SEEPAGE INVESTIGATION FOR THE HOLEY LAND

by:
Bruce L. Cutright
Gerry V. Winter
William D. Culberson

Groundwater Division
Resource Planning Department
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT

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SUMMARY AND CONCLUSIONS

Ten exploratory borings were completed in the proposed retention area. In addition 16 permeability tests were performed at 11 sites. From these borings and from falling head permeability tests, 5 hydrogeologic units were defined. The composite transmissivity for these units plus flow through the levee was estimated to be 14,259.9 GPD/foot. The flow through a levee to a boundary canal was calculated for various head differentials from 1 to 10 feet and for an incrementally increasing distance of flow from 150 feet to 177 feet using the modified Darcy equation Q = TIL. These values of seepage ranged from a maximum of 7.77 cfs per mile of levee to 0.66 cfs per mile of levee. Assuming an average head of 5 feet, the average seepage will be 3.53 cfs per mile of levee, or for the total 27.7 mile perimeter of the proposed retention area, the seepage will be 63.19 million gallons/day.

SEEPAGE INVESTIGATION FOR THE HOLEY LAND

The proposed Holey Land retention area is located in southwest Palm Beach County west of Highway 27, east of the Miami Canal and L-23 and north of L-5 (Figure 1). This area comprises approximately 29,000 acres of relatively undisturbed Everglades terrain. The only major man-made influence on this area has been its use as a practice bombing range during and after World War II, and from which it derives its name. The purpose of this investigation was to examine and define the shallow stratigraphy, to determine the water transmitting characteristics of the defined hydrogeologic units, and to quantify seepage that could occur under varying head differentials through and beneath existing and proposed levees to an outside boundary canal.

METHODS OF INVESTIGATIONS

On September 8, 1975, a preliminary site inspection was made to select areas providing ease of access and representative characteristics for relevant interpolation to the entire area of investigation. As a result of this reconnaissance it was concluded that site accessibility for drilling equipment was a major limiting factor in selecting the locations for exploratory drilling and for conducting the necessary field investigations required to meet the objectives of this study. Figure 2 shows the location of the sites selected. Figure 3 shows typical cross sections from the proposed retention area through the levee to the Miami Canal and to the L-5 Borrow Canal. The only areas sufficiently firm enough to support the drill rig were immediately adjacent to the canals. The area on the retention side of the levees was covered with dense brush and 0-6 inches of water underlain by soft plastic muck. From September 15 to September 24 ten exploratory borings were completed. Detailed lithologic logs of the earth materials encountered were made during the drilling operations. One and one-half inch inside diameter PVC pipe was set in six of these holes in order to isolate and test the permeability of a specific stratum. The results of these permeability tests were then extrapolated to areas in which the same geologic materials were encountered.

The permeability tests were conducted using a falling head method outlined by Hvorslev (1951)[1]. An open ended casing was set flush with the bottom of the hole and sealed with a packer to prevent any upward leakage of water around the outside of the casing. The water level within the casing was allowed to come to equilibrium with the surrounding water table. A slug of water was then introduced into the well and the rate of water level decline vs. time was measured. The permeability was then determined by using the following formula:

$$kvh = \frac{2\pi R}{11\ (t_2 - t_1)} \ln \frac{(h_1)}{h_2}$$

where,

R = radius of the well in feet.

h_1= head in feet above static conditions at time t_1 in minutes.

h_2= head in feet above static conditions at time t_2 in minutes.

The accuracy and reproducability of this type of test depends on many factors that are beyond the investigators control in the field. The values derived serve only to indicate the magnitude of the in situ permeability.

This same type of falling head test was conducted on the retention area side of the levees at three separate sites using 8 inch I.D. PVC pipe. These installations were constructed by digging an open hole and placing the 8 inch casing flush with the bottom of the hole. Muck mixed with bentonite was then backfilled tightly around the pipe to provide an effective seal. Water was then added and the change of head with respect to time recorded.

An alternate method for estimating the permeability was also employed on two of the exploratory holes in which no casing was to be installed. This method consisted of boring a hole to the desired depth, removing all cuttings and drill tools, and then adding a slug of water. The rate of change of head with respect to time is then recorded and the permeability determined from the formula:

$$k = \frac{R}{16\ DS} \frac{(H_2 - H_1)}{(t_2 - t_1)} \qquad (2)$$

where,

R = radius of the hole.

D = static depth of water table.

S = shape factor coefficient.

H_1 = Initial head in feet at time t_1 minutes.

H_2 = Final head in feet at time t_2 in minutes.

Again, this method is only useful for estimating the magnitude of the permeability. Conceptual diagrams of all of the permeability tests have been included in the appendix.

Using the measured values for permeability determined by the above methods in the general Darcy equation for groundwater flow, the quantities of underflow can be calculated. However, the Darcy equation:

$Q = KIA$

was modified to:

$Q = TIL$

in order to include transmissivity. The transmissivities of the individual units were then summed to derive the total transmissivity of the geologic materials to a depth of 30 feet. This composite transmissivity term includes the transmissivity of the levee and fill material which overlie the muck. For purposes of calculating the seepage it was assumed that for each one foot reduction in head differential one foot of aquifer thickness having the permeability of the levee and fill material was subtracted from the composite transmissivity term. The following restraints were also assumed for mathematical simplicity:

1) The retention area will be bounded by a levee with an outside boundary canal.
2) The levee slopes will be approximately 1 vertical to 3 horizontal and the minimum distance between the canal and the impounded water will be 150 feet.
3) The maximum head differential between the water level in the canal and the retention area will be 10 feet.
4) The maximum thickness of saturated material influencing the quantity of seepage is 30 feet + 9 feet of levee and fill.
5) When calculating the quantity of seepage, engineering judgment was used to select the most representative value of permeability for each unit. In all cases a conservative figure was selected in order to overestimate rather than underestimate the total seepage.

GEOLOGY

The Holey Land is underlain by a series of limestone, sandy limestone, and clayey sands of Miocene to Holocene age topped by a layer of peaty muck ranging in thickness from 2 to 3 feet. No attempt has been made to separate the material into specific geologic units; rather the boundaries have been selected on the basis of hydrologic properties. Parker, Ferguson, Love and Others (1955)[3] compiled the most extensive description of the geology and hydrology of southeast Florida including the Holey Land area. The U.S. Army Corps of Engineers was responsible for the design of the levees and canals and published the results of their soil boring investigations in Design memorandum Part I (1954)[4]. Figures 4 and 5 are geologic cross sections for L-23 and L-5, respectively, taken as interpreted by the Corps. The boring logs completed for this investigation have been included in the appendix. Figure 6 is a cross section constructed from these borings. The agreement between the Corps of Engineers' interpretation of the subsurface structure and the District's interpretation is relatively good. Emphasis of the present investigation was focused primarily on shallower units than the Corps Boring Program. The minor discrepancies that are apparent between Figures 4 and 5 and Figure 3, are due to the District's selection of unit boundaries based on hydraulic properties and not on strictly lithologic or fossil criteria.

Generally, the shallow (<30 feet) stratigraphy can be separated into five hydrogeologic units based on composition and water transmitting characteristics.

The surface unit is the black peaty muck which varies in thickness from 2 to 3 feet. It is composed largely of organic material, plant roots and a small percentage of sand. On the retention area side of the levees the muck is exposed at the surface, on the opposite side of the levees, adjacent to the canals, the muck is overlain by 1 to 2 feet of fill material and has been compacted considerably. The permeability measured in the muck during the course of this study ($\approx 10^{-2}$ feet/minute) was much higher than expected. However, similar studies by Meyer (1971)[5] on Hoover Dike and by Klein and Sherwood (1961)[6] on Levee 30 found muck permeabilities within the same range. The measured permeability of the buried and compacted muck was 1 to 2 orders of magnitude less than the exposed muck.

Underlying the muck unit is a layer of hard siliceous limestone 2 to 4 feet in thickness. The water transmitting characteristics of this unit are moderate to poor, varying from one to two orders of magnitude less than the overlying uncompacted muck.

Below the muck and limestone units is a heterogenous zone of sands, clayey sands, and sandy limestones extending to a depth of approximately 20 to 22 feet below ground surface. The grouping of these various rock types into one unit was based on their similar water transmitting abilities. In one infiltration test a very low value of permeability at a 12 foot depth was measured. This appeared to be the result of a local lense of clay and was not indicative of an extensive bed. An average permeability of $\approx 10^{-3}$ feet/minute was used for the entire unit.

At a depth of 22-23 feet, immediately below the hetrogenous unit, a zone of high permeability was encountered in Borings Nos. 1, 7, 8, and 9. This one foot thick unit appeared to exist throughout the area of investigation. Inspection of the Corps of Engineers' cross sections does not indicate any unusual zones or lithologies at this depth, however, such a radical increase in permeability dictated that this zone be considered as a separate unit. Attempts to measure the permeability were unsuccessful due to its unusually high water transmitting ability. Field estimates placed the permeability at approximatley 10^{-1} feet/minute.

Underlying this highly permeable zone is a poorly sorted unit composed of silt and fine to medium sand. The exact thickness is unknown but the zone does extend 30 feet or more below ground level and is therefore considered the basal unit of interest. The measured permeability (10^{-5} feet/minute) is low and indicative of the unsorted composition of the unit.

The compacted levee and fill material overlying the muck are composed of material taken from the adjacent canal or borrow. As such, it is an extremely unsorted conglomerate possessing a low permeability. One open hole permeability test was conducted on the levee, resulting in a measured permeability of approximately 10^{-4} feet/minute.

SEEPAGE CALCULATIONS

Table I summarizes the field derived permeabilities used to calculate the flow through the levee. Table II is the calculated values for various head differentials of 1 to 10 feet and the calculated quantity of underflow.

The modified Darcy equation, $Q = TIL$ was used to calculate the seepage out of the retention area. The transmissivity (T) of the material is a product of the permeability and the thickness and is a measure of the quantity of water that will flow through a one foot vertical strip of an aquifer under a hydraulic gradient of one. As the head declines the saturated thickness is reduced and therefore the transmissivity is lowered. The change in transmissivity is dependent on the permeability of the unit being dewatered.

The gradient is the ratio of the vertical change in head with respect to distance. As the level of water in the retention area declines, the distance between the impounded water and the canal increases at the rate of 3 horizontal feet for each vertical foot decline. The relationship between the change in head and the change in transmissivity and gradients introduces a nonlinearity into the Darcy equation. Figure 6 summarizes this relationship in graphic form.

The depth of water that is proposed for the retention area is 3 to 4 feet. If the average water depth in the canal is 1 to 2 feet below ground surface, then an average head differential of 5 feet can be assumed. From Figure 6 it can then be seen that under normal operating conditions, 2.28 million gallons per day per mile of levee or 3.53 cfs per mile of levee will seep out of the proposed retention area. For the proposed perimeter distance of 27.7 miles, the total seepage per day would be 63.19 million gallons.

TABLE 1

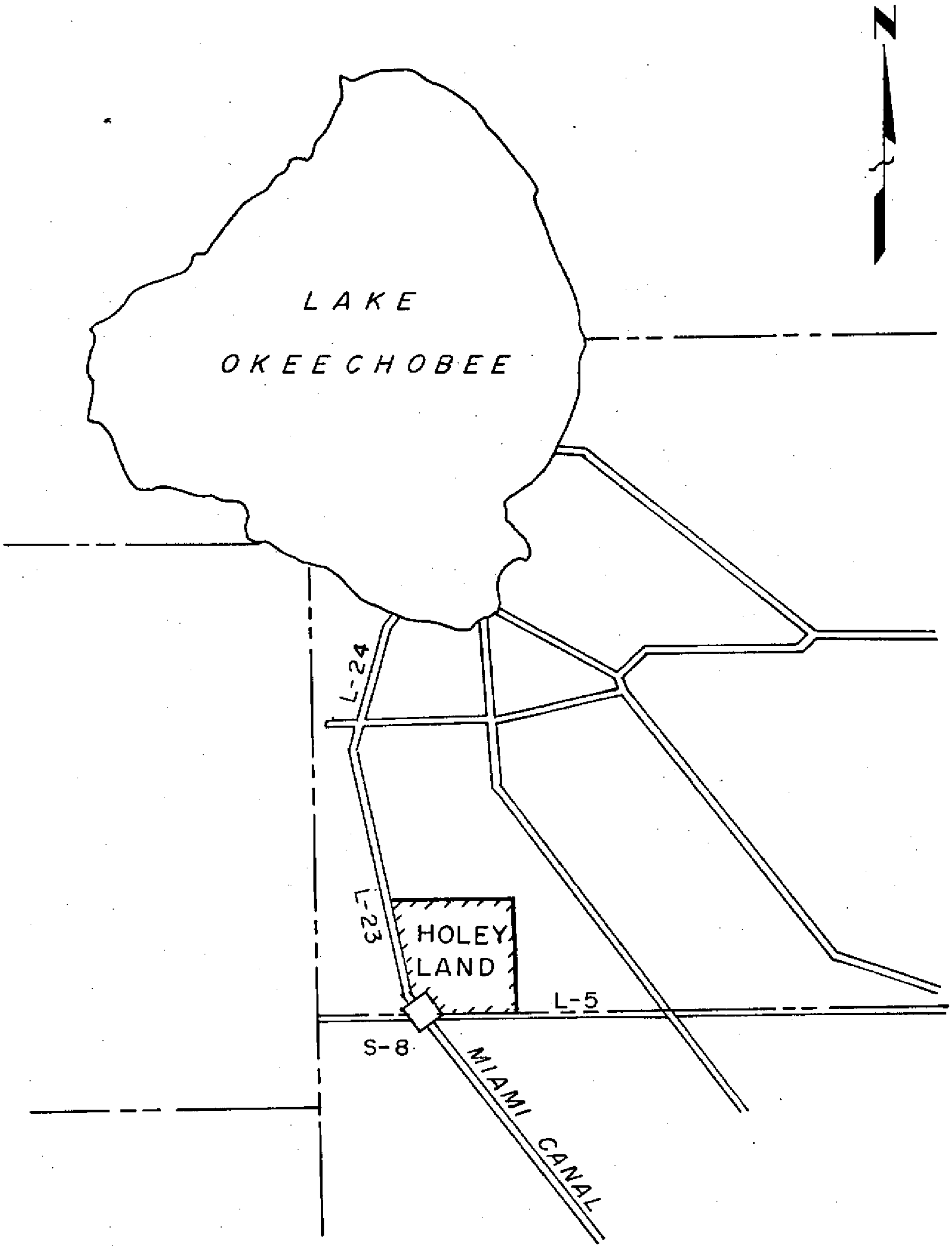
TOTAL DEPTH (FEET)	HYDROGEOLOGIC UNIT	PERMEABILITY (k)	THICKNESS (m)	TRANSMISSIVITY T = (k X m)
+7 to-0.5	Levee Material	1.65 GPD/FOOT^2	7	11.55 GPD/FOOT
-0.5 to 2.5	Fill Material	1.5 GPD/FOOT^2	2	3.0 GPD/FOOT
-2.5 to 6.0	Muck	762 GPD/FOOT^2	3.5	2,669.1 GPD/FOOT
-6.0 to -10	Hard Limestone	90 GPD/FOOT^2	4	360 GPD/FOOT
-10 to -22	Interbedded Sand, Limestone, and Clayey Sand	37 GPD/FOOT^2	12	444 GPD/FOOT
-22 to -23	Highly Permeable Limestone	10,771 GPD/FOOT^2	1	10,771 GPD/FOOT
-23 to -30	Poorly Sorted Silt and Fine to Medium Sand	1.18 GPD/FOOT^2	7	1.26 GPD/FOOT
				= 14,259.9 GPD/FOOT

TABLE 2

SEEPAGE CALCULATIONS FOR HEAD DIFFERENTIALS ACROSS THE LEVEE OF 1 TO 10 FEET

Q = TIL, L = 5,280

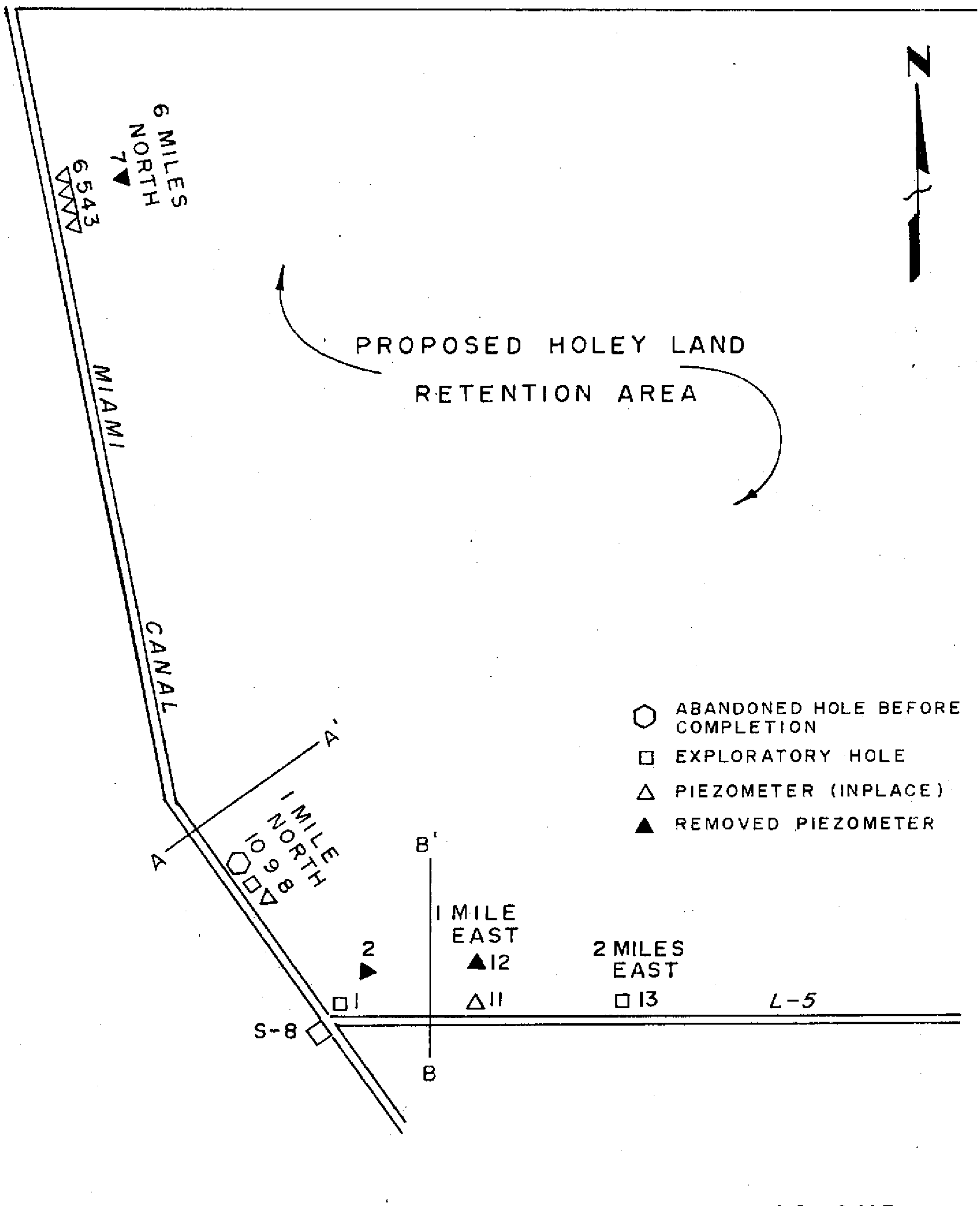
HEAD DIFFERENTIAL	GRADIENT (I)	TRANSMISSIVITY (T) GPD/FOOT	SEEPAGE Q/MILE OF LEVEE	
10	.067	1.42599×10^4	5.02×10^6 GPD	7.77 CFS
9	.059	1.42583×10^4	4.43×10^6 GPD	6.85 CFS
8	.051	1.42566×10^4	3.86×10^6 GPD	5.98 CFS
7	.044	1.42550×10^4	3.31×10^6 GPD	5.13 CFS
6	.037	1.42533×10^4	2.79×10^6 GPD	4.31 CFS
5	.030	1.42517×10^4	2.28×10^6 GPD	3.53 CFS
4	.024	1.42500×10^4	1.79×10^6 GPD	2.77 CFS
3	.018	1.42484×10^4	1.32×10^6 GPD	2.04 CFS
2	.011	1.42469×10^4	8.65×10^5 GPD	1.34 CFS
1	.006	1.42454×10^4	4.25×10^5 GPD	.657 CFS



PROPOSED HOLEY LAND RETENTION AREA

SCALE 1" = 10 Miles

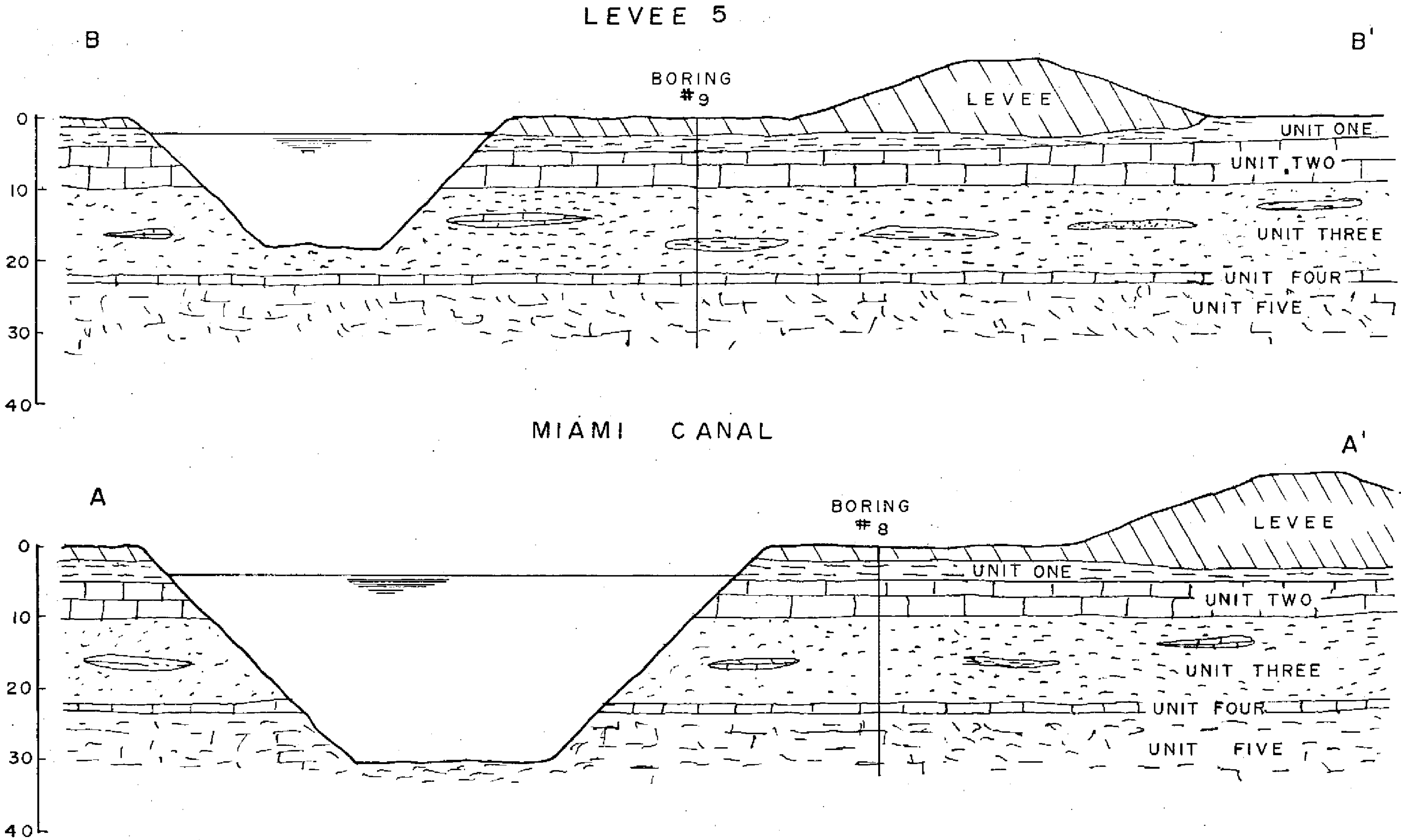
FIGURE 1



LOCATION OF EXPLORATORY BORINGS AND PIEZOMETERS RELATIVE TO S-8 PUMPING STATION

SCALE 1" = 1 Mile

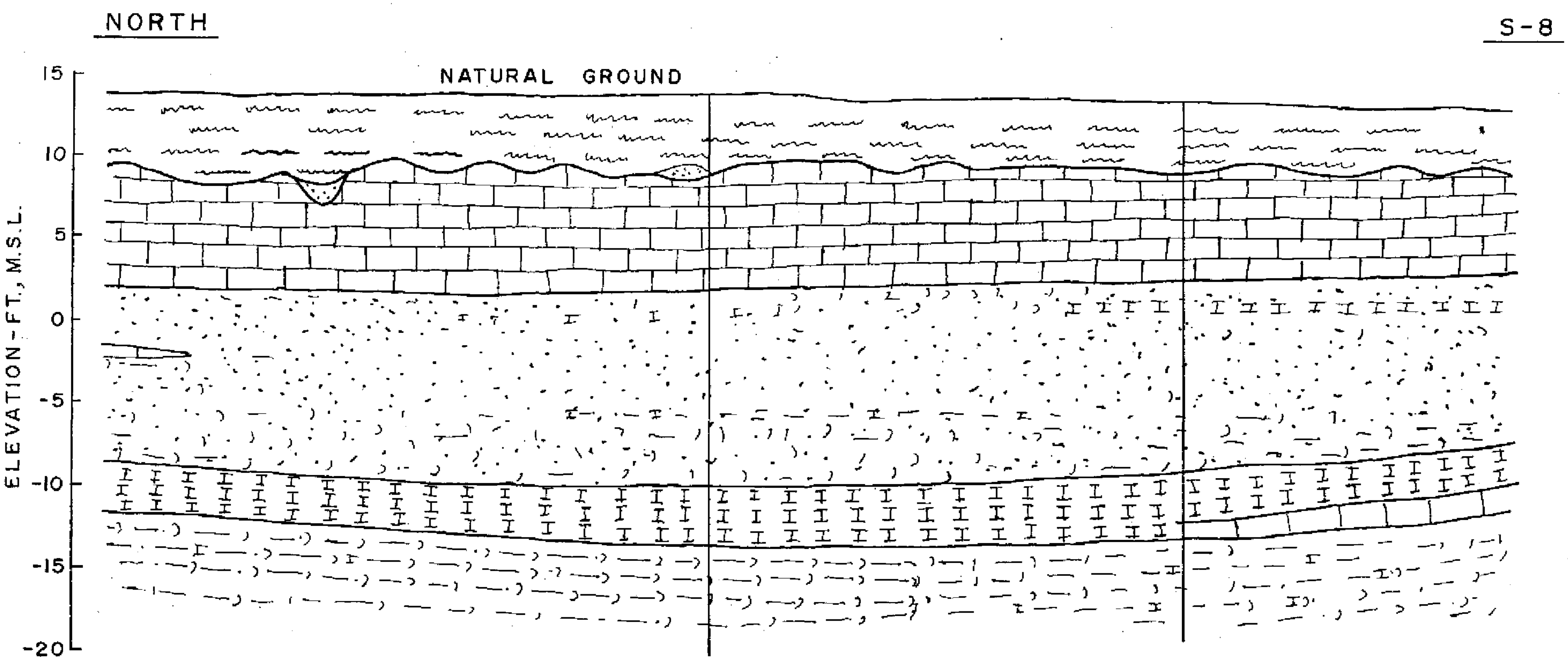
FIGURE 2



TYPICAL CROSS SECTIONS THROUGH MIAMI CANAL AND LEVEE 5 BORROW CANAL

SCALE 1" = 20'

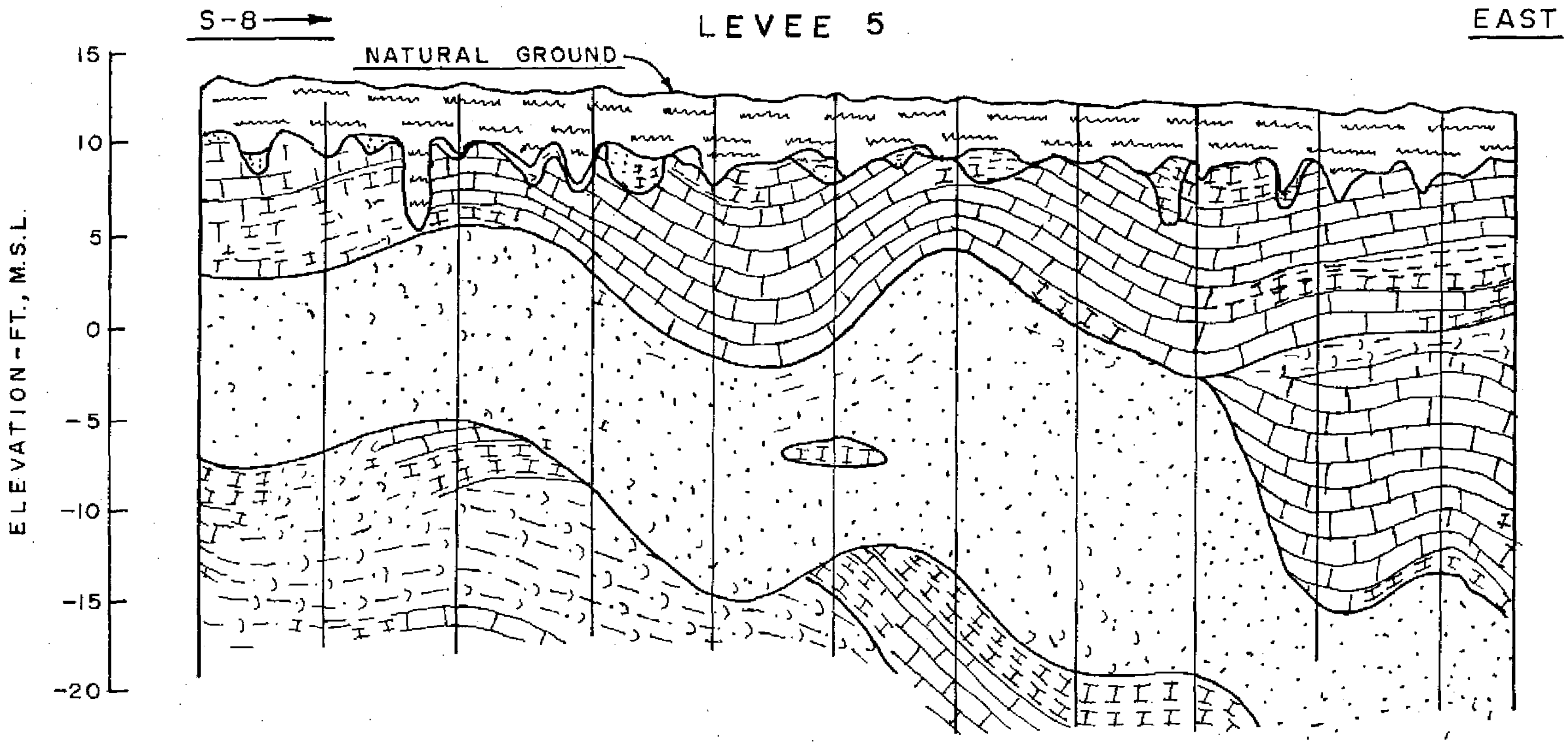
FIGURE 3



CORPS OF ENGINEERS BORING LOG FOR L-23 LEVEE FROM S-8 NORTH

SCALE 1"=2,000'

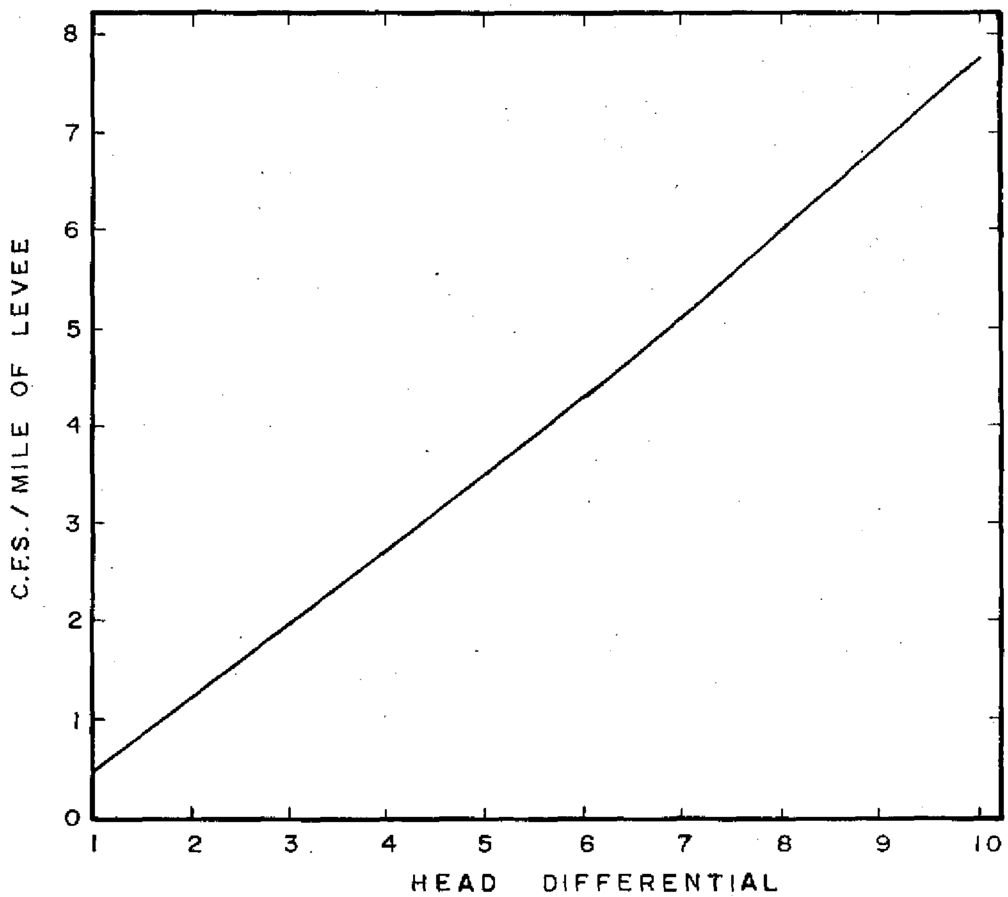
FIGURE 4



CORPS OF ENGINEERS BORING LOG FOR L-5 LEVEE FROM S-8 EAST

SCALE 1"= 4,000'

FIGURE 5



NONLINEAR RELATIONSHIP BETWEEN HEAD DIFFERENTIAL AND SEEPAGE

FIGURE 6

REFERENCES

1) Hvorslev, M. J., 1951, Time Lag and Soil Permeability in Groundwater Observations. Waterways Experiment Station, Vicksburg, Mississippi, Bull No. 26.

2) Navy Design Manual DM-7, March, 1971, Department of the Navy, p. 7-4-9.

3) Parker, Ferguson, Love, and Others, Water Resources of Southeastern Florida, 1955, United States Geological Survey Water Supply Paper 1255, 965 pp.

4) United States Army Corps of Engineers, Design Memorandum for the Central and Southern Florida Flood Control District Project, 1954, Part I, Supplement #20 and #21.

5) Meyer, F. W., Seepage Beneath Hoover Dike, Southern Shore of Lake Okeechobee, Florida. 1971, Florida Geological Survey, Report of Investigations No. 58, 98 pp.

6) Klein, H., and C. B. Sherwood, Hydrologic Conditions in The Vicinity of Levee 30, Northern Dade County, Florida, 1961, Florida Geological Survey Report of Investigations No. 24, Part I, 24 pp.

APPENDIX

A P P E N D I X

BORING #1

Approximately 200 feet northeast of S-8 on the apron of L-5, Borrow Canal.

0 - 4 feet	Fill; silt, sand, limestone pebbles
4 - 9 feet	Top 2 feet is hard siliceous limestone underlain by unsorted silt, sand, and broken limestone fragments
9 - 10 feet	Light brown silt and sand with limestone pebbles
10 - 14 feet	Silt, fine to coarse sand
14 - 19 feet	Light brown silt, sand, and limestone fragments
19 - 24 feet	No return but probably same as above. At 22 foot depth, mud and cuttings flow back into hole, no change in drilling rate but radical increase in permeability

TOTAL DEPTH 24 feet

BORING #2

6 miles north of S-8 along the apron of the Miami Canal approximately 15 feet in from the water's edge.

0 - 1.5 feet	Fill; pebbles, sand, and silt some hard rock
1.5 - 3 feet	Wet sand and limestone pebbles, poorly sorted some hard rock
3 - 5 feet	Black plastic mud (muck), total depth 5.2 feet casing set at 5.2 feet

BORING #3

6 miles north of S-8, 10 feet north of #2.

0 - 5 feet	Same as #1
5 - 6.5 feet	Muck underlain by thin (<6 inches) dark brown sandy clay, grading into light tan silty sand
6.5 - 10 feet	Hard drilling, no return, probably siliceous limestone

Casing set in limestone at 10 foot depth

BORING #4

6 miles north of S-8, 10 feet north of Boring #2.

0 - 10	same as #1 and #2
10 - 14	fairly hard drilling, no return, probably limestone with some thin sand lenses

Total depth 14 feet, however, hole collapsed to 12 foot depth where casing was set.

BORING #5

6 miles north of S-8, 10 feet north of Boring #4.

0 - 11 feet	Same as Nos. 1 through 4
11 - 14 feet	Very easy drilling, no return but probably sand

Casing set at 15 foot total depth.

BORING #6

1 mile north of S-8 on the apron of the Miami Canal, 15 feet from the water's edge.

0 - 3 feet	Fill? sand, clay, and limestone pebbles
3 - 4 feet	Muck
4 - 8 feet	Sandy limestone, high percentage of clay
8 - 11 feet	Sandy-clayey limerock

Casing set at 11 feet.

BORING #7

1 mile north of S-8

0 - 3 feet	Sandy clay, limestone cobbles
3 - 5 feet	Muck
5 - 6 feet	Soft light grey sandy clay, clayey sand
6 - 9 feet	Dark grey brown sandy clay
9 - 11 feet	Medium hard limerock

Continued BORING #7

11 - 14 feet	No return - very easy drilling, probably sand
14 - 19	Same as above until 17', at 17' large boulder encounter, deflecting hole sharply to one side and forcing the abandonment of the hole

BORING #8

1 mile north of S-8, 5 feet south of Boring #7.

0 - 19 feet	Same as Boring #7
19 - 24 feet	Very easy drilling, loose silt and fine to medium sand flowing out of hole until 22', at 22' mud flowed back into hole
24 - 27 feet	Medium hard drilling, no return
27 - 29 feet	Easy drilling, no return

BORING #9

1 mile east of S-8 on L-5 apron approximately 10 feet north of water's edge.

0 - 2 feet	Fill? light grey sandy clayey lime
2 - 5 feet	Muck
5 - 7 feet	Hard Limestone
7 - 10 feet	Loose silt and fine to medium sand
10 - 14 feet	Very soft drilling, no return, probably sand
14 - 19 feet	Same as above

Continued BORING #9

19 - 22 feet	No change in drilling but mud flows back into hole
22 - 23 feet	Very hard layer
23 - 29 feet	Very soft drilling-no return

BORING #10

2 miles east of S-8 on L-5 Levee

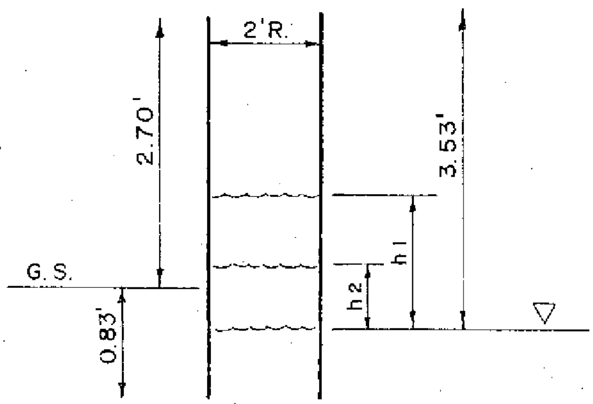
0 - 4 feet	Conglomeratic mixture of limestone sand, silt, and clay relatively low permeability, hard drilling
4 - 9 feet	Same as above, last 3 inches of drill rod covered with muck

PERMEABILITY TESTS FOR HOLEY LAND

SEEPAGE INVESTIGATION

1. Test Location: 200 feet northeast of S-8 pumping station on north side of Levee #5.

Test Set-up: 8 inch I.D. PVC pipe, fully cased hole, casing flush with bottom in muck layer.



Test #1 Parameters

h_1 = 1.26 feet

h_2 = 1.16 feet

Δt = 10 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \frac{h_1}{h_2} = 1.89 \times 10^{-2} \frac{\text{feet}}{\text{min.}}$$

Test #2 Parameters

h_1 = 1.82 feet

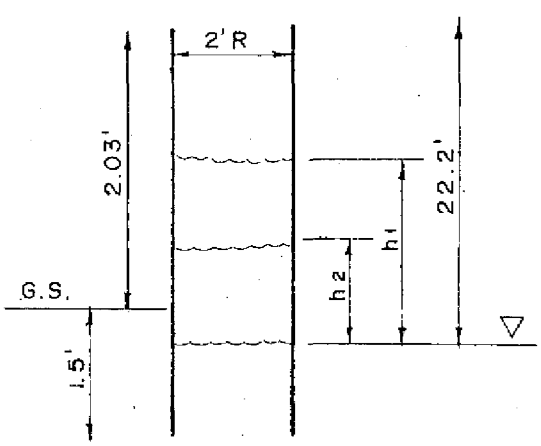
h_2 = 1.33 feet

Δt = 15 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \frac{h_1}{h_2} = 4.78 \times 10^{-2} \frac{\text{feet}}{\text{min.}}$$

2. Test location: 200 feet northeast of S-8 pumping station, 3 feet east of location #1.

Test Set-up: 8 inch I.D. PVC pipe set 1.5 feet deep in muck. Casing set flush with bottom of hole.



Test #3 Parameters

h_1 = 1.07 feet

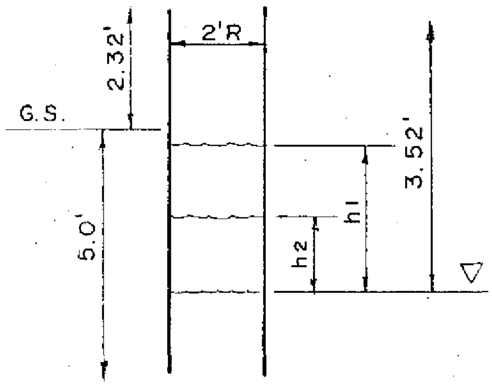
h_2 = 0.56 feet

Δt = 64 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \frac{h_1}{h_2} = 4.78 \times 10^{-2} \frac{\text{feet}}{\text{min.}}$$

3. Test location: Six miles north of S-8 pumping station on east berm of Miami Canal.

Test Set-up: One and one-half inch I.D. PVC pipe set 5 feet at base of compacted muck. Casing is flush with bottom of hole.



Test #4 Parameters

h_1 = 0.44 feet

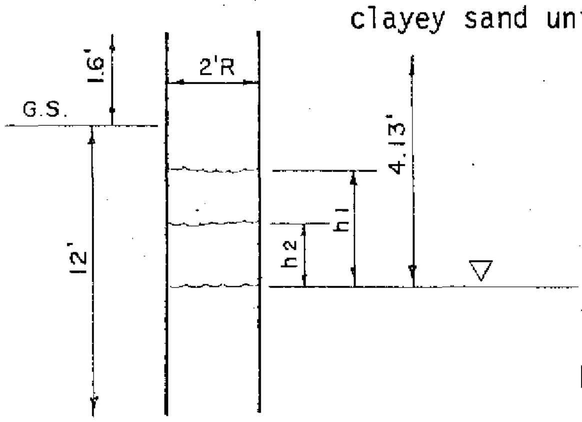
h_2 = 0.38 feet

Δt = 79 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ \ln \frac{h_1}{h_2} = 7.95 \times 10^{-4} \ \frac{\text{feet}}{\text{min.}}$$

4. Test location: Six miles north of S-8 pumping station on east berm of Miami Canal 10 feet north of location #3.

Test Set-up: One and one-half inch I.D. PVC pipe set 12 feet deep in clayey sand unit. Casing flush with bottom of hole.



Test #5 Parameters

h_1 = 3.86 feet

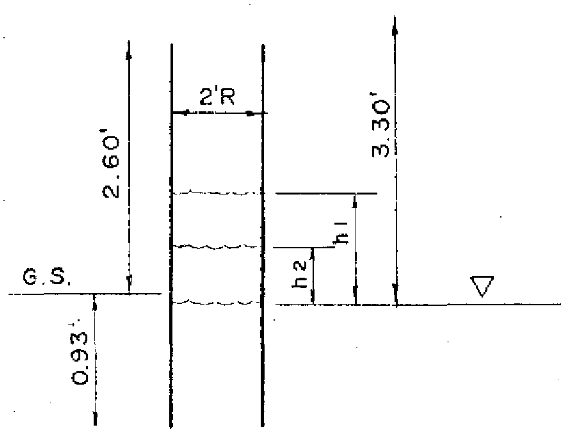
h_2 = 3.80 feet

Δt = 46 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ \ln \frac{h_1}{h_2} = 1.22 \times 10^{-5} \ \frac{\text{feet}}{\text{min.}}$$

5. Test location: Six miles north of S-8 pumping station on the retention area side of the Miami Canal east levee.

Test Set-up: Eight inch I.D. PVC pipe one foot deep in muck unit.



Test #6 Parameters

h_1 = 0.77 feet

h_2 = 0.38 feet

Δt = 46 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ \ln \frac{h_1}{h_2} = 3.5 \times 10^{-2} \ \frac{\text{feet}}{\text{min.}}$$

Test #7 Parameters

h_1 = 0.49 feet

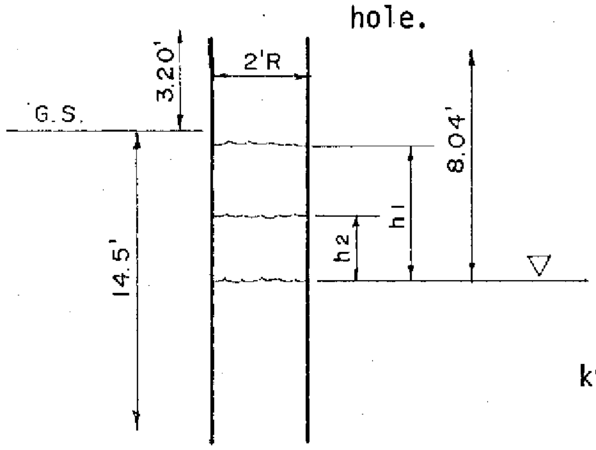
h_2 = 0.12 feet

Δt = 75 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \left[\frac{h_1}{h_2}\right] = 4.29 \times 10^{-2}\ \frac{\text{feet}}{\text{min.}}$$

6. Test location: Six miles north of S-8 pumping station on east berm of Miami Canal 10 feet north of location #3.

Test Set-up: One and one-half inch I.D. PVC pipe set 14.5 feet deep in hetrogenous unit. Casing set flush with bottom of hole.



Test #8 Parameters

h_1 = 6.70 feet

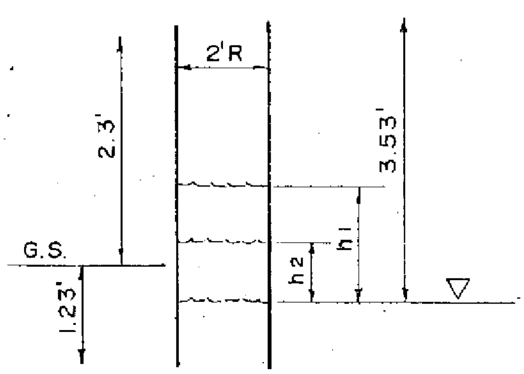
h_2 = 5.86 feet

Δt = 111 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \left[\frac{h_1}{h_2}\right] = 4.29 \times 10^{-2}\ \frac{\text{feet}}{\text{min.}}$$

7. Test location: One mile north of S-8 pumping station on east side of Miami Canal east levee.

Test Set-up: Eight inch I.D. PVC pipe set 1.2 feet deep in muck. Casing set flush with bottom of hole.



Test #9 Parameters

h_1 = 1.28 feet

h_2 = 0.38 feet

Δt = 59 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \left[\frac{h_1}{h_2}\right] = 4.7 \times 10^{-2}\ \frac{\text{feet}}{\text{min.}}$$

Test #10 Parameters

h_1 = 1.28 feet

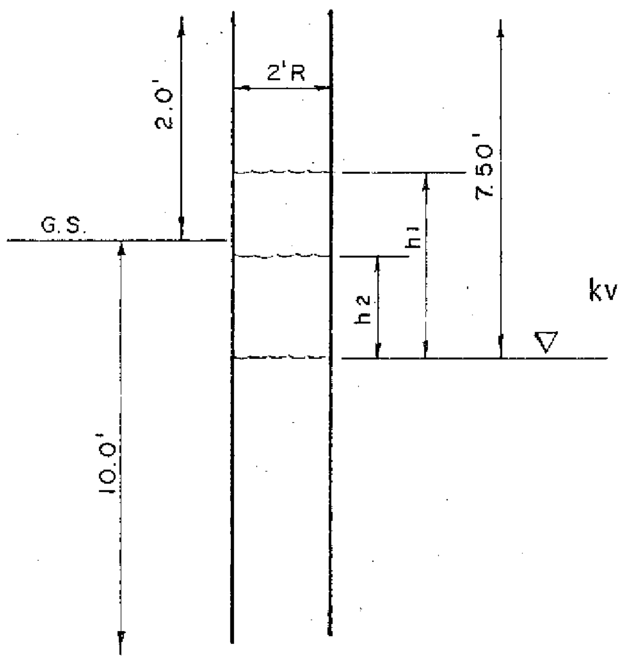
h_2 = 0.46 feet

Δt = 60 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln\left[\frac{h_1}{h_2}\right] = 3.90 \times 10^{-2}\ \frac{\text{feet}}{\text{min.}}$$

8. Test location: One mile north of S-8 pumping station on east berm of Miami Canal.

Test Set-up: One and one-half inch I.D. PVC pipe set 10 feet deep at base of limestone unit. Casing set flush with bottom of hole.



Test #11 Parameters

h_1 = 7.5 feet

h_2 = 5.3 feet

Δt = 15 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln\left[\frac{h_1}{h_2}\right] = 9.92 \times 10^{-3}\ \frac{\text{feet}}{\text{min.}}$$

Test #12 Parameters

h_1 = 5.53 feet

h_2 = 0.99 feet

Δt = 103 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln\left[\frac{h_1}{h_2}\right] = 7.15 \times 10^{-3}\ \frac{\text{feet}}{\text{min.}}$$

9. Test location: One mile east of S-8 on north berm of L-5 borrow canal.

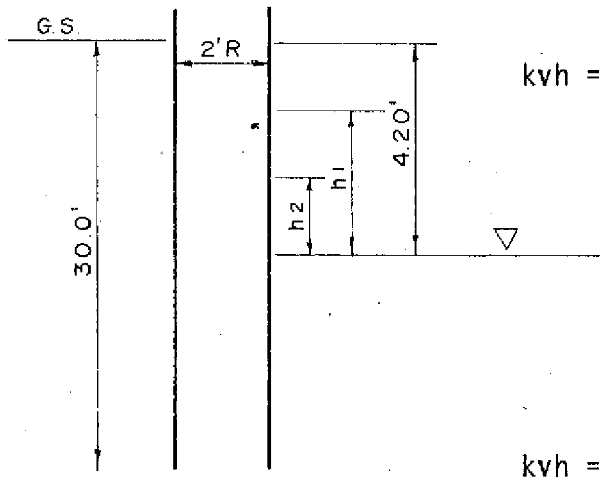
Test Set-up: One and one-half inch I.D. PVC pipe set 30 feet deep in fine grained unit. Casing set flush with bottom of hole.

Test #13 Parameters

h_1 = 1.34 feet

h_2 = 1.16 feet

Δt = 120 minutes



Test #13 (con't)

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \frac{h_1}{h_2} = 4.29 \times 10^{-5} \frac{feet}{min.}$$

Test #14 Parameters

h_1 = 1.50 feet

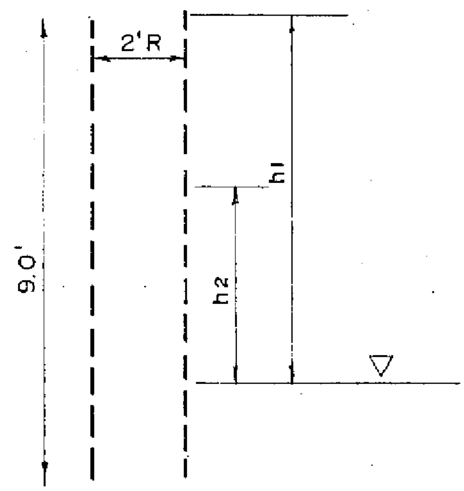
h_2 = 0.16 feet

Δt = 1320 minutes

$$kvh = \frac{2\pi R}{11\ (\Delta t)} \ln \frac{h_1}{h_2} = 6.05 \times 10^{-5} \frac{feet}{min.}$$

10. Test location: Two miles east of S-8 on Levee #5, north side of borrow canal.

Test Set-up: Nine foot deep uncased hole 4 inches in diameter. Base of hole is on top of compacted muck underlying the levee and fill material. Static water level is at 8 foot depth.



Test #15 Parameters

h_1 = 8 feet

h_2 = 5.03 feet

Δt = 10 minutes

R = 2 inches

D = 9 feet

S = 1.5 (Dimensionless)

$$K = \frac{R}{16\ DS} \left(\frac{H_2 - H_1}{\Delta t}\right) = 2.29 \times 10^{-4} \frac{feet}{min.}$$

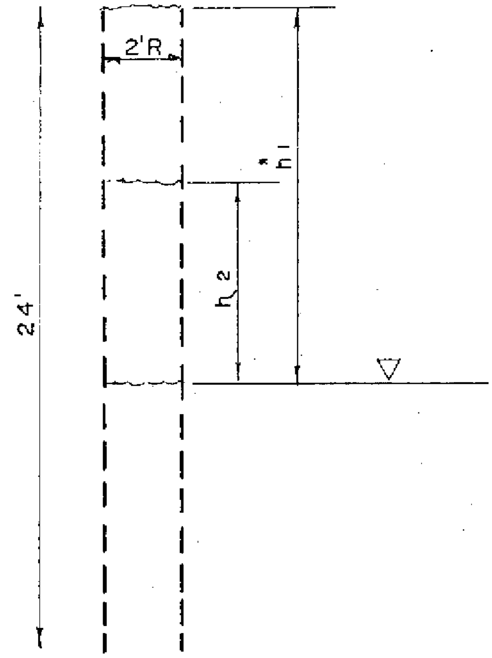
11. Test location: 200 feet northeast of S-8 pumping station at intersection of L-5 Borrow Canal and Miami Canal.

Test Set-up: Uncased four inch diameter hole 24 feet deep. Static depth of water at 4.20 feet.

Test #16 Parameters

h_1 = 4.20 feet

h_2 = 0.0



Test #16 (con't)

Δt = 8 minutes

R = 2 inches

D = 24 feet

S = 1.5

$$K = \frac{R}{16\ DS} \frac{(H_2 - H_1)}{\Delta t} = 1.52 \times 10^{-4} \frac{\text{feet}}{\text{min.}}$$