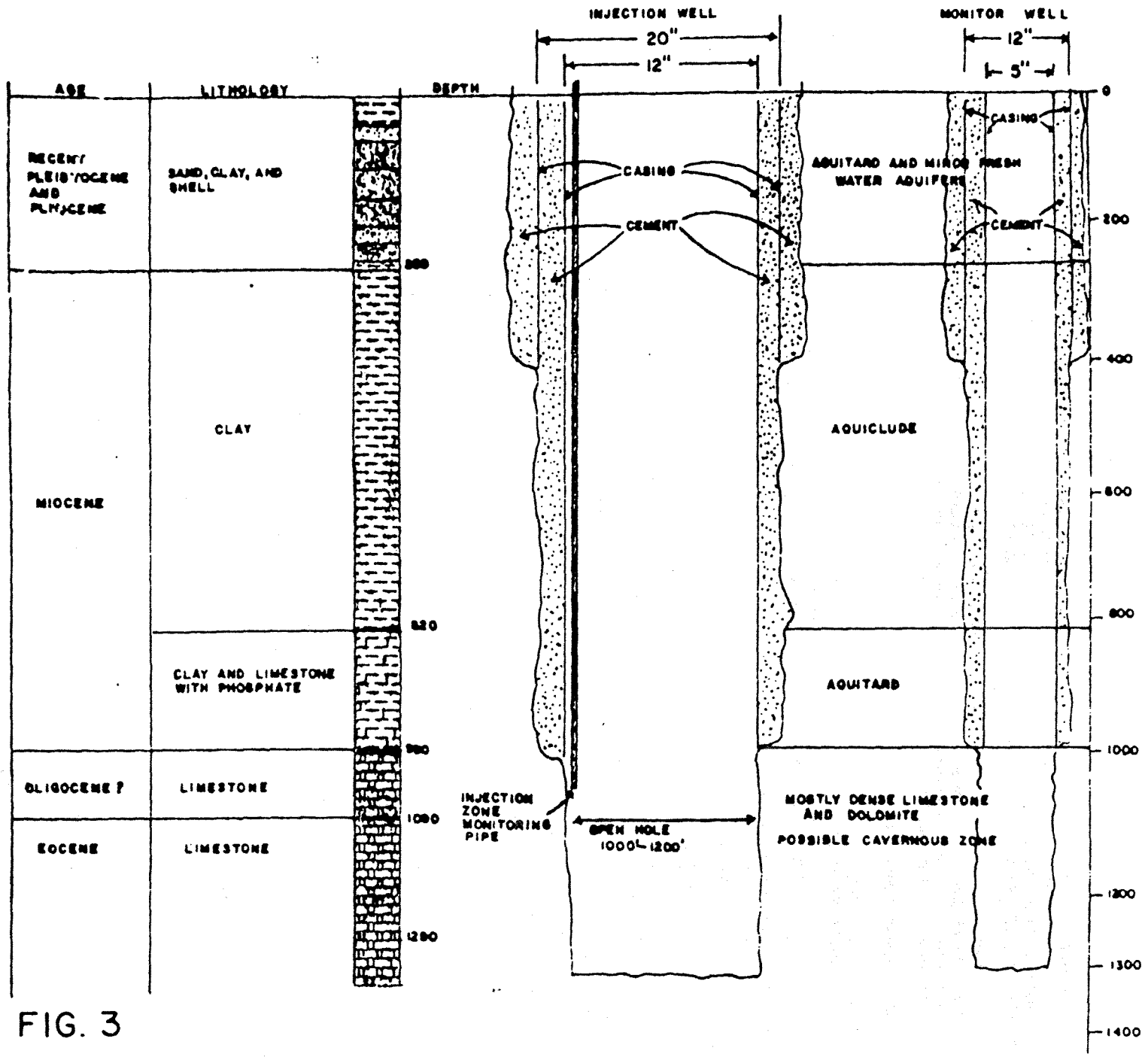
GEOLOGIC LOG AND WELL CONSTRUCTION
INJECTION WELL
20"
12"
MONITOR WELL
12"
5"
AGE
LITHOLOGY
DEPTH
RECENT PLEISTOCENE AND PLIOCENE
SAND, CLAY, AND SHELL
MIOCENE
CLAY
CLAY AND LIMESTONE WITH PHOSPHATE
OLIGOCENE ?
LIMESTONE
EOCENE
LIMESTONE
800
820
980
1080
1280
CASING
CEMENT
AQUITARD AND MINOR FRESH WATER AQUIFERS
AQUICLUDE
AQUITARD
MOSTLY DENSE LIMESTONE AND DOLOMITE
POSSIBLE CAVERNOUS ZONE
INJECTION ZONE MONITORING PIPE
OPEN HOLE 1000'-1200'
0
200
400
600
800
1000
1200
1300
1400

FIG. 3