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MEMORANDUM FOR: Myron Fliegel, Section Leader
Hydrology Section
Geotechnical Branch
Division of Waste Management

FROM: Matthew Gordon
Hydrology Section
Geotechnical Branch
Division of Waste Management

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SUBJECT: ROCKWELL HANFORD OPERATIONS DOCUMENT SD-BWI-TI-109, "... HYDRAULIC TESTING OF MIDDLE SENTINEL BLUFFS..."

Enclosed please find a review of the subject document for your information. The subject document describes a hydraulic test of the current preferred candidate repository horizon. The enclosed review identifies the following problems with the data collection and analysis described in the subject document:

1) BWIP has ignored the fact that the responses to the four steps of the described constant head injection test are inconsistent with theoretical responses. This inconsistency calls the constant head injection test results into question.

2) BWIP chose an average, rather than a conservative value for their "best estimate" of constant head injection test results.

3) The described overpressure pulse test appears to have been analyzed in two ways: one contrary to existing literature on the subject (yielding a low value of transmissivity) and the second consistent with existing literature on the subject (yielding a transmissivity value an order of magnitude higher). The results of the second (correct, based on existing literature) analysis were thrown out, apparently because the yielded transmissivity was higher than expected.

4) No storativity values were reported.

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5) The BWIP best estimate of horizontal hydraulic conductivity assumes that the entire test interval contributes uniformly to the transmissivity. This is a non-conservative assumption that requires further justification.

I recommend that the review be transmitted to WMRP for possible transmittal to BWIP and other interested parties.

Original Signed By

Matthew Gordon
Hydrology Section
Geotechnical Branch
Division of Waste Management

Enclosure:
As stated

OFC	:WMGT MG kd	:	:	:	:	:
NAME	:MGordon	:	:	:	:	:
DATE	:84/12/10	:	:	:	:	:

WASTE MANAGEMENT DOCUMENT REVIEW

DOCUMENT: Preliminary Results of Hydraulic Testing of the Middle Sentinel Bluffs Basalt Colonnade/Entablature (3175-3244) feet at Borehole RRL-2, Rockwell Hanford Operations (RHO), SD-BWI-TI-109, released January 1983.

FILE CODE: 3101.2, 3101.5, 3109.2, 3109.3

DATE REVIEW COMPLETED: December 7, 1984

REVIEWER: Matthew J. Gordon

SUMMARY OF DOCUMENT: [Quoted from document abstract]

"This report presents preliminary results and description of hydrologic test activities for a section of Middle Sentinel Bluffs [now called Cohassett] basalt colonnade/entablature at borehole RRL-2 over the depth interval 3175 to 3244 feet. Hydrologic tests conducted include a four-step constant head injection test and one over-pressure pulse test. Preliminary results from hydrologic tests performed indicate transmissivity values ranging between 3.2 x 10-6 and 5.5 x 10-5 ft^2/day with [BWIP's] assigned best estimate of 4.4 x 10-6 ft^2/day. [BWIP's] best estimate of equivalent hydraulic conductivity, based on a thickness for the effective test interval of 69 feet, is 6.4 x 10-8 feet/day."

SIGNIFICANCE OF INFORMATION TO NRC PROGRAM:

The zone tested is the currently preferred candidate horizon for a HLW facility at BWIP, and RRL-2 is the closest hole to the planned location of shaft drilling for underground facility construction. The hydraulic properties measured in this zone are critical parameters for repository performance assessment.

In this review, several problems with the data collection and analysis techniques are identified which have a significant negative impact on the reliability of the test results and conclusions as reported by BWIP.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

Comments on four-step constant head injection test

The constant head injection test, described by Zeigler (1976), yields test zone transmissivity through a calculation which relates the measured steady state inflow of water required to maintain a constant imposed head in the borehole to the imposed head as a function of transmissivity. BWIP performed this test in four steps, i.e., they imposed four different constant heads and measured the corresponding constant flow rates needed to maintain these heads.

BWIP does not indicate the temperature of injected fluid; this could make their estimates of imposed heads erroneous, as NRC has pointed out in reference to other tests at BWIP (c.f., Wright to Olson, May 25, 1984). Regardless of this point, however, the results presented by BWIP in Table 2 of the subject report (attached) indicate substantial irregularities in these tests. Figure 1 shows the calculated transmissivities as a function of the steady-state flow rates for each step. These should theoretically plot along a straight horizontal line. Figure 2 shows the steady flow rate as a function of the imposed head. This should plot as a straight line of positive slope with flow (Q)=0 intercept at imposed head (H)=0. However, this is not the case for the BWIP tests. For example, the BWIP tests indicate that the lowest head imposition required the highest flow rate to maintain, which is contrary to the theoretical response. The only portion of the plot which even has positive slope is section B; however, this section has a Q-intercept (H=0) at -1.56e-5 gpm, rather than zero.

BWIP uses the arithmetic mean transmissivity value calculated by these four tests to get a best estimate for the constant head injection tests. It is not clear why they did not use the highest (most conservative) value as their best estimate as they have done occasionally in other interval reports. The high value (1.1e-5 ft^2/d) is twice the assigned best estimate (5.5e-6 ft^2/d) for these tests.

<u>Comments on overpressure pulse test</u>

After the constant head injection tests, an "overpressure pulse test" was performed. As BWIP notes, "the recovery pressures monitored are in response to a constant head injection test and, therefore, would appear to violate the test specification for a "sudden" pressurization and shut-in as described by Bredehoeft and Papodopulos (1980)." BWIP claims that the difference is expected to have a minor effect on pressure response for zones of transmissivity less than 10-4 ft^2/d. They provide no analysis or reference to support this assumption; however, based on the relatively long duration of the recovery to shut-in pressurization compared to the duration of the constant head injection test, this assumption appears reasonable.

The BWIP pulse test is analyzed in two ways in the document. BWIP describes the first case as one where the initial pre-test (prior to filling the open borehole with water) head in the unit is assumed to be known. They incorrectly identify this "method" as the Bredehoeft and Papodopulos (1980) analytical method. The second analytical case is described as one where the initial head is unknown. They identify this "method" as the Neuzil (1982) analytical method. Actually, neither the Bredehoeft and Papodopulos (1980) nor the Neuzil (1982) methods require knowledge of pre-test head.

For case one, BWIP assumes that the pressure pulse is equal to the sum of the pressure imposed by filling the open-hole test system and the pressure imposed by the overpressure pulse; and for the second case they assume that the pulse is equal only to the overpressure pulse. The Bredehoeft and Papodopolus (1980) as well as the Neuzil (1982) methods assume the pressurized response to be due predominately to the overpressure pulse, since near-equilibrium conditions are considered to apply after filling the open borehole, and directly prior to pressurization and shut-in. Bredehoeft and Papodopulos (1980) and Neuzil (1982) consider that the slow decline of the water-filled open-hole system can simply be extrapolated linearly past the shutting-in of the well. (This assumption is discussed below.) Therefore, BWIP's case one is inconsistent with the referenced analytical procedure, and the second case is the correct analytical method in this respect. The two analysis methods yield different transmissivities: Method ("case") one yields 3.2e-6 ft^2/d, while method ("case") two yields 5.5e-5 ft^2/d. BWIP explains that the "difference [in results] is not completely understood; however, it may be attributable to not fully compensating for the effects of filling the test system in the analysis procedure for case two." For case two, the pressure response caused by filling the open test system with water (determined to be -4.46e-4 psi/minute) was subtracted from the pulse response, as it should be according to Bredehoeft and Papodopulos (1980). The only question BWIP should be asking in analyzing the test with method ("case") two is whether the -4.6e-4 psi/minute trend represents near-equilibrium conditions. In any case, the case one analysis is incorrect, based on Bredehoeft and Papodopulos (1980) and Neuzil (1982).

BWIP states that "due to [the "uncertainty" in case two], results of analyzing the overpressure pulse test for case two are not included in the best estimate calculation of transmissivity." I consider that the case one analysis should have been rejected, rather than the case two analysis, because an incorrect analytical procedure was followed, according to the existing literature referenced by BWIP.

I must admit that Bredehoeft and Papodopulos' (1980) and Neuzil's (1982) assumption that even slow water level declines prior to pressurization may be separated from the pulse response in the manner that they describe does seem questionable to me. That is, direct extrapolation of a water level decline past shut-in, when the response will be due to decompression of a small volume of water rather than release of water from well storage, does not seem intuitively correct. However, these papers are identified by BWIP as the basis for BWIP's test procedure and analysis, and have been accepted by the technical community after their publication in a major peer review journal. The issue, therefore, is whether BWIP is correctly following the testing and analytical procedures that they identify in the document. A different analytical procedure that they wish to follow would be a new procedure which should be documented, substantiated, and accepted by the technical community.

It should also be mentioned that no storativity values are reported for either case one or case two. Calculated storativity values should be reported along with all calculated transmissivity values for tests which yield these values. NRC recognizes that these storativity values are unreliable; however, they are part of the test analysis which may help to establish the validity of the result and should be included in the test analysis documentation. For example, if the storativity necessary to match a type curve is "unreasonable" (e.g., greater than about 1e-3 for a tight unit), then certainly this calls the associated transmissivity value into question.

Comments on choice of "best estimates" for transmissivity and hydraulic conductivity

Since the constant head injection test results are erratic and inconsistent with theory, and since the case one analysis of the overpressure pulse test was performed incorrectly while the case two analysis was rejected even though it was performed correctly, according to methods described in the existing literature, I consider the best estimate of transmissivity from these tests would be the case two pulse test result, 5.5e-5 ft^2/d, rather than the BWIP best estimate of 4.4e-6 ft^2/d.

BWIP assumes that the entire 69 foot test interval contributes uniformly to the transmissivity (T). By dividing their "best estimate" T by the entire thickness, they arrive at a "best estimate" of horizontal hydraulic conductivity (K) of 6.4e-8 ft/day. Due to uncertainty in the contributing zone thickness, K should be reported as a range rather than a single value. If the contributing zone were much thinner than the assumed 69 foot thickness, a correspondingly higher K would be effective for that zone. It is these high-K zones which may provide the major conduits for groundwater flow.

ACTION TAKEN: None.

ACTION RECOMMENDED: None.

Matthew Gordon 12/10/84

Matthew Gordon
Hydrology Section
Geotechnical Branch
Division of Waste Management

References:

Bredehoeft, J., and S. Papadopulos, "A Method for Determining the Hydraulic Properties of Tight Formations," Water Resources Research, 16(1), February, 1980.

Neuzil, C., "On Conducting the Modified 'Slug' Test in Tight Formations," Water Resources Research, 18(2), April, 1982.

Wright, R., (NRC), Letter to O. L. Olson (DOE), May 25, 1984, File 3101.2, U.S. Nuclear Regulatory Commission, Division of Waste Management Document Control Center, Mail Stop SS-623, Washington, D.C.

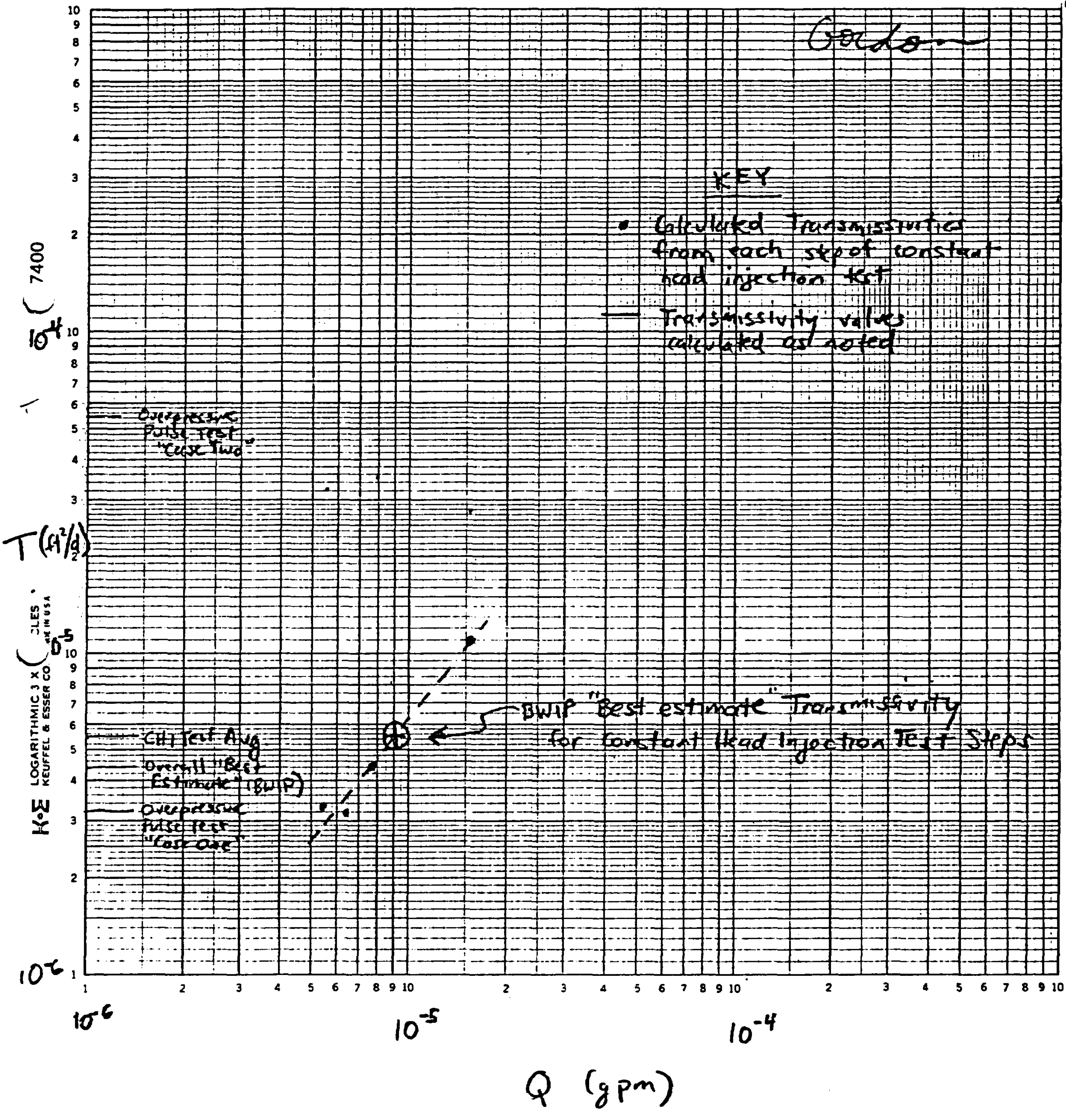
Ziegler, T., "Determination of Rock Mass Permeability," Technical Report S-76-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., January, 1976.

Table 2. Summary of Hydraulic Property Values Determined at Various Injection Steps During the Constant Head Injection Test for the Middle Sentinel Bluffs Basalt Colonnade/Entablature at Borehole RRL-2.

INJECTION STEP	STEP DURATION (min.)	Hg (ft)	Ho (ft)	$\bar{Q}$ (gpm)	r_w (ft)	R (ft)	Transmissivity (ft^2/day)
#1	62	240.2	38.1	1.53×10^{-5}	0.124	69	1.1×10^{-5}
#2	104	240.2	72.1	5.55×10^{-6}	0.124	69	3.4×10^{-6}
#3	117	240.2	109.3	7.90×10^{-6}	0.124	69	4.4×10^{-6}
#4	52	240.2	146.1	6.42×10^{-6}	0.124	69	3.2×10^{-6}
						Average	5.5×10^{-6}
						Best Estimate	5.5×10^{-6}

Hg + Ho = total imposed head

Figure 1. Flowrate vs. transmissivity for each step.
TI-109 Cohassett Interior
4 Step Injection Test



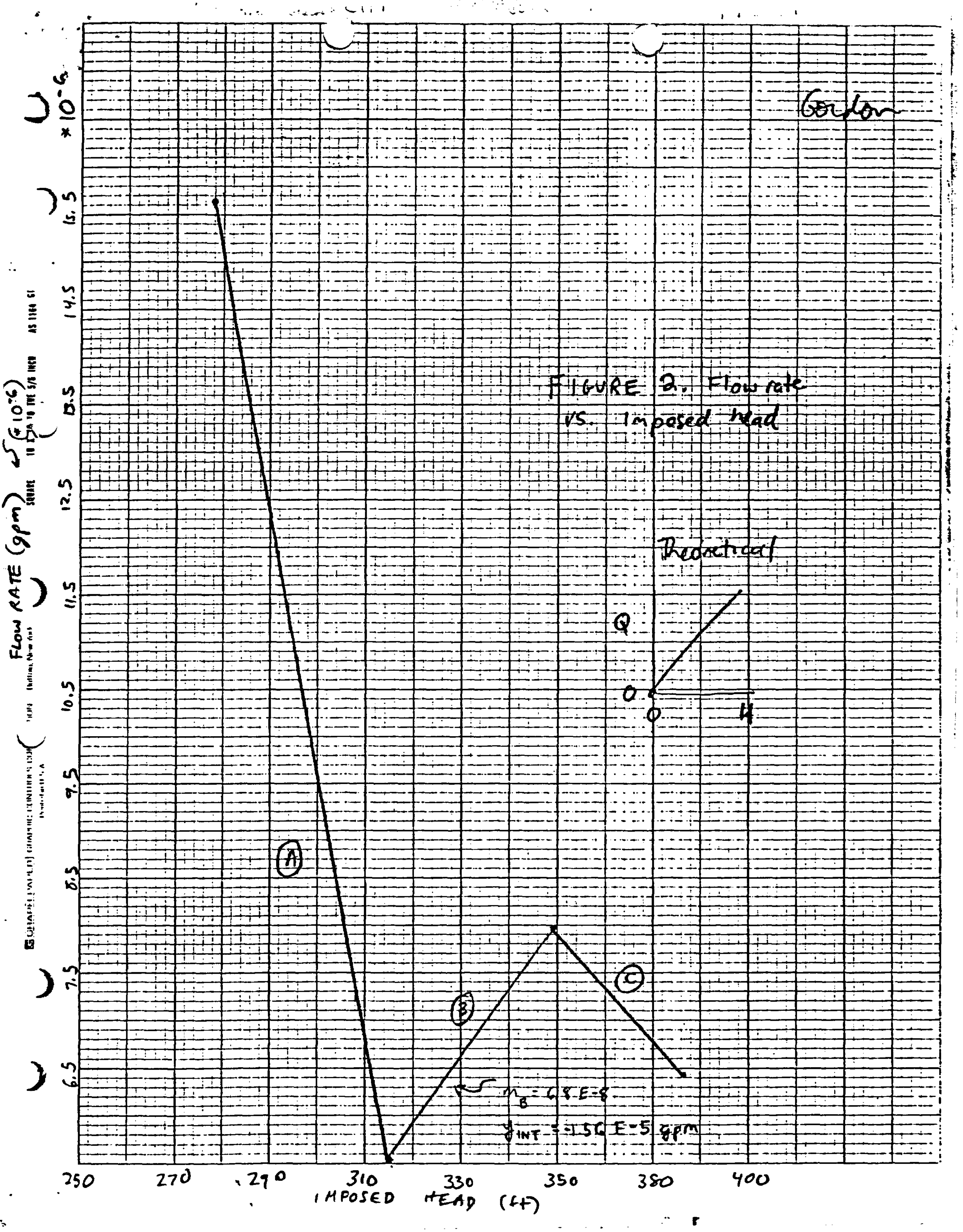

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FIGURE 2. Flow rate vs. Imposed head
Theoretical
Q
0
0
H
A
B
C
m_B = 6.8 E-8
y_{INT} = -1.56 E-5 gpm
FLOW RATE (gpm) (*10^-6)
*10^-6
15.5
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
250
270
290
310
330
350
380
400
IMPOSED HEAD (ft)