Office of Environmental Management – Grand Junction

MOAB UTAH

UMTRA Project

Revised Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

Attachment 3: Ground Water Hydrology

June 2007

U.S. Department of Energy

Office of Environmental Management

Work Performed Under DOE Contract No. DE-AC01-02GJ79491
for the U.S. Department of Energy Office of Environmental Management.
Approved for public release; distribution is unlimited.

Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

Attachment 3: Ground Water Hydrology

Work performed under DOE Contract No. DE–AC01–02GJ79491
for the U.S. Department of Energy Office of Environmental Management.

Calculation Cross-Reference Guide

Location	Calculation Number	Calculation Title
Attachment 1: Disposal Cell Design Specifications		
Appendix A	MOA-02-08-2006-5-19-01	Freeze/Thaw Layer Design
Appendix B	MOA-02-08-2006-5-13-01	Radon Barrier Design Remedial Action Plan
Appendix C	MOA-02-05-2007-5-17-02	Slope Stability of Crescent Junction Disposal Cell
Appendix D	MOA-02-05-2007-3-16-01	Settlement, Cracking, and Liquefaction Analysis
Appendix E	MOA-02-09-2005-2-08-01	Site Drainage – Hydrology Parameters
Appendix F	MOA-02-06-2006-5-08-00	Crescent Junction Site Hydrology Report
Appendix G	MOA-02-04-2007-5-25-02	Diversion Channel Design, North Side Disposal Cell
Appendix H	MOA-02-08-2006-6-01-00	Erosional Protection of Disposal Cell Cover
Appendix I	MOA-01-06-2006-5-02-01	Volume Calculation for the Moab Tailings Pile
Appendix J	MOA-02-08-2006-5-03-00	Weight/Volume Calculation for the Moab Tailings Pile
Appendix K	MOA-01-08-2006-5-14-00	Average Radium-226 Concentrations for the Moab Tailings Pile
Attachment 2: Geology		
Appendix A	MOA-02-04-2007-1-05-01	Site and Regional Geology – Results of Literature Research
Appendix B	MOA-02-04-2007-1-01-01	Surficial and Bedrock Geology of the Crescent Junction Disposal Site
Appendix C	MOA-02-04-2007-1-06-01	Site and Regional Geomorphology – Results of Literature Research
Appendix D	MOA-02-04-2007-1-07-01	Site and Regional Geomorphology – Results of Site Investigations
Appendix E	MOA-02-04-2007-1-08-01	Site and Regional Seismicity – Results of Literature Research
Appendix F	MOA-02-04-2007-1-09-02	Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration
Appendix G	MOA-02-04-2007-1-02-01	Photogeologic Interpretation
Attachment 3: Ground Water Hydrology		
Appendix A	MOA-02-02-2006-2-07-00	Saturated Hydraulic Conductivity Determination of Weathered Mancos Shale
Appendix B	MOA-02-03-2006-2-10-00	Field Permeability "Bail" Testing
Appendix C	MOA-02-03-2006-2-06-00	Field Permeability "Packer" Testing
Appendix D	MOA-02-04-2006-2-03-00	Hydrologic Characterization – Ground Water Pumping Records
Appendix E	MOA-02-05-2006-2-13-00	Hydrologic Characterization – Vertical Travel Time to Uppermost (Dakota) Aquifer
Appendix F	MOA-02-02-2007-3-01-00	Geochemical Characterization – Radiocarbon Age Determinations for Ground Water Samples Obtained From Wells 0203 and 0208
Appendix G	MOA-02-06-2007-2-14-00	Hydrologic Characterization – Lateral Spreading of Leachate
Attachment 4: Water Resources Protection		
Appendix A	MOA-02-06-2006-5-24-00	Material Placement in the Disposal Cell
Appendix B	MOA-02-06-2006-3-05-00	Geochemical Attenuation and Performance Assessment Modeling
Attachment 5: Field and Laboratory Results, Volume I		
Appendix A	MOA-02-03-2006-1-03-00	Corehole Logs for the Crescent Junction Site
Appendix B	MOA-02-03-2006-1-11-00	Borehole Logs for the Crescent Junction Site
Appendix C	MOA-02-03-2006-1-04-00	Geophysical Logs for the Crescent Junction Site
Appendix D	MOA-02-03-2006-1-10-00	Test Pit Logs for the Crescent Junction Site
Appendix E	MOA-02-03-2006-4-01-00	Geotechnical Properties of Native Materials
Appendix F	MOA-01-06-2006-5-22-00	Cone Penetration Tests for the Moab Processing Site
Appendix G	MOA-02-05-2006-4-07-00	Seismic Rippability Investigation for the Crescent Junction Site
Appendix H	MOA-02-03-2007-3-04-01	Background Ground Water Quality for the Crescent Junction Site
Appendix I	MOA-01-08-2006-4-08-00	Boring and Test Pit Logs for the Moab Processing Site
Appendix J	MOA-01-08-2006-4-09-01	Geotechnical Laboratory Testing Results for the Moab Processing Site
Appendix K	MOA-02-04-2007-4-03-01	Supplemental Geotechnical Properties of Native Materials
Attachment 5: Field and Laboratory Results, Volume II		
Appendix L	MOA-02-08-2006-1-06-00	Compilation of Geologic and Geophysical Logs
Appendix M	N/A	Radiological Assessment for Non-Pile Areas of the Moab Project Site
Appendix N	MOA-02-05-2007-4-04-00	Supplemental Geotechnical Properties of Tailings Materials from the Moab Processing Site

Attachment 3

Table of Contents

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-02-2006-2-07-00 **Discipline:** Geotechnical/Hydrological **No. of Sheets:** 10
Doc. No.: X0136700

Location: Attachment 3, Appendix A

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Saturated Hydraulic Conductivity Determination of Weathered Mancos Shale

Sources of Data:

See Appendix A

Sources of Formulae and References:

Bouwer, H. 1966. "Rapid field measurement of air-entry value and hydraulic conductivity of soils as significant parameters in flow systems analysis," in *Water Resources Research*, 2(4), pp. 729–738.

DOE (U.S. Department of Energy), 1994. "In Situ Testing to Determine Field-Saturated Hydraulic Conductivity of UMTRA Project Disposal Cell Covers, Liners, and Foundation Areas Special Study," DOE/AL/62350-100, prepared by Jacobs Engineering Group, Inc., Albuquerque, New Mexico, February.

Youngs, E.G., P.B. Leeds-Harrison, and D.E. Elrick, 1995. "The Hydraulic Conductivity of Low Permeability Wet Soils Used as Landfill Lining and Capping Material: Analysis of Pressure Infiltrometer Measurements," *Soil Technology*, Vol. 8, pp. 153–160.

Waugh, W.J., S.J. Morrison, G.M. Smith, M. Kautsky, T.R. Bartlett, C.E. Carpenter, and C.A. Jones, 1999. *Plant Encroachment on the Burrell, Pennsylvania, Disposal Cell: Evaluation of Long-Term Performance and Risk*, GJO-99-96-TAR, Environmental Sciences Laboratory, U.S. Department of Energy, Grand Junction, Colorado.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: [signature] 5-31-07
Name Date

Checked by: [signature] 5/30/07
Name Date
[signature] 31 May 07
Name Date
[signature] 5/31/07
Name Date
[signature] 5/31/07
Name Date

Approved by: [signature] 5/31/07
Name Date

No text for this page

Problem Statement:

Determine the saturated hydraulic conductivity of the weathered Mancos Shale (wrthd K_m) interval at the proposed Crescent Junction Disposal Site.

Method of Solution

Use Air-Entry Permeameter (AEP) testing following installation procedures and methods as discussed in the Calculation section.

Assumptions:

1. AEP testing provides realistic saturated hydraulic conductivity results for wrthd K_m located at the Crescent Junction Disposal Site.
2. Excavating a soil "pedestal" and placing the AEP permeameter ring around the pedestal accurately tests pedestal materials.
3. Hydrated sodium bentonite adequately seals the AEP test and does not adversely affect results.

Computer Source:

Microsoft Excel

Calculation:

The AEP, developed by Herman Bouwer (Bouwer 1966) for determining air-entry and saturated hydraulic conductivity values for soils above the ground water table, is illustrated in Figure 1.

The AEP was initially designed to test agricultural soil; however, the device and method have been successfully extended to test air-entry and saturated hydraulic conductivity values for bedrock foundation materials. Sandstone and sandstone/siltstone bedrock materials have been tested with the AEP at the DOE Estes Gulch Disposal Site north of Rifle, Colorado (DOE 1994).

When the AEP is used to test soils, the permeameter ring is driven into the soil forming a tight seal between the soil and ring. When foundation bedrock materials are tested, a circular channel must be excavated into the bedrock, see the following Figures 2 through 6. The channel is subsequently filled with sodium bentonite to create the seal around the permeameter ring. By doing this, an assumption is made that the saturated hydraulic conductivity of the foundation materials is greater than the saturated hydraulic conductivity of the bentonite. This assumption is easily tested by comparing the computed saturated hydraulic conductivity value to 5×10^{-9} cm/sec, which is a typical saturated hydraulic conductivity value for sodium bentonite.

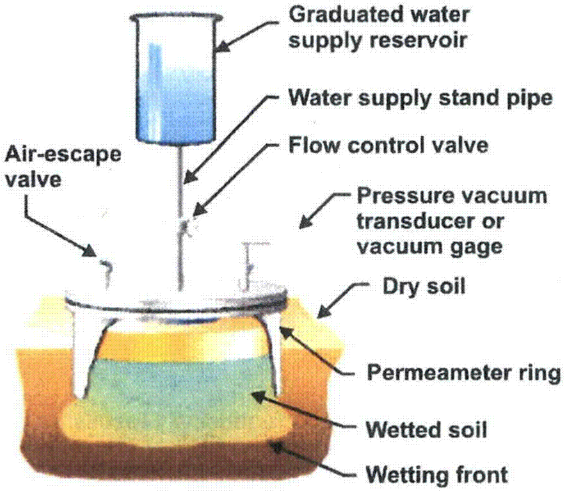


Figure 1. Air-Entry Permeameter
(ref. unknown)

The AEP consists of a 12-inch (30-centimeter)-tall sealed ring with a 12-inch (30 centimeter) inside diameter embedded approximately 6 inches (15 centimeters) into the surface. A graduated water supply is mounted to the sealed ring via a standpipe of varying lengths allowing different hydraulic heads to be applied to the soil.

Field Procedure

Installation:

1. Clear and smooth a surface excavated into the wrthd K_m approximately 2 feet by 2 feet.
2. Excavate a circular channel approximately 2 inches wide and approximately 6 inches deep into the wrthd K_m as shown in Figure 2. Diameter of the circular channel should be such that the AEP test ring can be positioned in the approximate center. Base of the channel should be smoothed to provide a level and horizontal contact for the AEP test ring as shown in Figure 3.

Figure 2. Excavating Circular Channel into Weathered Mancos Shale to Place AEP Ring

Figure 3. Smoothing and Leveling Channel Base

3. Two to 3 inches of powered sodium bentonite should be place in the base of the channel as shown in Figure 4.

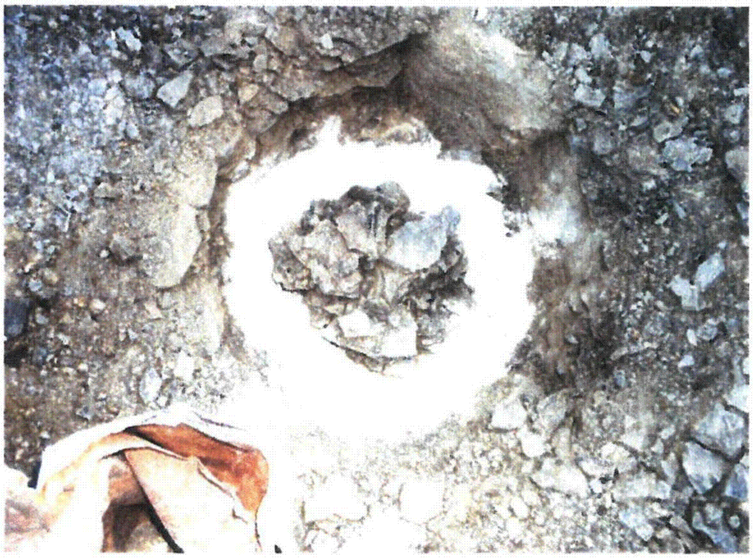


Figure 4. Sodium Bentonite in Bottom of Circular Channel Excavated into Weathered Mancos Shale

4. Mix water with bentonite in channel before placing ring in channel. Add more bentonite, refill channel with water and allow to hydrate bentonite for a minimum of 3 days (see Figure 5).

Figure 5. AEP Ring Placed in Channel With Bentonite Prior to Adding Water to Fully Hydrate Bentonite

5. Backfill the channel along the ring exterior with spoil as shown in Figure 6.

Figure 6. Channel Along Ring Exterior Filled with Spoils Prior to Testing

6. The ring is filled with water prior to attaching and sealing the lid and water supply cylinders.
7. The water supply is filled and flow-control and air values are opened to allow water to flow out of the AEP setup. All air bubbles are removed from the ring to ensure complete saturation of the permeameter. Figure 7 shows an installed AEP.

Figure 7. AEP Installed in wthrd K_m – TP 0154

Testing:

1. The water supply is refilled; initial readings (listed below) are taken and recorded before the flow control valve is opened to initiate the test.
2. Water level readings are taken and recorded at specified time intervals until steady-state infiltration is achieved.
3. The flow control value is closed and a final water level (H_f) is recorded.
4. A hand held vacuum pump is attached to the vacuum gauge and valve attachment. A vacuum is applied to the AEP and the greatest vacuum pressure achievable is recorded. The highest vacuum pressure will occur immediately prior to air bubbles flow.

Analysis:

The equation to compute a saturated hydraulic conductivity (K_{sat}) value from the AEP test is (Bouwer 1966; DOE 1994):

$$K_{sat} = 2\frac{dH}{dt}L\frac{R_r^{\ 2}}{R_s^{\ 2}} \Big/ (H + L - \frac{1}{2}P_a) \qquad [1]$$

where:
- dH/dt (cm/sec) = change in hydraulic head with respect to time,
- L (cm) = depth of infiltration,
- R_r (cm) = radius of water supply reservoir,
- R_s (cm) = radius of soil pedestal,
- H_f (cm) = final height of water in water supply reservoir, and
- P_a (cm) = air-entry pressure (vacuum pressure + gauge height + depth of infiltration).

Three test pits, TP 0152, TP 0154, and TP 0156, were excavated to the wthrd K_m interface at the Crescent Junction Disposal Site. Two AEPs were installed in TP 0152, one AEP in TP 0154 and two AEPs in TP 0156. Bentonite failed to seal one AEP permeameter ring in each of TP 0152 and TP 0156; thus, a total of three AEP test were performed.

Copies of field data sheets and plots of hydraulic head versus time for each test are attached to this report in the Appendix. Also included are copies of hand calculations.

Results:

Table 1 presents results of the AEP tests. Shown on the table are values for air-entry (cm), dH/dt (cm/sec) and computed K_{sat}.

Table 1. AEP Results

Location	Air-Entry (cm)	dH/dt (cm/sec)	K_{sat} (cm/sec)
TP 0152	183	7.8×10^{-4}	4.4×10^{-5}
TP 0154	140	5.8×10^{-3}	1.6×10^{-4}
TP-0156	241	1.7×10^{-2}	2.6×10^{-4}

Geometric mean of all K_{sat} values = **1.2×10^{-4} cm/sec.**

Discussion:

Other methods exist to compute field saturated hydraulic conductivity in fine-grained materials based on infiltration results. A method proposed by Youngs et al. (1995) has been used to validate the saturated hydraulic conductivity of compacted clay barrier layers on UMTRA disposal cells (Waugh et al. 1999). This method assumes that the soils are initially "wet", or close to saturation. Based on the air-entry values tested, the wrthd K_m is considered sufficiently "dry" to account for soil suction, therefore the method proposed by Youngs et al. (1995) is no longer considered.

Tests were performed during the winter of December 2005 and January 2006. Upon returning to TP 0152 after installation of permeameter rings and the required 3 days for bentonite hydration was allowed to occur, the installation was frozen as shown in Figure 8.

The ice was chipped out and the diameter of the enclosed wrthd K_m inspected. The approximate upper 1 inch of soil was frozen over an approximate 6 inch diameter forming an "ice cap" on the soil pedestal. Water does not infiltrate into soils below the ice cap. Accordingly, the area receiving flow was measured to compute the flow area. The test was run, and an effective area representing the reduced flow area was used computation of K_{sat}. This consisted of computing an equivalent area and radius, R_s in equation [1] of the soil pedestal. Errors introduced by doing this are considered to be of the same order as errors introduced by excavating the circular channel and embedding the permeameter ring, so the results are still considered applicable for use in design.

Figure 8. Frozen Hydration Water in the Non-Leaking AEP Test Performed in TP 0152

Conclusion and Recommendations:

A design saturated hydraulic conductivity value of 1.2×10^{-4} cm/sec should be used for wrthd K_m material, based on AEP test results conducted December 2005 and January 2006 at the proposed Crescent Junction, Utah, Disposal Site.

The resulting geometric mean of measured in situ saturated hydraulic conductivity values for the weathered Mancos Shale at the proposed disposal cell site, should be considered a first-order approximation, due to of the small sample size. Although the 12-inch-diameter size of the permeameter ring is large enough to measure preferential flow around shale fragments, as illustrated in Figure 4, statistical confidence in the mean is low. Increasing the number of data points will provide more confidence of the mean, however given that the range of tested values are within one-order of magnitude, the mean is not expected to vary significantly.

End of current text

Appendix A

Field Notes and Hand Computations for K_{sat} Determination

TP 0152 Field Data Sheets and Plots

Air-Entry Permeameter Tests

Date: 1/10/06

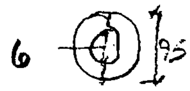
Staff: R. Rupp
G. Smith

152 W

Measured Parameters

R_{ws} (Radius of Water Supply Reservoir)
2.5 cm

R_{sr} (Radius of Soil Ring)
9.5" Ø/2 ~~cm~~ ≈12.1 cm 10.9



G (Height of gauge above soil surface)
8.5" ~~cm~~ 21.6 cm

H_f (Final water head reading when water flow valve is shut)
23.7 cm +38.1 = 61.8

P_{min} (Gauge pressure at air entry, a negative value)
10 ~~cm~~ centibars x 10.2 cm/centibar = 102 cm

L (Depth from soil surface to wetting front) = 26.7 cm
2" below base of ring excess bentonite after installation

Data

h = 15.0" x 2.54 = 38.1

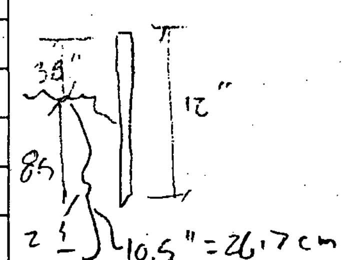
	Time (min)	Reservoir Reading (cm)	Head (cm	dH (cm)	dT (s)	dH/dT (cm/s)	mean dH/dT
0	1:15:00	27.6					
0.5	:15:30	27.4					
1	:16:00	27.2					
2	:17:00	27.0					
4	:19:00	26.8					
8	:23:00	26.5					
15	:30:00	26.0					
	:45:00	25.1					
45	2:00:00	24.4					
60	2:15:00	23.7					

Soil in ring initially [illegible]
water @ 4"

—

test applicable

152E leaks
upon removing water stayed high in hole



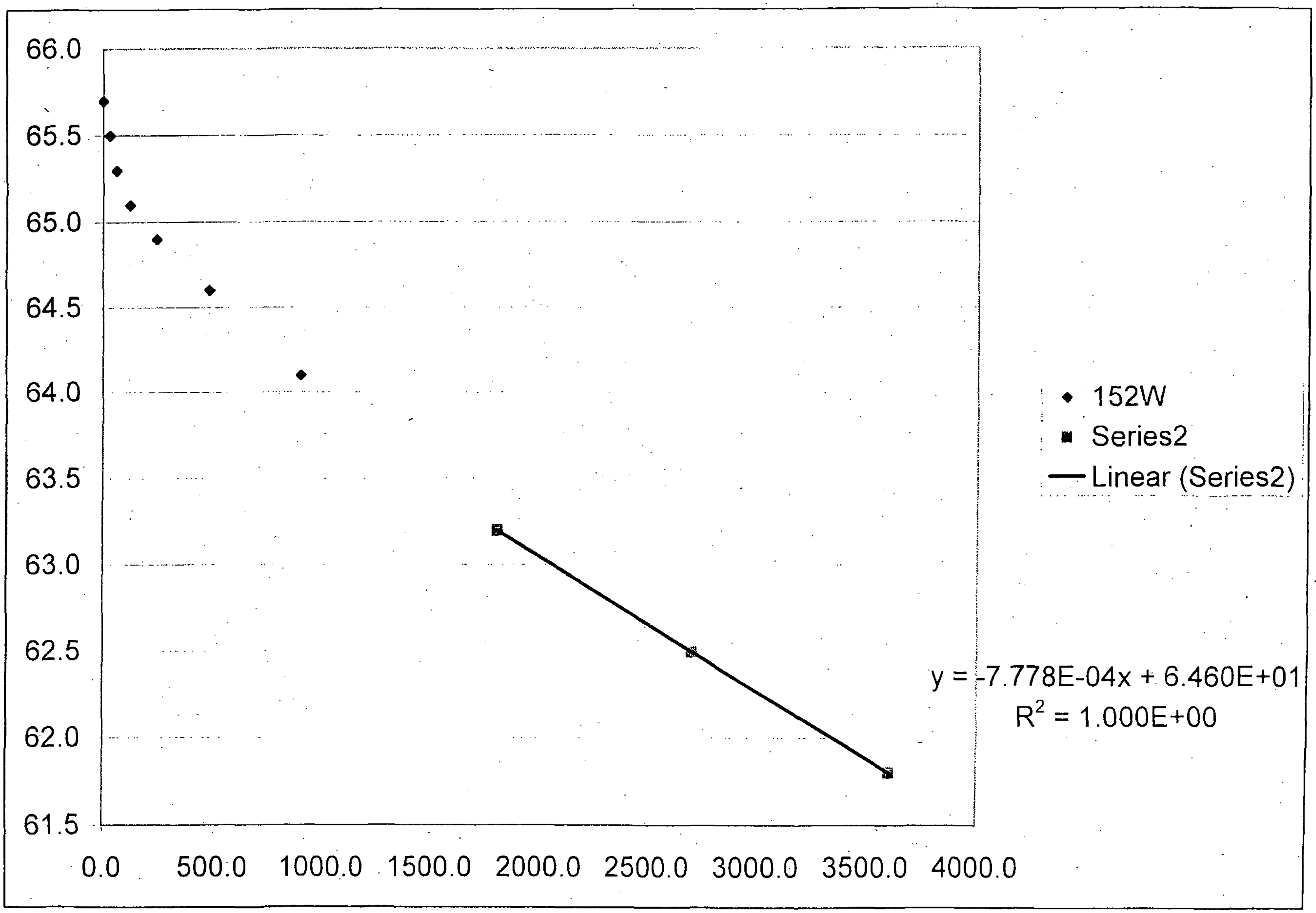
P_a (Air entry value, negative value) = P_{min} + G + L =102 + 21.6 + 26.7 = 150.3 cm

dH/dT = (Change in head/Change in time) for last two data points -0.000844 cm/s

K_{sat} = -(2 * dH/dT * L * $(R_{ws}/R_{sr})^2$) / (H_f + L - (0.5 * P_a)) (cm/s) = $2.37 \times 10^{-3} / 13.35$ 1.8×10^{-4} cm/s
$= 2 \times 10^{-4}$ cm/sec

$A_6 = 70.88$
$A_4 = 12.57$
58.32

$58.32 = \pi d^2/4$
$d = 8.62$; $r = 8.62/2 = 4.31$ in $= 10.9$ cm ✓


66.0
65.5
65.0
64.5
64.0
63.5
63.0
62.5
62.0
61.5
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
152W
Series2
Linear (Series2)
y = -7.778E-04x + 6.460E+01
R^2 = 1.000E+00

0152W

Given

$R_{ws} = 25\ mm = \underline{2.5\ cm}$

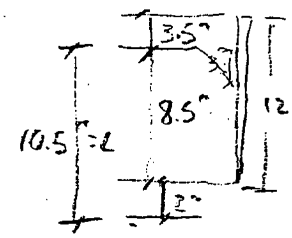
$R_{sr} = 9.5''/2\ (2.54) = \underline{12.1\ cm}$

$G = 8.5''\ (2.54) = \underline{21.6\ cm}$

$H_f = 23.7\ cm + 15''(2.54) = \underline{61.8\ cm}$

L => 2'' below base of ring $= 10.5''(2.54) = \underline{26.7}\ cm$

to $10.5-3\ (2.54) = \underline{19.1}\ cm$



$P_a = 10$ centi-bar $(10.2\ cm/\text{centi-bar}) = \underline{102\ cm}$

Find

K_{sat}

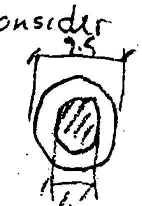
Solution

$$K_{sat} = \frac{-(2\ dH/dt\ L\ (R_{ws}/R_{sr})^2)}{H_f + L - P_a/2} \qquad dH/dt = -7.778\times10^{-4}\ cm/s$$

$$= \frac{-(2(-7.778\times10^{-4}\ cm/s)(26.7\ cm)(2.5/12.1)^2)}{(61.8 + 26.7 + 102)/2} = \frac{1.773\times10^{-3}\ cm^2/s}{95.3\ cm} = 1.9\times10^{-5}\ cm/sec$$

$$= \frac{-(2(-7.778\times10^{-4})(19.1)(2.5/12.1)^2}{(61.8 + 19.1 + 102)/2} = \frac{1.268\times10^{-3}\ cm^2/s}{91.5} = \underline{1.4\times10^{-5}\ cm/s}$$

consider upper 6" ϕ of pedestal frozen:



$A_{9.5} = 70.882\ in^2$

$A_6 = \underline{28.274\ in^2}$

$\left(\frac{42.608\ in^2 \times 4}{\pi}\right)^{1/2} =$ equivalent $\phi = 7.37\ in = R'_{sr}$

0152W

$$k_{sat} = \frac{-(2(7.778\times10^{-4}\ cm/s)(19.1)(^{2.5}/_{7.37})^2)}{(61.8+19.1+102)/2}$$

$$= \frac{3.42\times10^{-3}\ cm^2/s}{95.3\ cm} = 3.6\times10^{-5}\ cm/s$$

$$k_{sat} = \frac{-2(7.778\times10^{-4}\ cm/s)(26.7)(^{2.5}/_{7.37})^2)}{(61.8+26.7+102)/2}$$

$$= \frac{4.78\times10^{-3}\ cm^2/s}{91.5\ cm} = 5.2\times10^{-5}\ cm/s$$

k_{sat} (cm/s)

L \ R_{sr}	12.1	7.37
26.7	1.9×10^{-5}	3.6×10^{-5}
19.1	1.4×10^{-5}	5.2×10^{-5}

Discussion

k_{sat} is not sensitive to L, is sensitive to R_{sr}

Since upper portion of pedestal was frozen, used approximated frozen diameter to compute k_{sat};

i.e. $k_{sat} = 4.4\times10^{-5}$ cm/s

TP 0154 Field Data Sheets and Plots

Air-Entry Permeameter Tests

Date: 1-10-06

Staff: G. Smith

Measured Parameters 154

R_{ws} (Radius of Water Supply Reservoir)
5 cm/2 cm = 2.5 cm

H_f (Final water head reading when water flow valve is shut)
3.8 + h cm = 35.6

R_{sr} (Radius of Soil Ring)
9.5 in ϕ cm = 24/2 = 12.1 cm

P_{min} (Gauge pressure at air entry, a negative value)
8 ~~cm~~ centibars × 10.2 cm/centibar = 81.6 cm

G (Height of gauge above soil surface)
6.375 ~~cm~~ in = 16.2 cm

L (Depth from soil surface to wetting front)
9 in ~~cm~~ = 22.9 cm

Data

h @ 0.0 cm = 12.5 in

ambient temp = 12 °C

	Time (MST) (min)	Reservoir Reading (cm)	Head (cm	dH (cm)	dT (s)	dH/dT (cm/s)	mean dH/dT
0	11:31:00	27.7			0		
0.5	:30	23.4					
1	:32:00	21.6					
2	:33:00	17.5					
4	:35:00	10.7					
6	:37:00	5.5					
0	11:39:00	28.8					
	:30	24.9					
1	:40:00	23.7					
2	:41:00	21.8					
4	:43:00	18.5					
8	:47:00	13.8					
15	:54:00	9.6					
30	12:09:00	3.8					

P_a (Air entry value, negative value) = P_{min} + G + L = 81.6 + 16.2 + 22.9 120.7 cm

dH/dT = (Change in head/Change in time) for last two data points -0.0073 cm/s

$K_{sat} = -(2 * dH/dT * L * (R_{ws}/R_{sr})^2) / (H_f + L - (0.5 * P_a))$ (cm/s) = -0.0144/-1.85 = 7.7 x10^{-3} cm/s

≅ 8 x10^{-3} cm/s

= 77 x10^{-4} cm/sec

0154

Given

Radius of reservoir = 50 mm / 2 = 25 mm = 2.5 cm = R_{ws}

Radius of soil ring (pedestal) ~9.5" dia
= 4.75" radius $\left(\frac{2.54 \text{ cm}}{\text{in}}\right)$
= 12.1 cm = R_{sr}

Gage height = 6 3/8" = 6.375 (2.54/1 in) = 10.2 cm

H_f = 3.8 cm − 12.5" (2.54 cm / in) = 35.6 cm

P_{min} = 8 centibars (10.2 cm/centibar) = 81.6 cm

L ≃ 9 in (2.54) = 22.9 cm

Find

K_{sat}

Solution

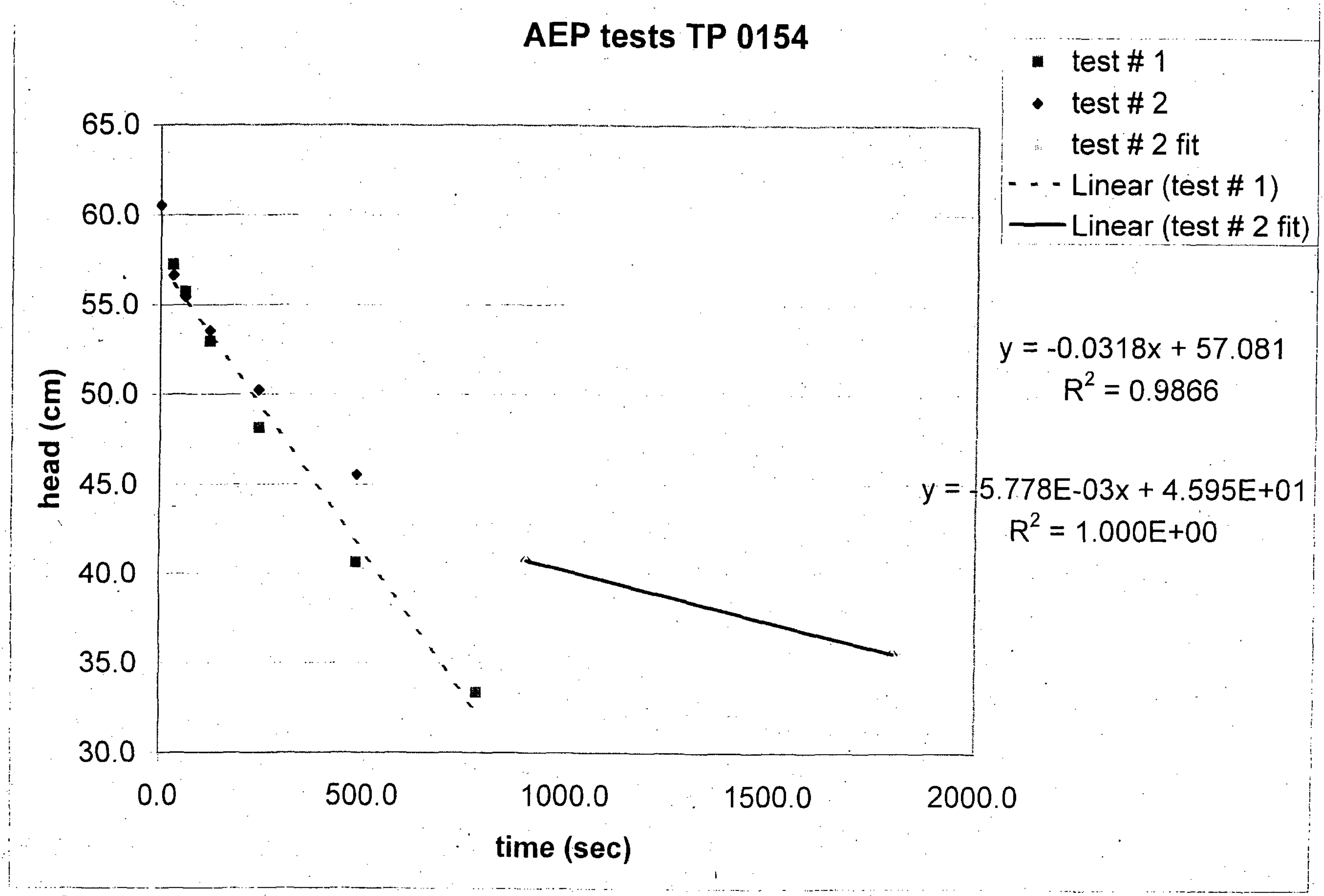
$$K_{sat} = -\left(2\, dH/dt\, L\, (R_{ws}/R_{sr})^2 / (H_f + L - \tfrac{1}{2} P_a)\right)$$

$dH/dt = -5.778 \times 10^{-3}$ cm/sec (see attached graph)

$$K_{sat} = \frac{-\left(2(-5.778\times10^{-3}\text{ cm/sec})(22.9\text{ cm})(2.5/12.1)^2\right)}{(35.6 + 22.9 + 81.6)/2}$$

$$= \frac{1.130\times10^{-2}\text{ cm}^2/\text{s}}{70\text{ cm}} = 1.6\times10^{-4}\text{ cm/sec}$$

TOPS.
35502



AEP tests TP 0154
test # 1
test # 2
test # 2 fit
Linear (test # 1)
Linear (test # 2 fit)
y = -0.0318x + 57.081
R2 = 0.9866
y = -5.778E-03x + 4.595E+01
R2 = 1.000E+00
head (cm)
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
0.0
500.0
1000.0
1500.0
2000.0
time (sec)

TP 0156 Field Data Sheets and Plots

Air-Entry Permeameter Tests

σ156 W

Date: 12-02-05

Staff: Greg Smith

Ralph Rupp

Measured Parameters

R_{ws} (Radius of Water Supply Reservoir)
50/2=25 cm

H_f (Final water head reading when water flow valve is shut)
37.1 cm

R_{sr} (Radius of Soil Ring)
11.11 cm $\left(\frac{8'' + 9\frac{1}{2}''}{2}\right)$

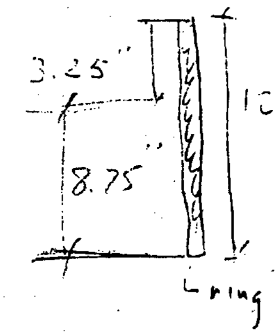
P_{min} (Gauge pressure at air entry, a negative value)
203.9 cm

G (Height of gauge above soil surface)
7.75'' cm 19.7

L (Depth from soil surface to wetting front)
17.8 cm

Head = reading + 1' 1.5'' = 34.3

Data



1'-1.5''

actual (MDT)	Time (min)	Reservoir Reading (cm)	Head (cm	dH (cm)	dT (s)	dH/dT (cm/s)	mean dH/dT
2:12	0	27.3	~~27.3~~				
	0.5	23.9	~~23~~				
	1.0	23.1					
	1.5	22.5					
	2.0	22.0					
12:16	4.0	19.8					
	8.0	15.6					
12.	15.0	9.2					
2:38¾	~~25.0~~ 24.75	~~0.0~~ 0.2					
12:11 12:41	0	29.9	restart				
	0.5	27.5					
	1.0	27.0					
12:43	2.0	25.7					
12:45	4.0	23.1					
12:49	8.0	18.5					
12:56	15.0	11.3					
1:01	20.0	6.6					
1:06	25.0	2.5					
		—	restarted				

P_a (Air entry value, negative value) = P_{min} + G + L $-203.9 + 19.7 + 17.8$ -166.40

dH/dT = (Change in head/Change in time) for last two data points −0.0187 ~~−1.1227~~ cm/s
(2.3×10⁻⁴ cm/s)

$K_{sat} = -(2 * dH/dT * L * (R_{ws}/R_{sr})^2) / (H_f + L - (0.5 * P_a))$ (cm/s) 2.5×10⁻⁴ cm/s

$-(-3.48\times10^{-2}) / (37.1 + 17.8 - (.5 \times \cancel{203.9}$ = 166.4

$3.48\times10^{-2} / 138.1 =$

6.3×10⁻⁴ w/o P_a

Air-Entry Permeameter Tests

Date:

Staff:

0156W cont

Measured Parameters

R_{ws} (Radius of Water Supply Reservoir) cm

H_f (Final water head reading when water flow valve is shut) 2.5+H cm

R_{sr} (Radius of Soil Ring) cm

P_{min} (Gauge pressure at air entry, a negative value) 20 centibars = 203.94 cm

G (Height of gauge above soil surface) cm

L (Depth from soil surface to wetting front) 7" ~~cm~~ — 17.8

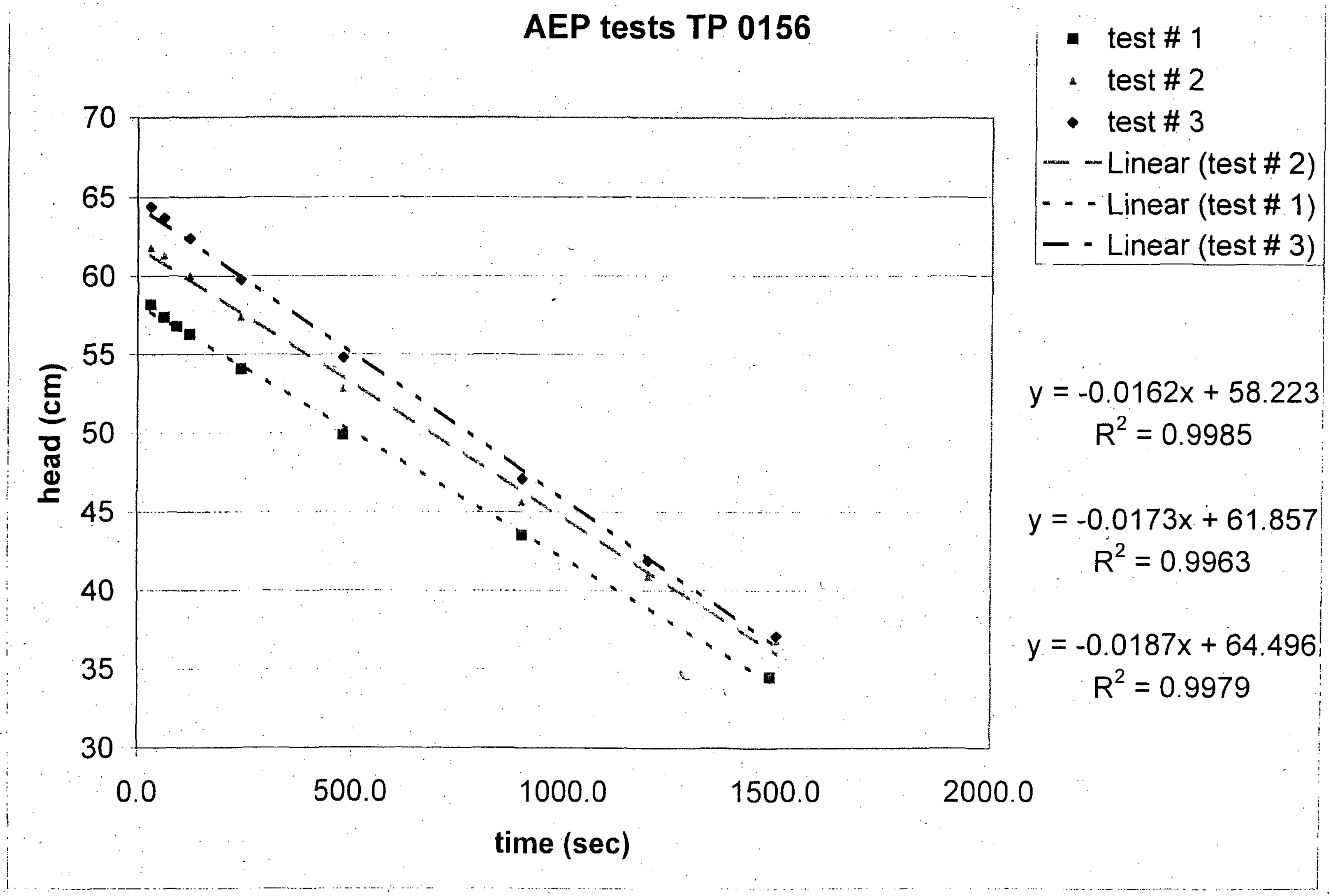
Data

Actual	Time (min)	Reservoir Reading (cm)	Head (cm	dH (cm)	dT (s)	dH/dT (cm/s)	mean dH/dT
1:10	0	32.7					
	0.5	~~31.1~~ 30.1					
1:11	1.0	29.4					
1:12	2.0	28.1					
1:14	4.0	25.5					
1:18	8.0	20.5					
1:25	15.0	12.8					
1:30	20.0	7.6					
1:35	25.0	2.8					

P_a (Air entry value, negative value) = P_{min} + G + L

dH/dT = (Change in head/Change in time) for last two data points cm/s

$K_{sat} = -(2 * dH/dT * L * (R_{ws}/R_{sr})^2) / (H_f + L - (0.5 * P_a))$ (cm/s) cm/s


AEP tests TP 0156
head (cm)
time (sec)
70
65
60
55
50
45
40
35
30
0.0
500.0
1000.0
1500.0
2000.0
test # 1
test # 2
test # 3
Linear (test # 2)
Linear (test # 1)
Linear (test # 3)
y = -0.0162x + 58.223
R2 = 0.9985
y = -0.0173x + 61.857
R2 = 0.9963
y = -0.0187x + 64.496
R2 = 0.9979

0156W

Given $R_{ws} = 25\,mm = \underline{2.5\,cm}$

$R_{sr} = \dfrac{\left(\dfrac{8+9.5}{2}\right) 2.54}{2} = \underline{11.1\ cm}$

$G = 7\tfrac{3}{4}''\ (2.54) = \underline{19.7\,cm}$

$H_f = 13\tfrac{1}{2}''(2.54) + 2.8\,cm = \underline{37.1\,cm}$

$P_{min} = -\left(20\,\text{centibars}\left(\dfrac{10.2\,cm}{\text{centibar}}\right)\right) = \underline{-204\ cm}$

$L = 7''(2.54) = \underline{17.8\,cm}$

Find

k_{sat}

Solution

$$k_{sat} = \frac{-\left(2\frac{dH}{dt}\,L\left(\frac{R_{ws}}{R_{sr}}\right)^2\right)}{H_f + L - P_a/2}$$

$P_a = P_{min} + G + L = -204 + 19.7 + 17.8 = -241.5$

$\frac{dH}{dt}$ = -avg. of all three slopes shown on attached plot

$$\frac{0.0162 + 0.0173 + 0.0187}{3} = 0.0174\ cm/sec$$

$$k_{sat} = \frac{0.0314\ cm^2/sec}{120.75\,cm} = \underline{2.6\times10^{-4}\,cm/sec}$$

TOPS
35502

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-03-2006-2-10-00 **Discipline: Hydrologic Properties** **No. of Sheets: 6**
Doc. No.: X0147300

Location: Attachment 3, Appendix B

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Field Permeability "Bail" Testing

Sources of Data:

Bail testing records were obtained electronically from pressure transducers installed in coreholes at the Crescent Junction Site during the field characterization project, November 2005 through January 2006.

Sources of Formulae and References:

Freeze, R. Allen, and J.A. Cherry, 1979. *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Hvorselv, M.J., 1951. *Time Lag and Soil Permeability in Ground-Water Observations,* Bulletin No. 36 U.S. Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author:	Name: [signature] Date: 5-31-07	**Checked by:**	Name: [signature] Date: 5/30/07
			Name: Dave Peterson Date: 5/31/07
Approved by:	Name: [signature] Date: 5/31/07		Name: [signature] Date: 31 May 07
			Name: D Metzler Date: MAY 31 07

No text for this page

Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified a 2,300-acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for a final disposal cell for the Moab uranium mill tailings. The proposed disposal cell would cover approximately 250 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction Disposal Site is being evaluated from several technical aspects, including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation is to impart the field permeability "bail test" results obtained from the Mancos Shale during the investigation of subsurface conditions at the Crescent Junction Disposal Site.

This calculation will be incorporated into Attachment 3 (Hydrology) of the Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site (RAP), and summarized in the appropriate sections of the Remedial Action Selection (RAS) report for the Moab Site.

Obtaining the hydraulic parameters of the host rock in which a disposal site will be situated is one of the fundamental measurements required to evaluate the suitability of the site. Because the bedrock is a shale aquitard containing only sparse saline groundwater, the number and type of measurements that might be made are rather limited. In addition, the types of measurements that are available, packer tests and piezometer tests, reveal different characteristics about the rock mass. Packer tests, which reveal spatially discrete estimates of hydraulic conductivity, were carried out on this project and are documented in the "Field Permeability 'Packer' Testing" calculation (Attachment 3, Appendix C) and in the "Saturated Hydraulic Conductivity Determination of Weathered Mancos Shale" calculation (Attachment 3, Appendix A).

Piezometer tests, which are described in Freeze and Cherry (1979), will yield vertically averaged hydraulic conductivities that do not represent the full vertical variability in hydraulic conductivity. These averaged hydraulic conductivity determinations were done to evaluate hydraulic properties representative of the entire rock mass. The tests are performed by causing an instantaneous change in the water level in a piezometer through a sudden introduction (or removal) of a known volume of water. When the water is removed, the tests are often called *bail tests*. For this project the hydraulic properties of the Mancos Shale are important for the purpose of developing the water resources protection strategy. The tests were performed in coreholes 201, 202, 203, 204, and 208 (see Table 1).

Method of Solution:

Instantaneous removal of ground water from each corehole was accomplished using dedicated submersible pumps. Water levels were measured using submersible electronic pressure transducers that were programmed to read either at 5- or 15-minute intervals. The water-level recovery data were downloaded into a portable laptop computer and then copied onto the data analyst's computer. The test results were analyzed using equation 8.34 in Freeze and Cherry (1979).

For a piezometer intake of length (L/R) > 8, Hvorslev (1951) has evaluated the so-called *shape factor* F of the piezometer and presented the following equation for calculating the hydraulic conductivity:

$$K = [r^2 \ln (L/R)]/(2LT_0), \qquad [1]$$

where:

K = hydraulic conductivity [length/time]
r = radius of corehole [length]
L = length of ground water intake zone [length]
R = radius of ground water intake zone [length]
T_0 = basic time lag [time]

To interpret a set of field recovery data, the data are plotted graphically in the form of dimensionless drawdown $[(H-h)/(H-H_0)]$ versus elapsed time. The basic time lag value is read off the graph at the point where the dimensionless drawdown equals 0.37.

Assumptions:

- Pumping ground water from a corehole tapping a low-permeability formation causes a valid, essentially instantaneous change in the water level.
- Bail tests in bedrock systems such as the Mancos Shale yield estimated values of average hydraulic conductivity for the entire test interval.
- The absence of a piezometer tube does not invalidate the recovery test data.

Calculation:

To interpret a set of field recovery data, the data are plotted graphically in the form of dimensionless drawdown $[(H-h)/(H-H_0)]$ versus elapsed time. Appendix A presents plots of each test that was conducted during this study. Each plot displays dimensionless drawdown versus the elapsed time since the bail test began. Using the Microsoft Excel program, the raw drawdown data were converted to dimensionless drawdowns, and the dimensionless drawdowns were plotted versus elapsed time. The basic time lag value was read off the graph at the point where the dimensionless drawdown equals 0.37. The basic time lag value is posted on each plot. Equation 1 was then used to solve for hydraulic conductivity..

Inputs to the equation are:

r = radius of corehole [length] = 0.16 ft
L = length of ground-water intake zone [length] = depth of static water in corehole
$L_{corehole\ 201}$ = 95 ft
$L_{corehole\ 202}$ = 188 ft
$L_{corehole\ 203}$ = 203 ft
$L_{corehole\ 204}$ = 75 ft
$L_{corehole\ 208}$ = 120 ft
R = radius of ground-water intake zone [length] = 0.16 ft
T_0 = basic time lag [time] = 0.37

Results from these calculations are tabularized below:

Table 1. Bail Test Results

Corehole	Hydraulic Conductivity (cm/sec)				
	Test 1	Test 2	Test 3	Test 4	Geometric Mean
201	1.4×10^{-6}	1.4×10^{-6}	1.9×10^{-6}	ND	1.6×10^{-6}
202	4.3×10^{-7}	3.9×10^{-7}	4.3×10^{-7}	ND	4.2×10^{-7}
203	2.4×10^{-6}	2.6×10^{-6}	2.6×10^{-6}	2.3×10^{-6}	2.5×10^{-6}
204	Indeterminable	Indeterminable	3.1×10^{-7}	ND	3.1×10^{-7}
208	3.1×10^{-7}	3.3×10^{-7}	3.1×10^{-7}	ND	3.2×10^{-7}

ND – No data were gathered for this test.

Discussion:

Results obtained from this calculation represent average hydraulic conductivities for the Mancos Shale. These results were obtained from the unweathered zones of the Mancos Shale that underlie the Crescent Junction Disposal Site. Sources of the ground water appear to be micro to mini fractures and/or bedding planes within the rock formation. The hydraulic conductivities of discrete zones contributing the water were not measured with this method. This method yields average hydraulic conductivities of the portions of the coreholes that are below the fluid level in that borehole.

Conclusion and Recommendations:

Overall, the hydraulic conductivity of the Mancos Shale was determined to be very low at the Crescent Junction Site. Based on results of bail testing, and in conjunction with findings of field investigations, the Crescent Junction Site appears to be suitable for disposal of the Moab uranium mill tailings and contaminated material. Based on this information, and in conjunction with findings of field investigations, this site is deemed suitable for the intended use.

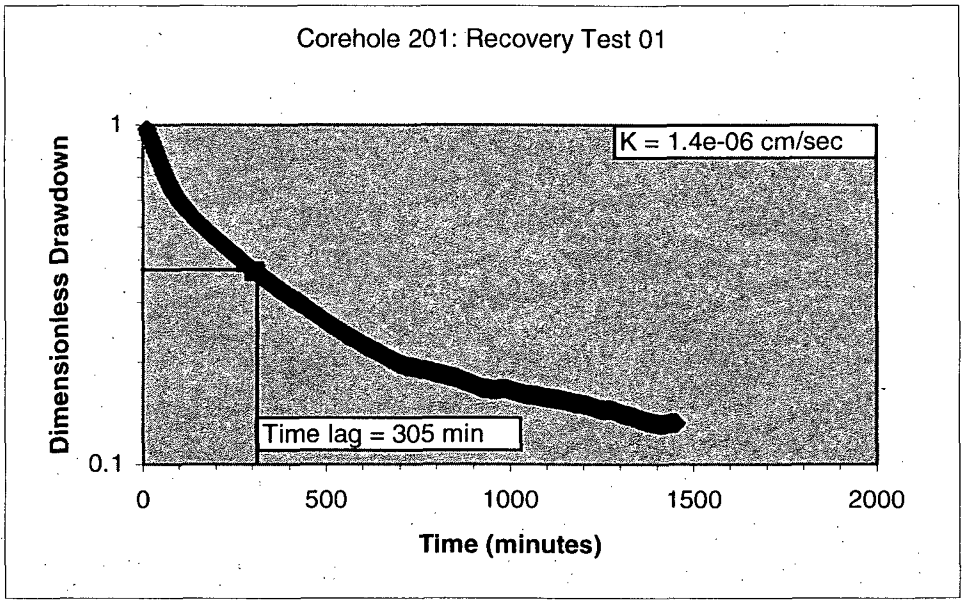
Computer Source:

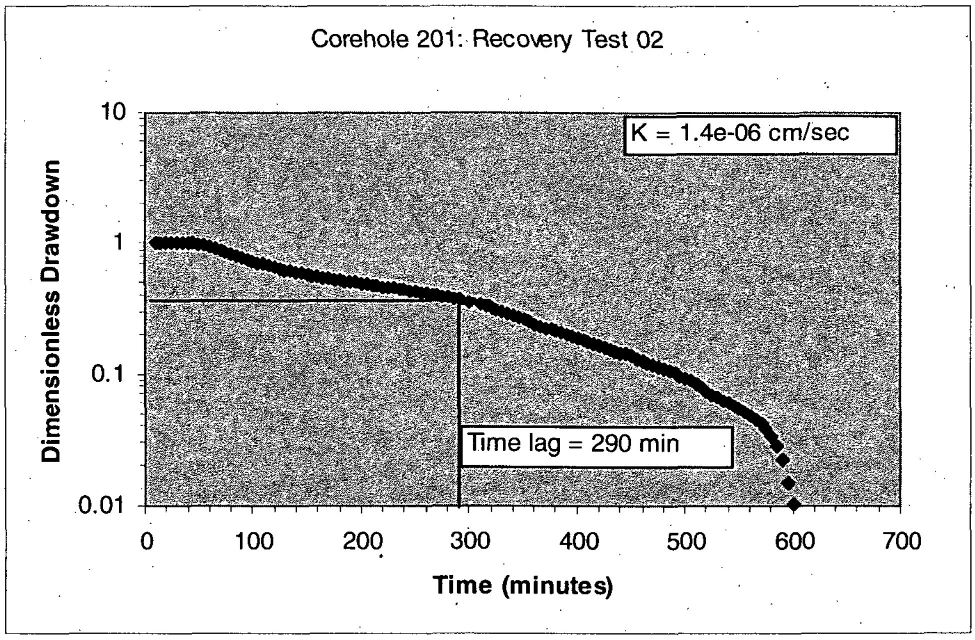
Microsoft Excel

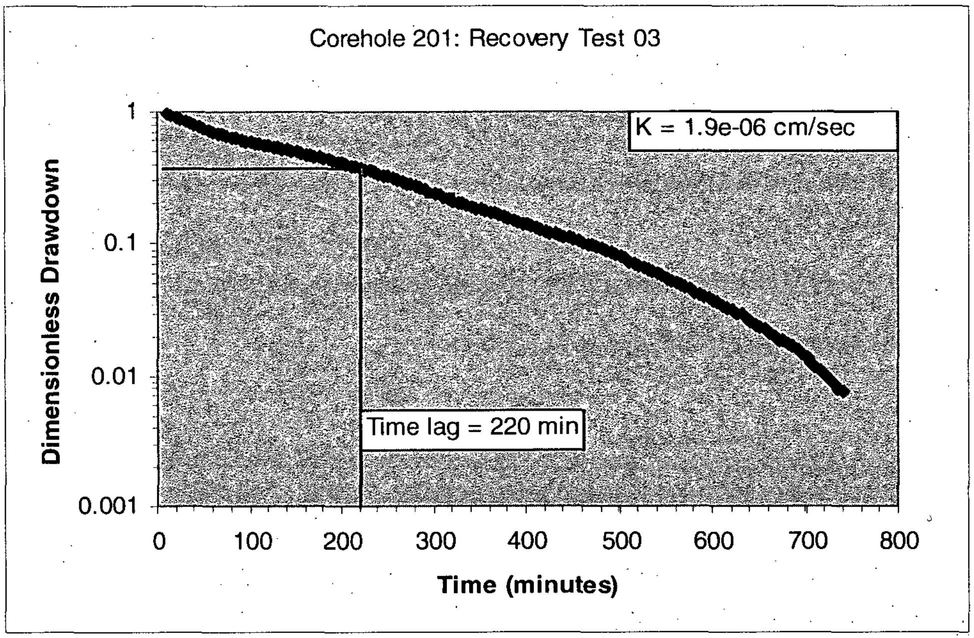
End of current text

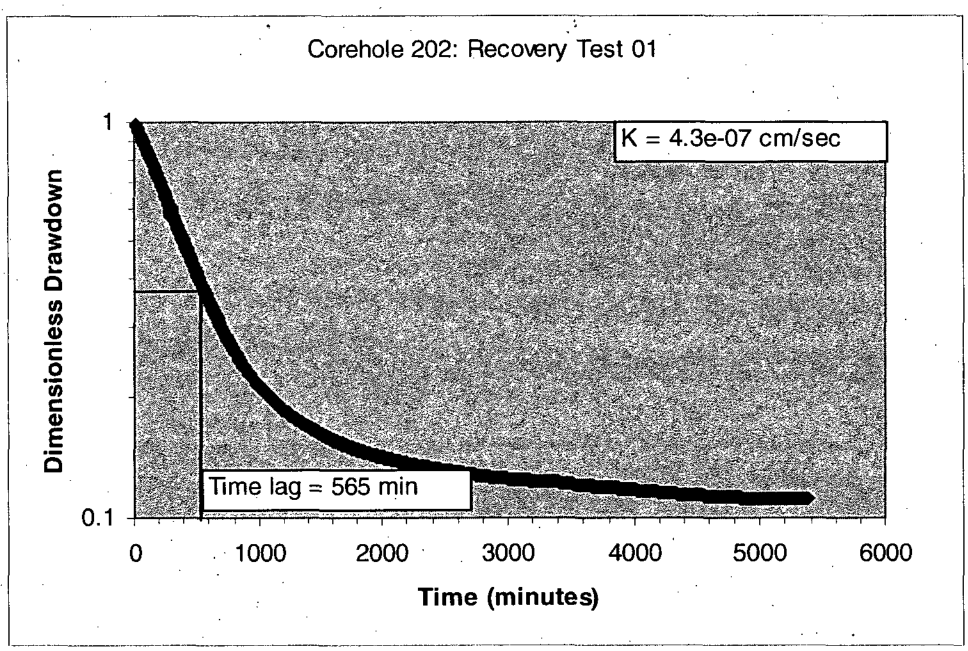
Appendix A

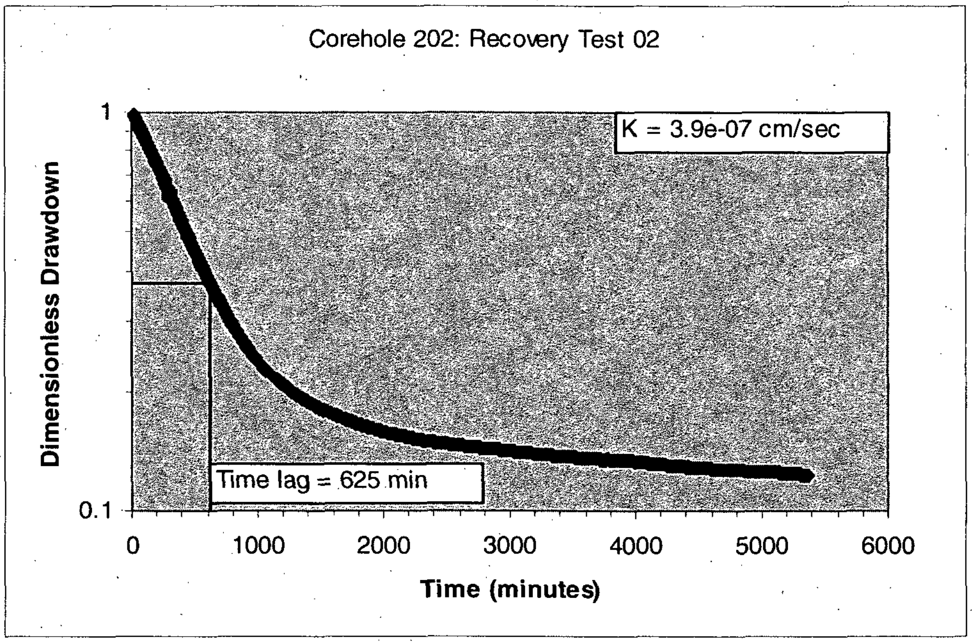
Copies of Packer Testing Raw-Data Sheets and Analysis Sheets

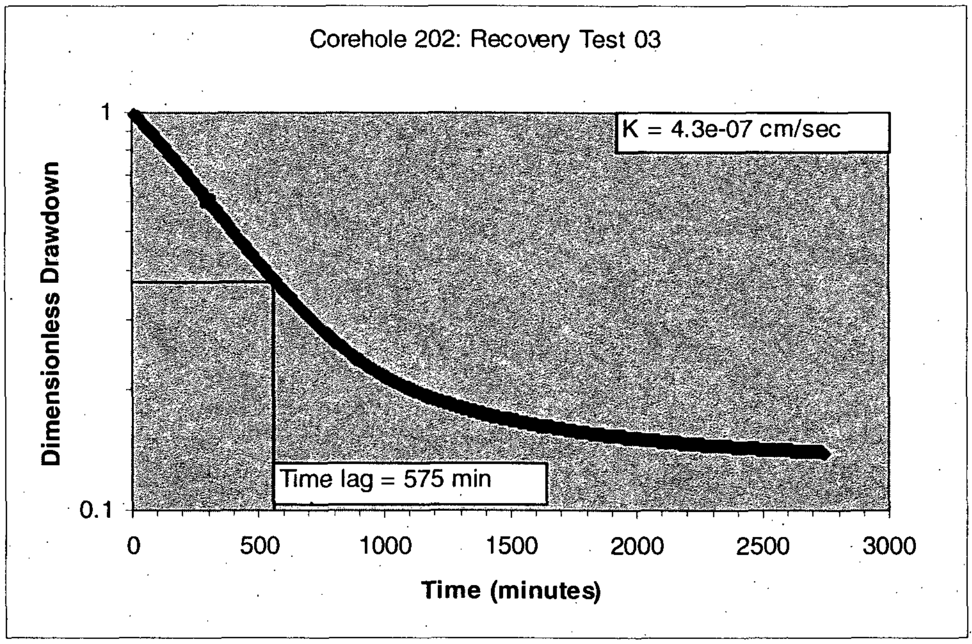

Corehole 201: Recovery Test 01
K = 1.4e-06 cm/sec
Time lag = 305 min
Dimensionless Drawdown
1
0.1
0
500
1000
1500
2000
Time (minutes)

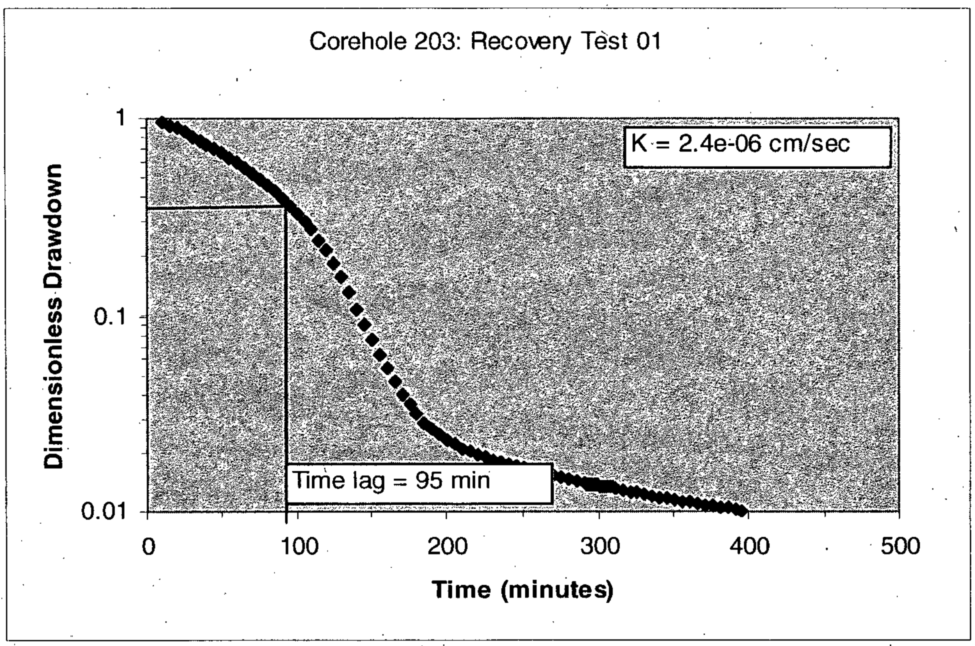

Corehole 201: Recovery Test 02
K = 1.4e-06 cm/sec
Time lag = 290 min
Dimensionless Drawdown
10
1
0.1
0.01
0
100
200
300
400
500
600
700
Time (minutes)

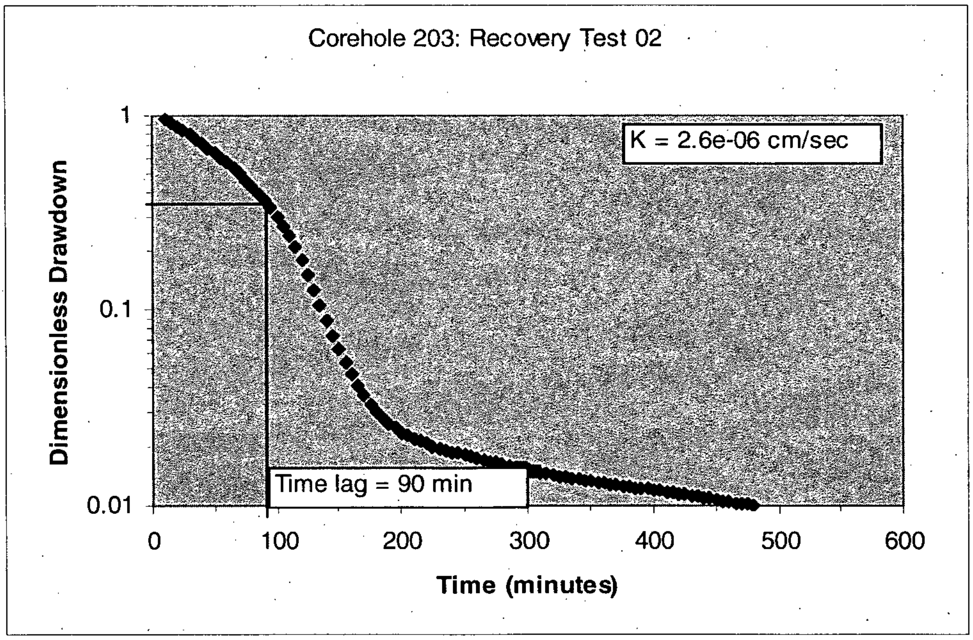

Corehole 201: Recovery Test 03
K = 1.9e-06 cm/sec
Time lag = 220 min
Dimensionless Drawdown
1
0.1
0.01
0.001
0
100
200
300
400
500
600
700
800
Time (minutes)

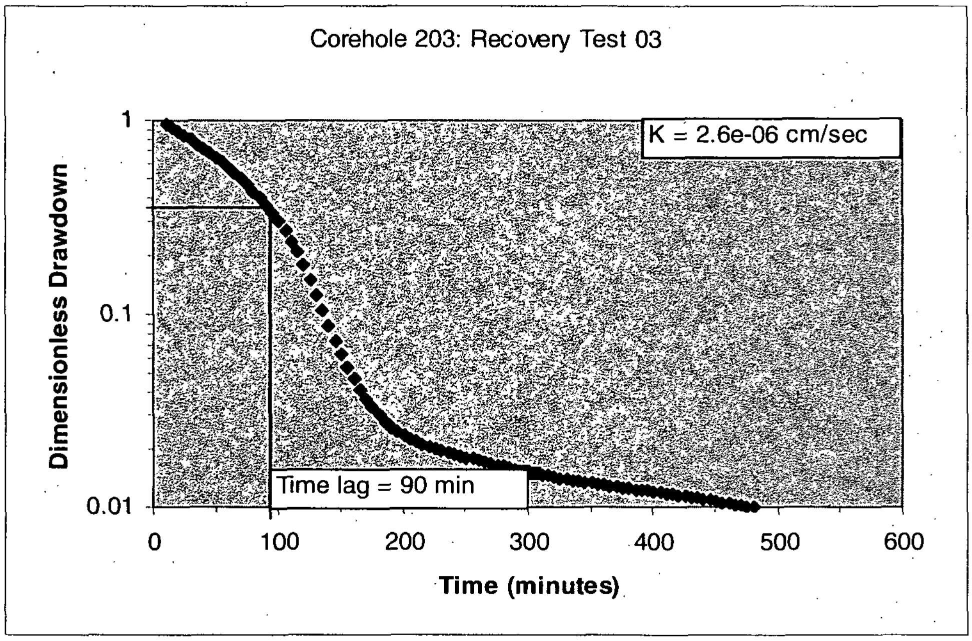

Corehole 202: Recovery Test 01
K = 4.3e-07 cm/sec
Time lag = 565 min
Dimensionless Drawdown
1
0.1
0
1000
2000
3000
4000
5000
6000
Time (minutes)


Corehole 202: Recovery Test 02
K = 3.9e-07 cm/sec
Time lag = 625 min
Dimensionless Drawdown
1
0.1
0
1000
2000
3000
4000
5000
6000
Time (minutes)

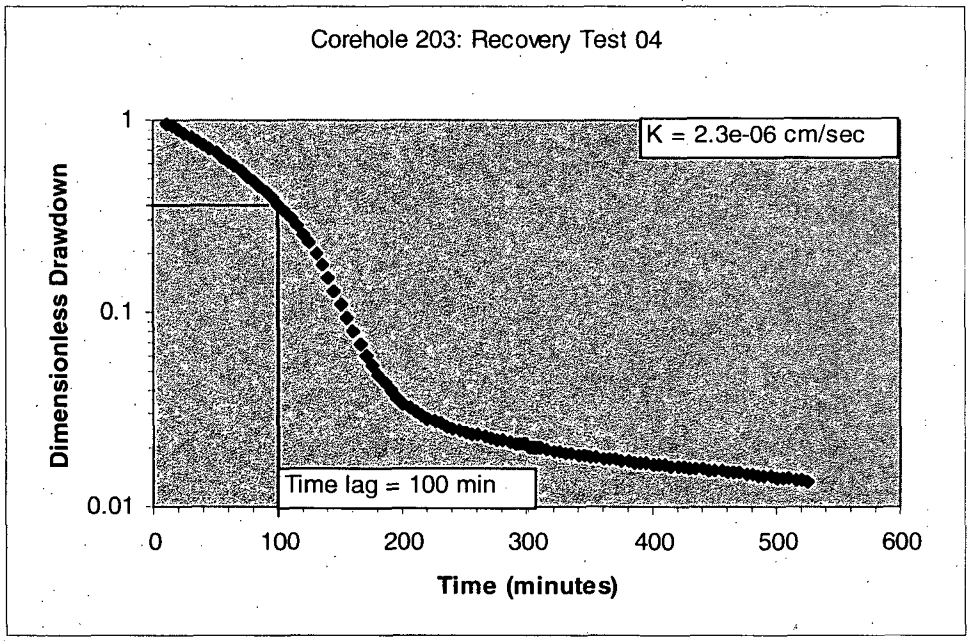

Corehole 202: Recovery Test 03
K = 4.3e-07 cm/sec
Time lag = 575 min
Dimensionless Drawdown
1
0.1
0
500
1000
1500
2000
2500
3000
Time (minutes)


Corehole 203: Recovery Test 01
K = 2.4e-06 cm/sec
Time lag = 95 min
Dimensionless Drawdown
1
0.1
0.01
0
100
200
300
400
500
Time (minutes)

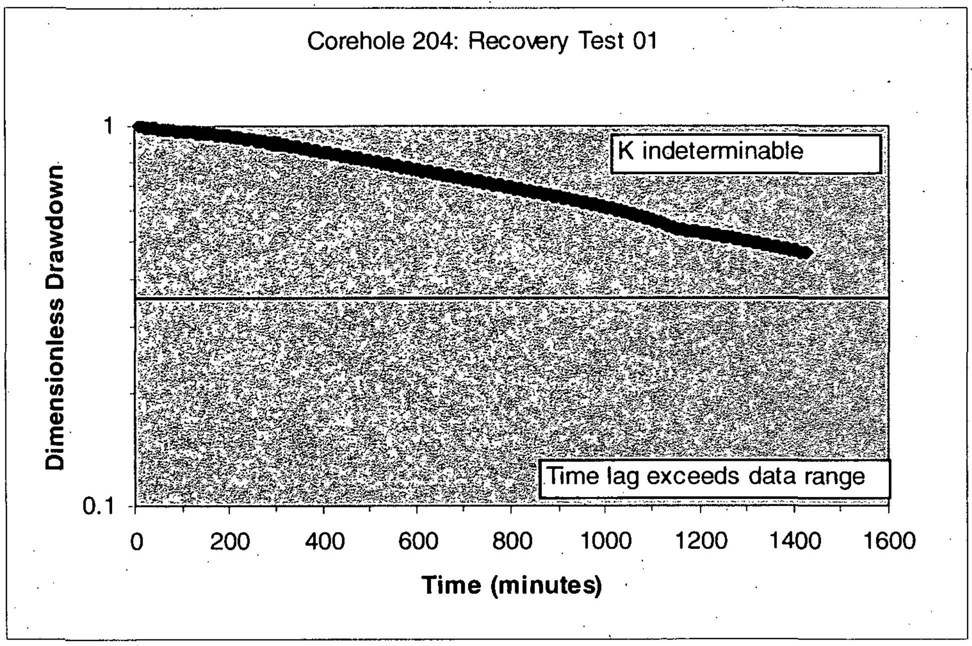

Corehole 203: Recovery Test 02
K = 2.6e-06 cm/sec
Time lag = 90 min
Dimensionless Drawdown
1
0.1
0.01
0
100
200
300
400
500
600
Time (minutes)



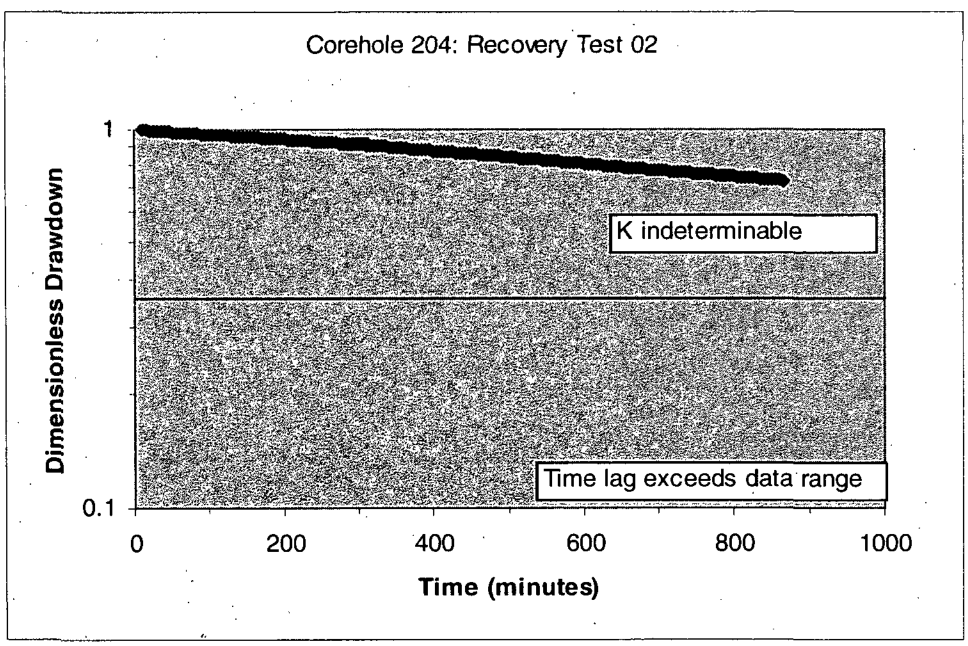
Corehole 203: Recovery Test 03
K = 2.6e-06 cm/sec
Time lag = 90 min
Dimensionless Drawdown
1
0.1
0.01
0
100
200
300
400
500
600
Time (minutes)



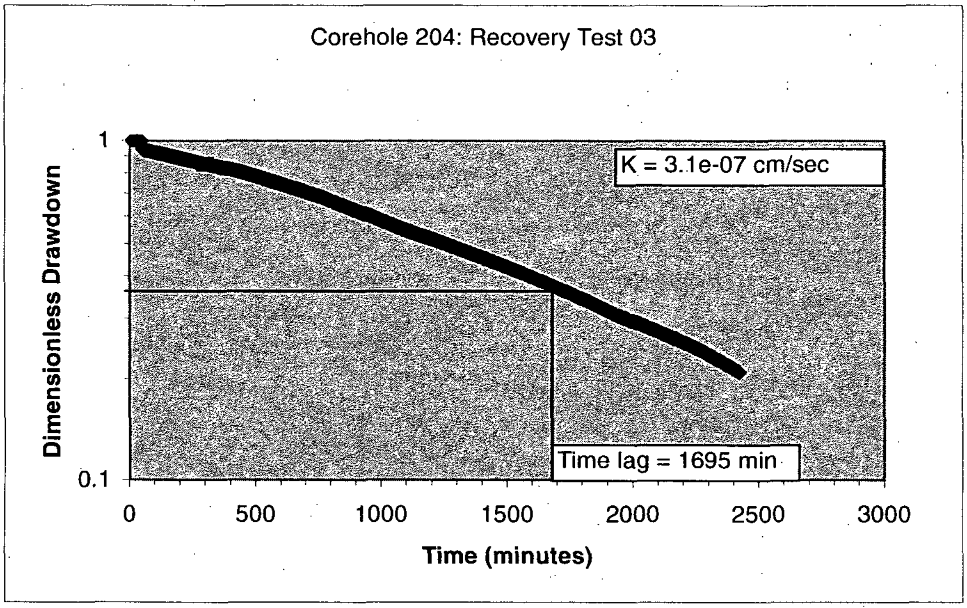
Corehole 203: Recovery Test 04
K = 2.3e-06 cm/sec
Time lag = 100 min
Dimensionless Drawdown
1
0.1
0.01
0
100
200
300
400
500
600
Time (minutes)

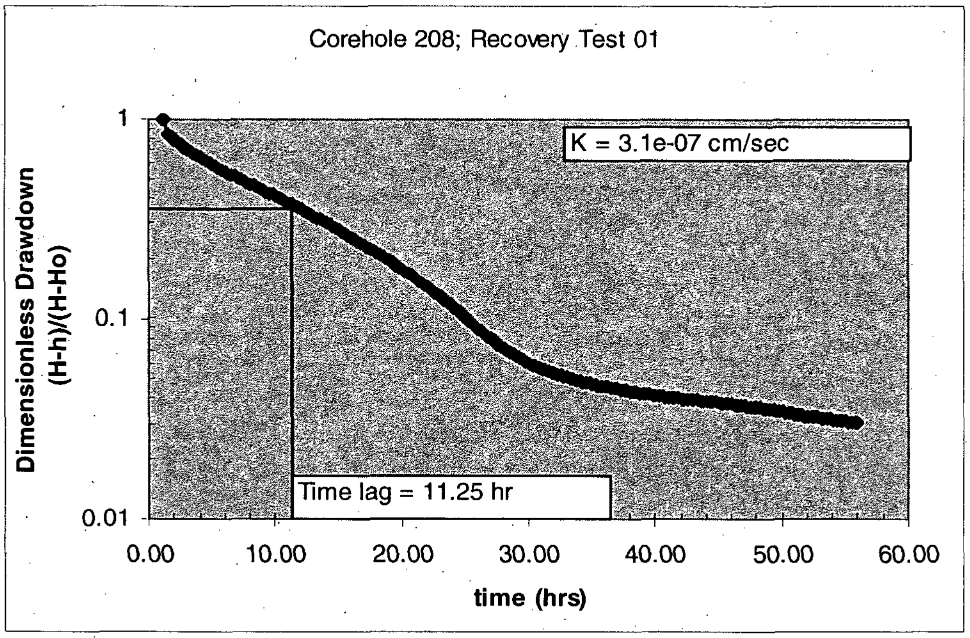


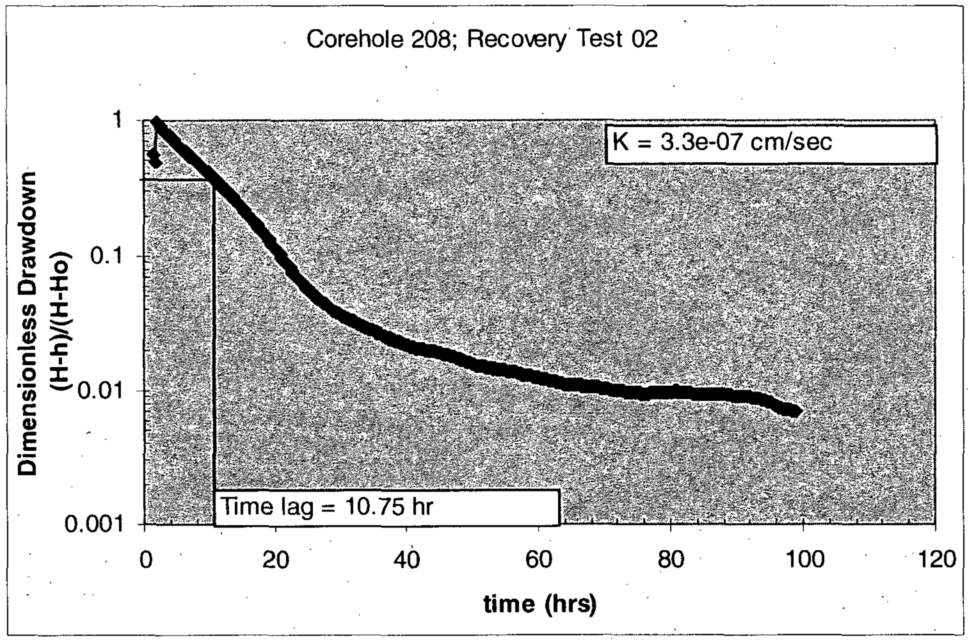
Corehole 204: Recovery Test 01
K indeterminable
Time lag exceeds data range
Dimensionless Drawdown
1
0.1
0
200
400
600
800
1000
1200
1400
1600
Time (minutes)

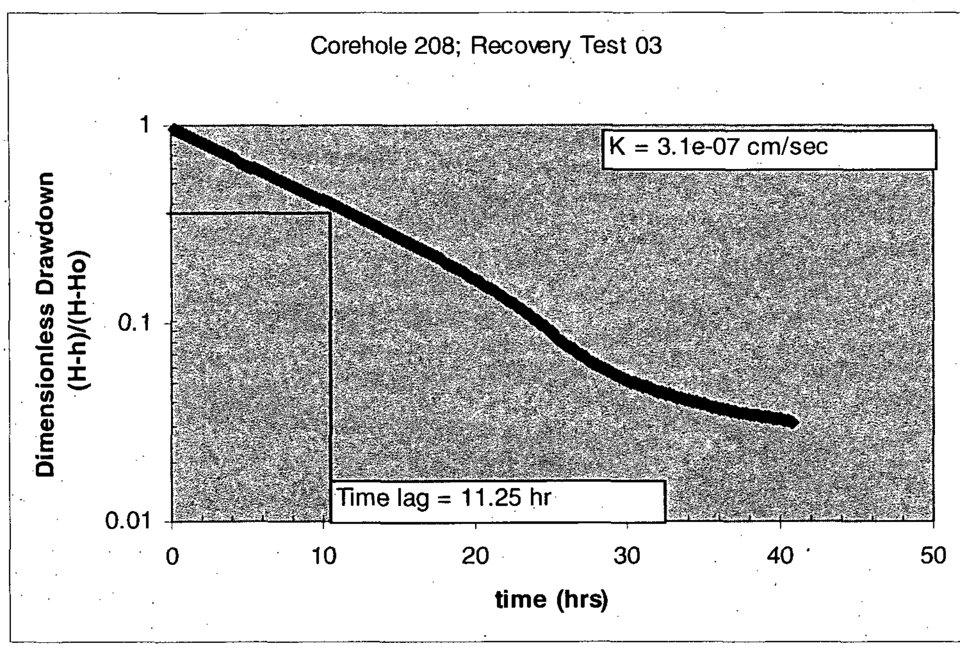


Corehole 204: Recovery Test 02
K indeterminable
Time lag exceeds data range
Dimensionless Drawdown
1
0.1
0
200
400
600
800
1000
Time (minutes)


Corehole 204: Recovery Test 03
K = 3.1e-07 cm/sec
Time lag = 1695 min
Dimensionless Drawdown
Time (minutes)
1
0.1
0
500
1000
1500
2000
2500
3000


Corehole 208; Recovery Test 01
K = 3.1e-07 cm/sec
Time lag = 11.25 hr
Dimensionless Drawdown
(H-h)/(H-Ho)
time (hrs)
1
0.1
0.01
0.00
10.00
20.00
30.00
40.00
50.00
60.00


Corehole 208; Recovery Test 02
K = 3.3e-07 cm/sec
Time lag = 10.75 hr
Dimensionless Drawdown (H-h)/(H-Ho)
1
0.1
0.01
0.001
0
20
40
60
80
100
120
time (hrs)


Corehole 208; Recovery Test 03
K = 3.1e-07 cm/sec
Time lag = 11.25 hr
Dimensionless Drawdown (H-h)/(H-Ho)
1
0.1
0.01
0
10
20
30
40
50
time (hrs)

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-03-2006-2-06-00 **Discipline:** Hydrologic Properties **No. of Sheets:** 8
Doc. No.: X0140400

Location: Attachment 3, Appendix C

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Field Permeability "Packer" Testing

Sources of Data:

Packer testing records obtained at the Crescent Junction Site during the field characterization project November 2005 through January 2006.

Sources of Formulae and References:

U.S. Bureau of Reclamation (USBR), 1998. *Engineering Geology Field Manual*, Second Edition, U.S. Department of the Interior, Washington D.C., (Chapter 17 "Water Testing for Permeability," available online at: www.usbr.gov/pmts/geology/geolman2/Chapter17.pdf).

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: Mark Kautsky 5-31-07 (Name, Date) **Checked by:** (Name) 5/30/07 (Date)

Dave Peterson 5/31/07 (Name, Date)

(Name) 31 May 07 (Date)

(Name) 5/31/07 (Date)

Approved by: (Name) 5/31/07 (Date)

No text for this page

Problem Statement:

During November 2005 through January 2006, the U.S. Department of Energy (DOE) contractor S.M. Stoller Corporation completed field permeability "packer" tests at the Crescent Junction Disposal Site. The objectives of these tests were to:

- Estimate the horizontal hydraulic conductivity of the weathered and unweathered sections of the Mancos Shale that underlie the disposal site.
- Evaluate the hydrogeologic suitability of the proposed disposal site.
- Establish design parameters for the proposed disposal site.
- Help formulate a water resources protection strategy for the proposed disposal site.

Method of Solution:

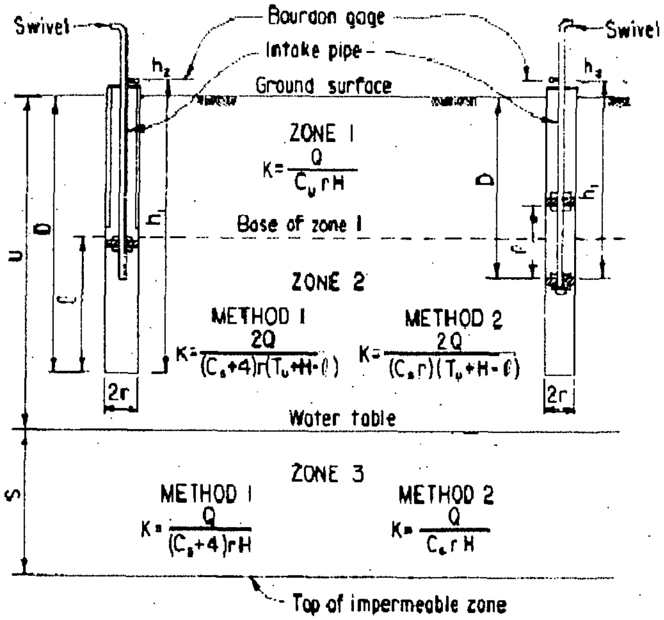
Packer tests are conducted in a corehole after the hole is cored and flushed with clear water. The method consists of lowering the testing apparatus into the corehole, inflating the packers so that they fit snugly against the wall of the corehole, and then injecting water under pressure into the test interval. The flow of water into the test interval is measured with a flow meter. The flow rate of water into the test interval is measured as a function of the injection pressure. This provides a measure of the hydraulic conductivity of the rock formation.

HQ-wire line core drilling was used to advance three shallow coreholes into the weathered Mancos Shale to a depth of 40 feet (ft) below the ground surface, and ten coreholes into the relatively unweathered Mancos Shale to a depth of 300 ft below the land surface. Corehole logs that describe the lithologic materials encountered during drilling are presented in the "Corehole Logs" calculation (Attachment 5, Appendix A).

Packer test methods are described in the U.S. Bureau of Reclamation Engineering Geology Field Manual (USBR 1998). Several methods are potentially applicable, depending on the zone that is being tested. The zone determinations and packer configurations are defined in Figure 1. According to Figure 1, there are three potential zones in the subsurface and two potential packer configurations. The packer tests for this project were done in all three zones, and both packer configurations were used. A single-packer system was used in the shallow coreholes (0211, 0212, and 0213) and each of the single-packer tests was performed above the water level in zone 1. Dual-packer tests were completed in the deep coreholes (0204 and 0208) in zones 1, 2, and 3, above and below the water table. Figure 2 presents the locations where the packer tests were undertaken. A *Moyno* pump was used to deliver steady, even pressure to the test interval. Totalized flows were read from a mechanical, inline flow meter until they stabilized.

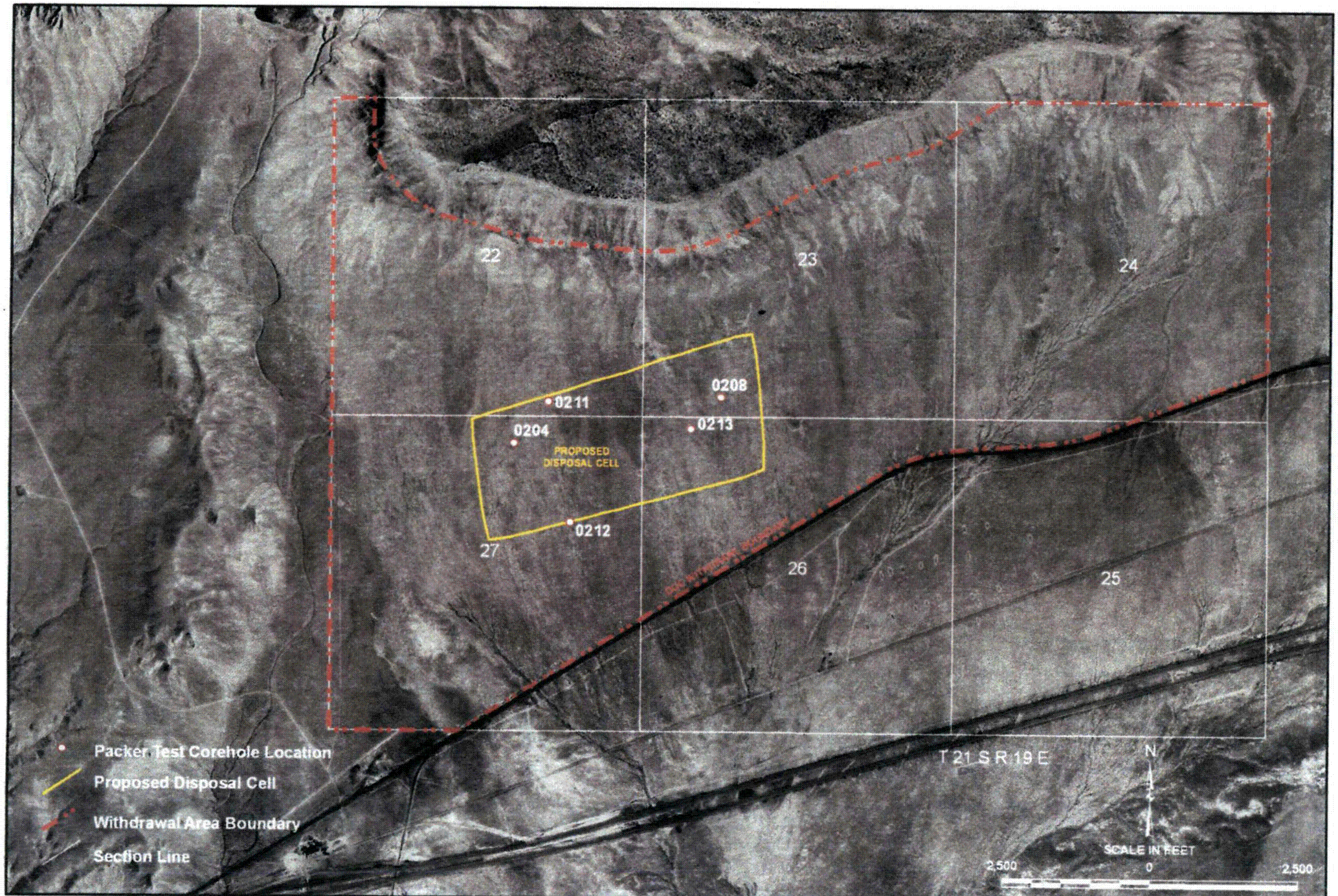
In coreholes 0211, 0212, and 0213, the tests were done in the shallow, weathered-bedrock intervals while the hole was being advanced. Water for coring and washing the selected test interval was obtained from the Thompson Springs municipal water supply system. The single-packer assembly was lowered through the drill rod into the shallow test interval using a wire line packer system (Figure 3). A 10-ft-long test interval was used for each injection test. The packer was inflated to 100 pounds per square inch (lb/in^2) to isolate each test interval.

Test intervals 20–30 ft and 30–40 ft below ground surface were selected to evaluate the hydraulic properties of the weathered Mancos Shale. Guidance provided in the Manual (USBR 1998, p.127) recommends that relatively homogeneous but fractured rock (such as the weathered Mancos Shale) can be tested at 1 lb/in^2 per ft of test-interval depth. Consequently, water was injected at 5-lb/in^2, 10-lb/in^2, and again at 5-lb/in^2 gage pressure at the surface. When combined with the hydrostatic pressure between the pressure gage and the test interval, the total head was less than the critical pressures that could have damaged the formation.



K = coefficient of permeability, feet per second under a unit gradient
Q = steady flow into well, ft^3/s
$H = h_1 + h_2 - L$ = effective head, ft
h_1 (above water table) = distance between Bourdon gage and bottom of hole for method 1 or distance between gage and upper surface of lower packer for method 2, ft
h_1 (below water table) = distance between gage and water table, ft
h_2 = applied pressure at gage, 1 lb/in^2 = 2.307 ft of water
L = head loss in pipe due to friction, ft; ignore head loss for $Q<4$ gal/min in $1\frac{1}{4}$-inch pipe; use length of pipe between gage and top of test section for computations
$X = \frac{H}{T_u}(100)$ = percent of unsaturated stratum
ℓ = length of test section, ft
r = radius of test hole, ft
C_u = conductivity coefficient for unsaturated materials with partially penetrating cylindrical test wells
C_s = conductivity coefficient for semi-spherical flow in saturated materials through partially penetrating cylindrical test wells
U = thickness of unsaturated material, ft
S = thickness of saturated material, ft
$T_u = U - D + H$ = distance from water surface in well to water table, ft
D = distance from ground surface to bottom of test section, ft
a = surface area of test section, ft^2; area of wall plus area of bottom for method 1; area of wall for method 2
Limitations:
$Q/a \leq 0.10$, $S \geq 5\ell$, $\ell \geq 10r$, thickness of each packer must be $\geq 10r$ in method 2

Figure 1. Illustration of Potential Packer Test Configurations, Solution Methods, and Explanation of Mathematical Symbols (modified after Bureau of Reclamation 1998, Figure 17-5)



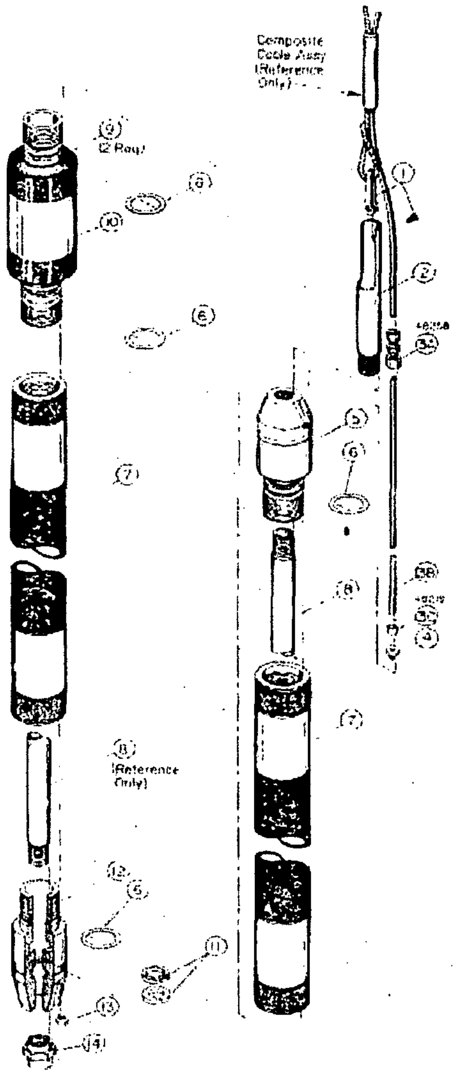
N:\MOA\999\0020\07\009\X01375\X0137500.mxd coatesc 5/22/2007 8:13:22 AM

X0137500

Figure 2. Packer Test Corehole Locations

BOART LONGYEAR Packers Wi

Wireline Packer



HQ Wireline Packer Type II			
1-14	48228	HQ Packer Assembly Type II	1
1	44018	Shakle	1
2	48239	Riser Tube	1
3	48218	Inflation Tube Jumper	1
4	44004	Adapter	1
5	48230	Fixed Head	1
6	48231	O-Ring	4
7	48232	Gland Element	2
8	48233	Center Tube	1
9	48235	Union Ring	2
10	48234	Gland Union	1
11	48237	Seal	2
12	48236	Sliding Head	1
13	44034	Plug	1
14	48238	Connector	1

Figure 3. Schematic Diagram of Single Wire Line Packer System Used on the Crescent Junction Project

The dual packer tests were done in the deep coreholes and were intended to test representative sections of the competent Mancos Shale. The tests began in the deepest part of the corehole and proceeded upward until three depth intervals were tested. The test intervals were selected on the basis of visual observations of the rock core retrieved from the corehole, which indicated a stratigraphic contact probably exists between the Prairie Canyon and Blue Gate Members of the Mancos Shale at a depth of approximately 100 ft in corehole 0204 and 110 ft in corehole 0208.

Each test interval was 12 ft in length. Test intervals were chosen to straddle that contact and ascertain if any observable differences exist in the hydraulic conductivity of those units. A test interval was also chosen near the bottom of each corehole. The diameter of each corehole was nominally 3.9 inches. Water for coring and washing the selected test interval was obtained either from the Thompson Springs or the

Moab municipal water supply system. Each interval was tested at multiple gauge pressures ranging from 5 to 30 lb/in^2. Because the flows were very low or nonexistent, a test duration of up to 30 minutes was used whenever practicable. The dual-packer system was inflated to pressures ranging from 230 to 300 lb/in^2 prior to testing each interval.

Assumptions:

- Injected water flows directly into the test interval without short-circuiting through the packer seal.
- For flows exceeding 4 gallons per minute (gpm), friction losses through the drill pipe follow the Pressure Loss Curve provided by the subcontractor, Layne Geoconstruction.
- Solutions provided in the Manual (USBR 1998) are applicable to the field conditions at the Crescent Junction Disposal Site.
- The analysis methods presented in the Manual (USBR 1998) are equally valid both above and below the water table.

Calculations:

Calculations are attached in Appendix A. Table 1 provides a summary of the test results for this project.

Discussion:

Table 1 presents a summary of the packer test results. The horizontal hydraulic conductivity values range from 10^{-3} centimeters per second (cm/s) to less than 10^{-7} cm/s. The hydraulic conductivity of the weathered bedrock is approximately 4 orders of magnitude higher than the unweathered bedrock. Based on the packer tests, the relatively high hydraulic conductivity in the weathered Mancos Shale extends to a depth of at least 40 ft below ground surface. At a depth of 80 to 130 ft below land surface, the hydraulic conductivities are less than 10^{-7} cm/s. The transition between weathered and unweathered bedrock probably correlates to the fracture intensity. Optical televiewer logs prepared for this project suggest that the transition between weathered and unweathered bedrock occurs at a depth of approximately 50 to 60 ft below the surface.

Table 1. Summary of Field-Permeability "Packer" Test Results for the Crescent Junction Site

Test Interval: Hole ID @ Depth (ft)	Calculated Permeability (cm/s) @ Injection Pressure (lb/in^2)				
	Test 1	Test 2	Test 3	Test 4	Test 5
Dual-Packer Tests: Unweathered Mancos Shale†					
0204 @ 80 to 92	J 1.3×10^{-8} @ 10	3.9×10^{-7} @ 20	J 9.6×10^{-9} @ 30	6.6×10^{-7} @ 20	J 1.3×10^{-8} @ 10
0204 @ 110 to122	J 7.5×10^{-9} @ 10	9.1×10^{-8} @ 20	4.2×10^{-7} @ 30	J 9.1×10^{-8} @ 20	J 7.5×10^{-9} @ 10
0204 @ 283 to 295	J 8.9×10^{-9} @ 5	1.2×10^{-6} @ 10	2.6×10^{-6} @ 20	J 1.1×10^{-8} @ 10	J 1.2×10^{-8} @ 5
0208 @ 90 to 102	J 6.0×10^{-9} @ 10	J 7.7×10^{-9} @ 20	J 2.2×10^{-9} @ 30	J 7.7×10^{-9} @ 20	J 6.0×10^{-9} @ 10
0208 @ 121 to 133	J 8.0×10^{-9} @ 10	J 1.4×10^{-8} @ 20	7.5×10^{-7} @ 30	J 1.4×10^{-8} @ 20	J 8.0×10^{-9} @ 10
0208 @ 282 to 294	6.3×10^{-7} @ 5	6.0×10^{-7} @ 10	J 6.0×10^{-9} @ 20	J 5.7×10^{-9} @ 10	2.1×10^{-7} @ 5
Single-Packer Tests: Weathered Mancos Shale‡					
0211@ 20 to 30	1.4×10^{-3} @ 5	1.3×10^{-3} @ 5	1.7×10^{-3} @ 5		
0211 @ 30 to 40	1.4×10^{-3} @ 5				
0212 @ 20 to 30	1.6×10^{-3} @ 5	1.8×10^{-3} @ 10	2.0×10^{-3} @ 5		
0212 @ 30 to 40	2.5×10^{-3} @ 5	2.3×10^{-3} @ 10	2.5×10^{-3} @ 5		
0213 @ 20 to 30	2.4×10^{-3} @ 5	2.2×10^{-3} @ 10	2.2×10^{-3} @ 5		
0213 @ 30 to 40	2.3×10^{-3} @ 5	2.6×10^{-3} @ 10	2.5×10^{-3} @ 5		

Notes:
Gray fields indicate no additional data collected at that test interval.
J flag represents the quantitation limit for a no-flow test.
† Geometric mean of unweathered Mancos Shale: 3.5×10^{-8} cm/s
‡ Geometric mean of weathered Mancos Shale: 2.0×10^{-3} cm/s

Conclusion and Recommendations:

Results from the packer tests illustrate that the hydraulic conductivity of the Mancos Shale at the Crescent Junction Disposal Site is much lower in the competent bedrock underlying the weathered interval that extends to at least 40 ft beneath the land surface. Below the weathered zone, the hydraulic conductivity of the Mancos Shale decreases by approximately 4 orders of magnitude.

Computer Source:

Not applicable

Appendix A

Copies of Packer Testing Raw-Data Sheets and Analysis Sheets

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization Date: 11/21/05

Field Representative: M. Kautsky Borehole No. 211 Total Depth: 30 ft.

Depth to Water (TOC): ± 120 ft. Borehole Cleaned? Yes X No____ Date: 11-21-05

Test Interval (BGL): from 20 to 30 ft. Swivel/Elbow Height (AGL) 5'

Conductor Pipe, Type and Size: HQ

Time	Gauge Pressure	Flow Meter Reading	
~~12:17~~ ∅	~~5 psi~~	34356	
12:19	5 psi	34376	12 gpm
12:21	5 psi	34400	12½ gpm
12:23	5 psi	34425	15 gpm
12:24	5 psi	34440	16 gpm
12:25	5 psi	34456	16.2 gpm
12:28	5 psi	34504.5	22.5 "
12:29	5 psi	34527	19.5 "
12:30	5 psi	34546.5	22 "
~~12:32~~ 12:31	5 psi	34568.5	22.2
12:~~32~~33	5 psi	34613	22.7
12:35	5 psi	34658.5	

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization Date: 11-21-05

Field Representative: M. Kautsky Borehole No. 211 Total Depth: 30 ft

Depth to Water (TOC): 12.6' Borehole Cleaned? Yes X No___ Date: ___

Test Interval (BGL): from 20 to 30 ft. Swivel/Elbow Height (AGL) 5 ft.

Conductor Pipe, Type and Size: HQ

Time	Gauge Pressure	Flow Meter Reading	
12:40	10 psi	34723	20 gpm
12:42	10 psi	34764	26 gpm
12:43	10 psi	34790	26 gpm
12:44	10 psi	~~448~~ 34816	26 gpm
12:45	10 psi	348 42	28 gpm
12:46	10 psi	34870	26.5 gpm
12:48	10 psi	34923	
Ran out of water @ 12:48			
14:08	10 psi	35000	23.5 gpm
14:09	10 psi	35023.5	22 gpm
14:10	10 psi	35045.5	20.5 gpm
14:11	10 psi	35066	21.5 gpm
14:12	10 psi	35087.5	20.5 gpm
14:13	10 psi	35108	22 gpm
14:14	10 psi	35130	22 gpm
14:15	10 psi	35152	22 gpm
14:16	10 psi	35174	

end of 10 psi test

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization Date: 11-21-05

Field Representative: M. Kautzky Borehole No. 211 Total Depth: 30

Depth to Water (TOC): 120 ft Borehole Cleaned? Yes X No ____ Date: 11-21-05

Test Interval (BGL): from 20 to 30 ft. Swivel/Elbow Height (AGL) 5 ft

Conductor Pipe, Type and Size: HQ / HX

Time	Gauge Pressure	Flow Meter Reading	Flow (gpm)
14:19	5 psi	35235	
			21 gpm
14:20	5 psi	35256	
			22 "
14:21	5 psi	35278	
			21 gpm
14:22	5 psi	35299	
			21.5 gpm
14:24	5 psi	35342	
			20.5 gpm
14:25	5 psi	35362.5	
			21.5 gpm
14:26	5 psi	35384	
			22 gpm.
14:27	5 psi	35406	
			19 gpm
14:28	5 psi	35425	
			21 gpm
14:29	5 psi	35446	
			22
		35468	

DATE 1-23-06

JOB NAME Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO. ______ OF ______

PACKER TEST ANALYSES

BOREHOLE : 211

Depth : 20 - 30 ft

Pressure (h_2) : 5psi (11.6 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = 120\text{ ft} - 30\text{ ft} + 44.5\text{ ft} = 134.5\text{ ft}$

$\frac{T_u}{l} = \frac{134.5\text{ ft}}{10\text{ ft}} = \boxed{13.4}$

$H = h_1 + h_2 - L = 35\text{ ft} + 11.6\text{ ft} - 2.1\text{ ft} = 44.5\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{44.5\text{ ft}}{134.5\text{ ft}}(100) = \boxed{33}$

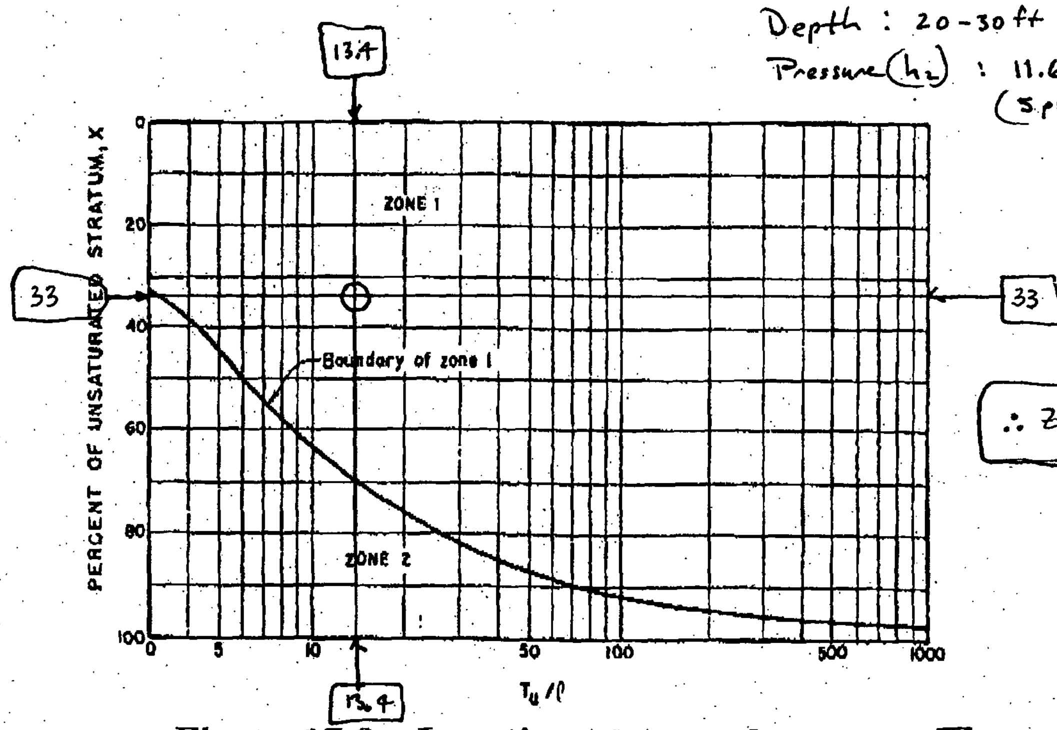
- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

1-30-06

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 211
Depth : 20-30 ft
Pressure (h_2) : 11.6 ft
(5 psi)



∴ Zone 1

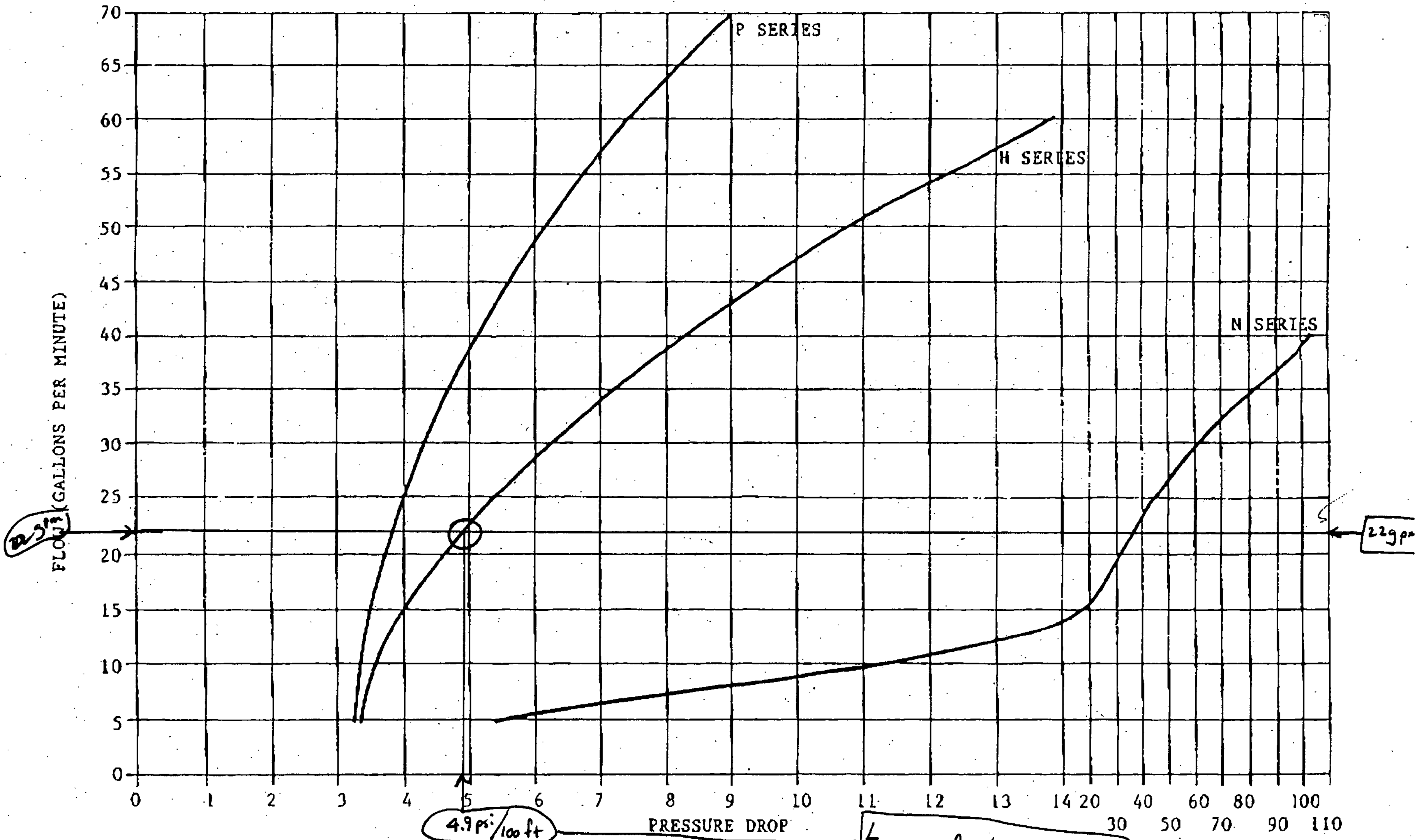
Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{l} = \boxed{13.4}$

$X = \boxed{33}$

A-6

PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From: WIRELINE TYPE II service manual, Boart Longyear.

Borehole: 211
Depth: 20-30 ft
Piezometer: 11.6 ft.

Stoller

PACKER TEST SET-UP SHEET

Zone 1

JOB NO.: ______ DATE: 1-30-06

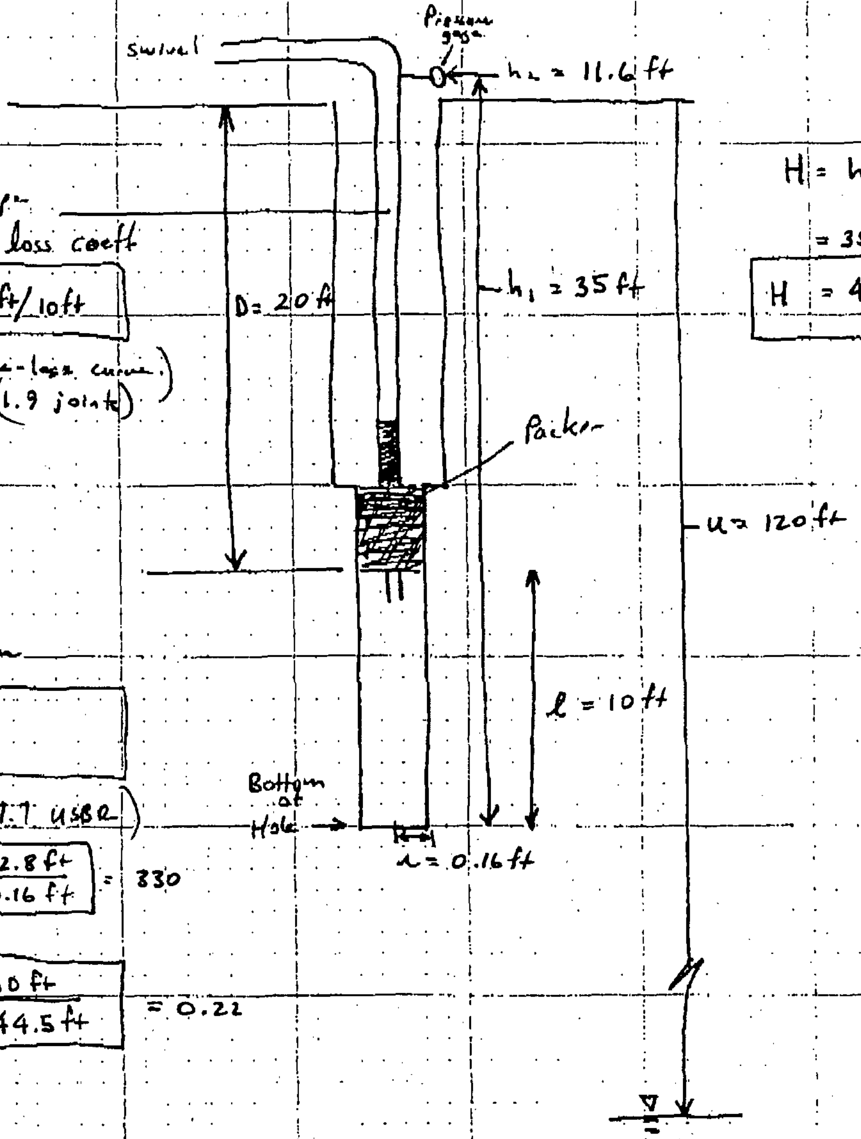
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED: ______

Borehole 211

SHEET NO.: 1 OF ______ Depth 20-30 ft

pressure (h_2) = 5 psi



Obtain L = head loss coeff

$\boxed{L = 1.1 \text{ ft}/10\text{ ft}}$

(from pressure-loss curve)

$L = \left(1.1 \text{ ft}/10\text{ ft}\right)\left(1.9 \text{ joints}\right)$

$L = 2.1$ ft

$H = h_1 + h_2 - L$

$= 35 \text{ ft} + 11.6 \text{ ft} - 2.1 \text{ ft}$

$\boxed{H = 44.5 \text{ ft}}$

Obtain C_u

$\boxed{C_u \approx 150}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{52.8 \text{ ft}}{0.16 \text{ ft}}} = 330$

$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{44.5 \text{ ft}}} = 0.22$

Calculate K:

Method 1,

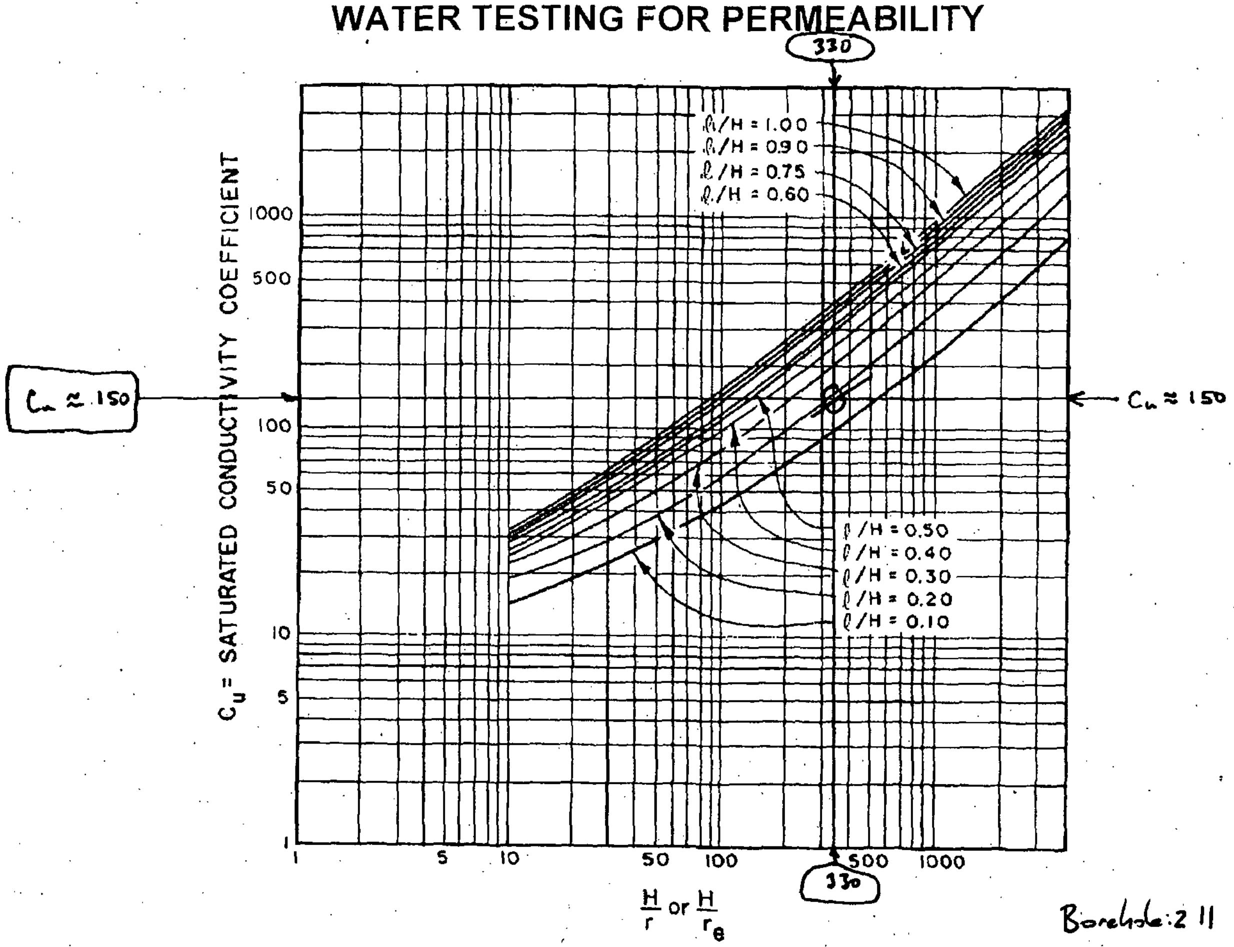
Zone 1,

USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{22 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)}{(150)(0.16 \text{ ft})(44.5 \text{ ft})}$$

$K = 4.0$ ft/day

$K = 1.4 \times 10^{-3}$ cm/sec



Borehole: 2 II
Depth: 20–30 ft
Pressure: 11.6 ft

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

1-23-06

Crescent Junction

M. Kautsky

Packer Test Analyses

Borehole : 211

Depth : 20-30 ft

Pressure (h_2) : 23.1 ft (10 psi)

Unsaturated Zone Calculation:

Definitions:

l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = 120\text{ ft} - 30\text{ ft} + 55.3\text{ ft} = \boxed{145.3}$

$\frac{T_u}{l} = \frac{145.3\text{ ft}}{10\text{ ft}} = \boxed{14.5}$

$H = h_1 + h_2 - L = \boxed{54.9\text{ ft}}$

$X = \frac{H}{T_u}(100) = \frac{54.9\text{ ft}}{145.3\text{ ft}}(100) = \boxed{38}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 211
Depth : 20-30 ft
Pressure (h_2) : 10 psi (23.1 ft)
1-23-06

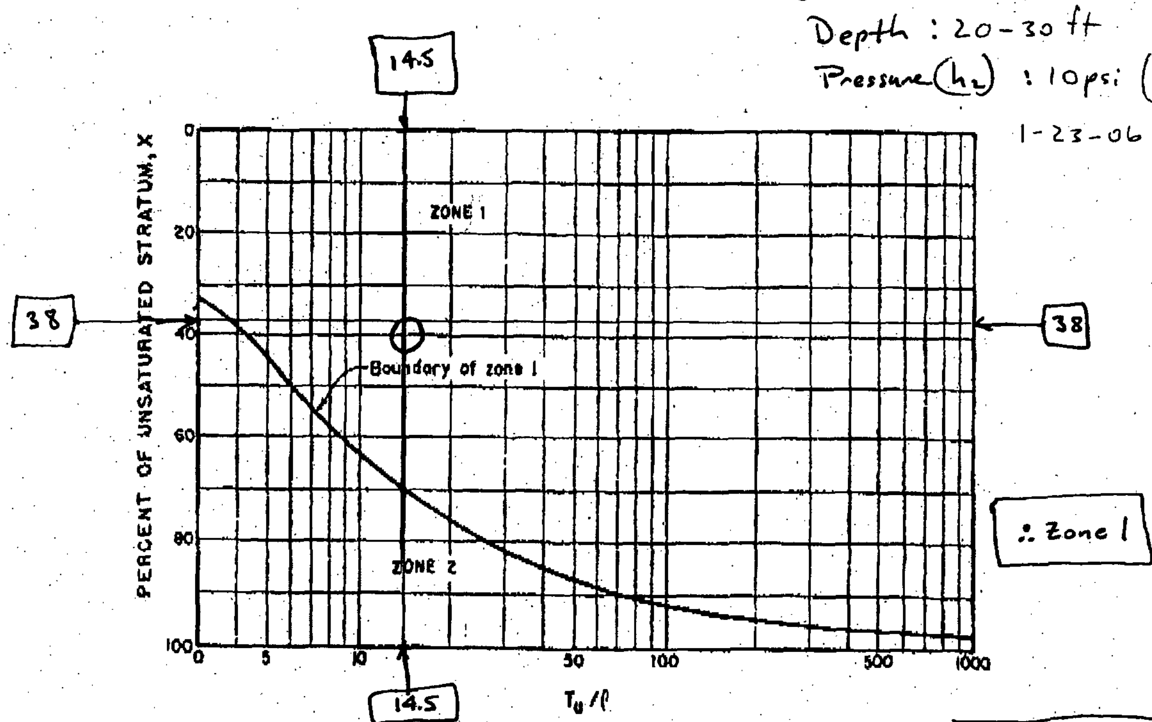


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 14.5$

$X = 38$

Stoller

PACKER TEST SET-UP SHEET

Zone 1

JOB NO.: ______ DATE: 1-30-06

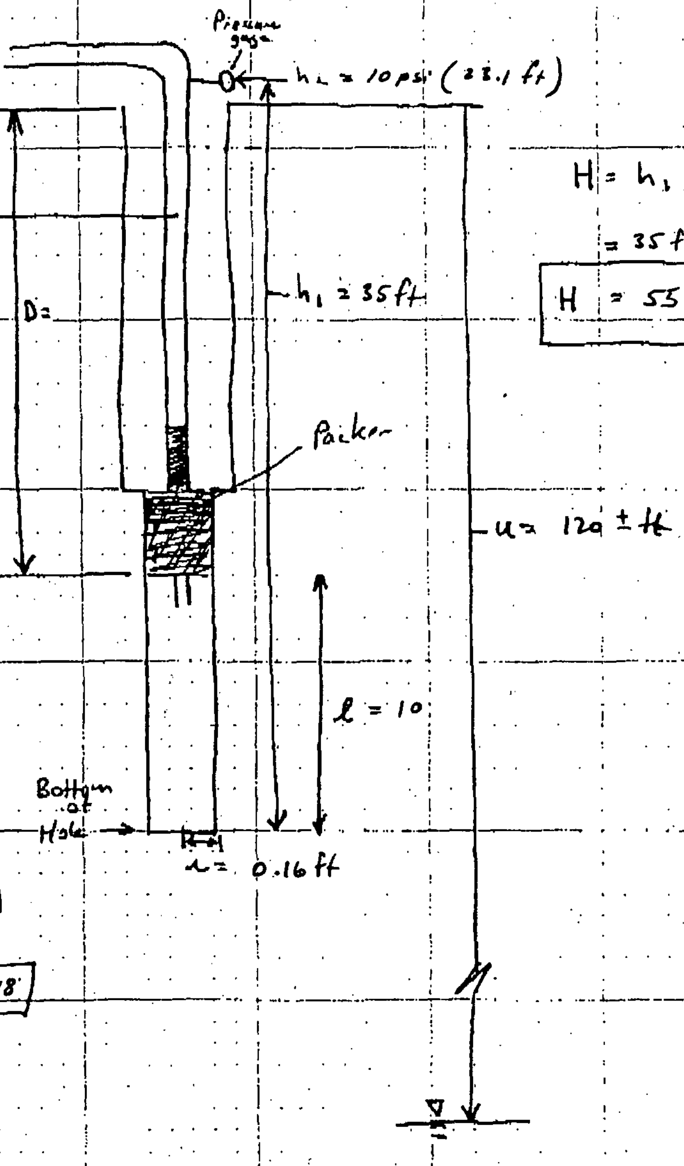
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED: ______

Borehole 211

SHEET NO.: 1 OF ___ Depth 20-30 ft

pressure: 10 psi



$H = h_1 + h_2 - L$

$= 35\ ft + 23.1\ ft - 2.8\ ft$

$\boxed{H = 55.3\ ft}$

Obtain L = head loss coeff

$\boxed{L = 1.1\ ft/10ft}$

(from pressure-loss curve)

$L = \left(1.27\ ft/joint\right)\left(2.5\ joints\right)$

$\boxed{L = 2.8\ ft}$

Obtain C_u

$\boxed{C_u \doteq 130}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{55.3\ ft}{0.16\ ft}} = \boxed{346}$

$\frac{l}{H} = \boxed{\frac{10\ ft}{55.3\ ft}} = \boxed{0.18}$

Calculate K:

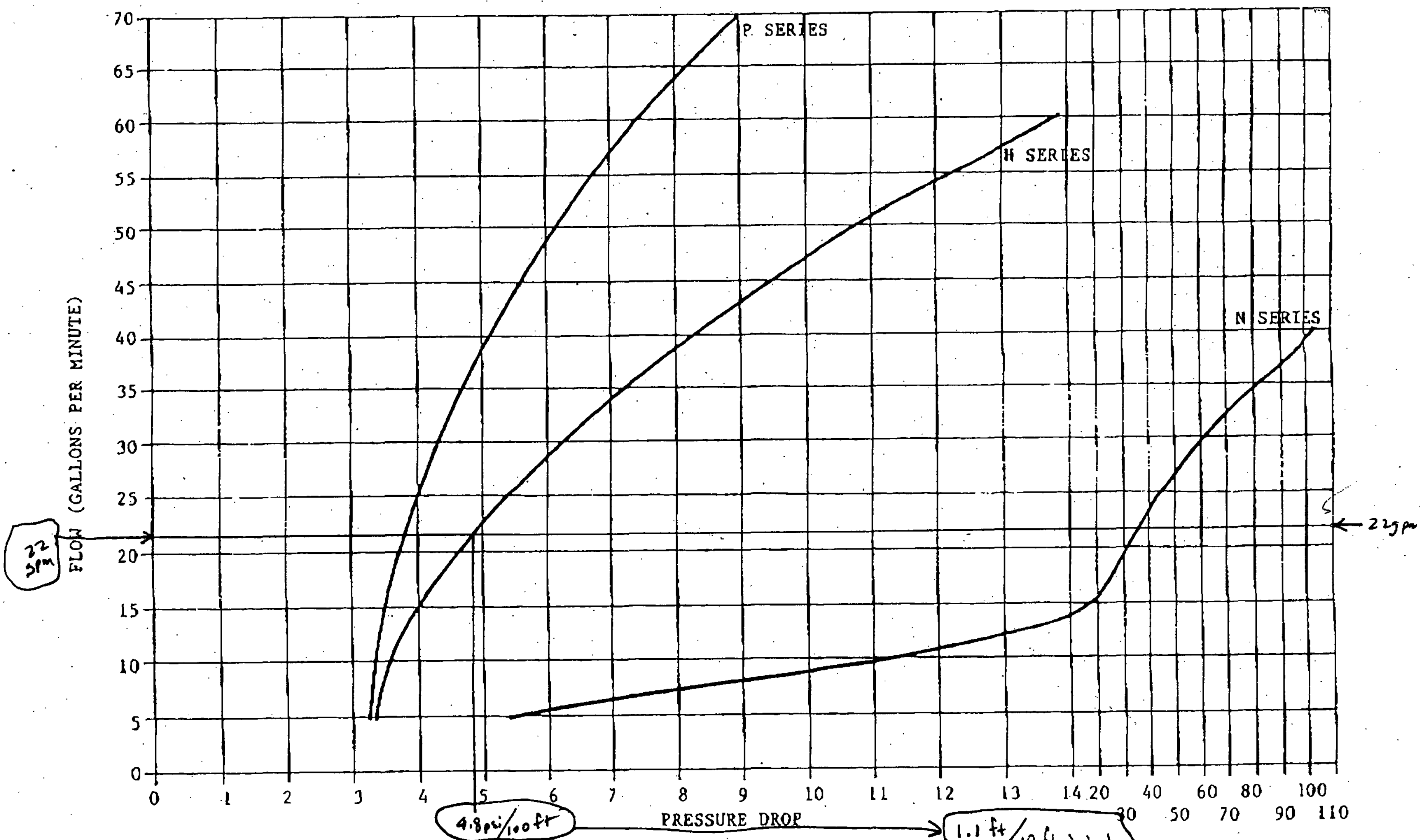
Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{22\ gal}{min}\right)\left(\frac{1440\ min}{d}\right)\left(\frac{ft^3}{7.48\ gal}\right)}{(130)\ (0.16\ ft)\ (55.3\ ft)}$$

$$\boxed{\begin{aligned} K &= 3.7\ ft/day \\ K &= 1.3 \times 10^{-3}\ cm/sec \end{aligned}}$$

A-12

PRESSURE LOSS CURVE

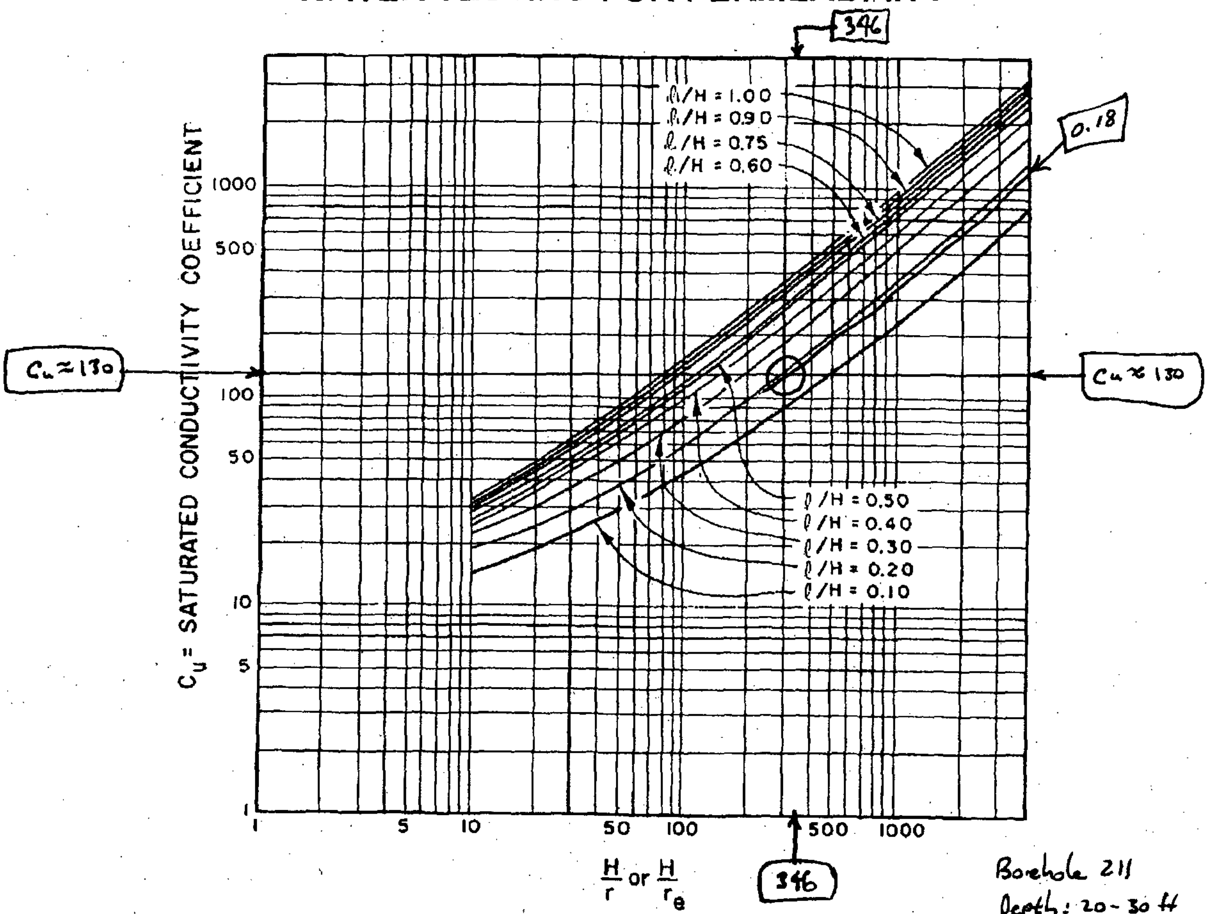


* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From : WIRELINE TYPE II service manual, Boart Longyear.

Borehole 211
Depth 20-30 ft
pressure 10 psi
1-30-06



Borehole 211
Depth: 20-30 ft
pressure: 10 psi
1-30-06

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: *U*, *ℓ*, *r*, h_2, *Q*, and *L* are as given in example 1, *D* = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total *L* is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Seciet

DATE: 1-23-06

JOB NAME: Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO ____ OF ____

PACKER TEST ANALYSES

BOREHOLE : 211

Depth : 20-30 ft

Pressure (h_2) : 5 psi (retest)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$

$T_u = U - D + H = (120 - 30 + 43.8)\text{ ft} = 134\text{ ft}$

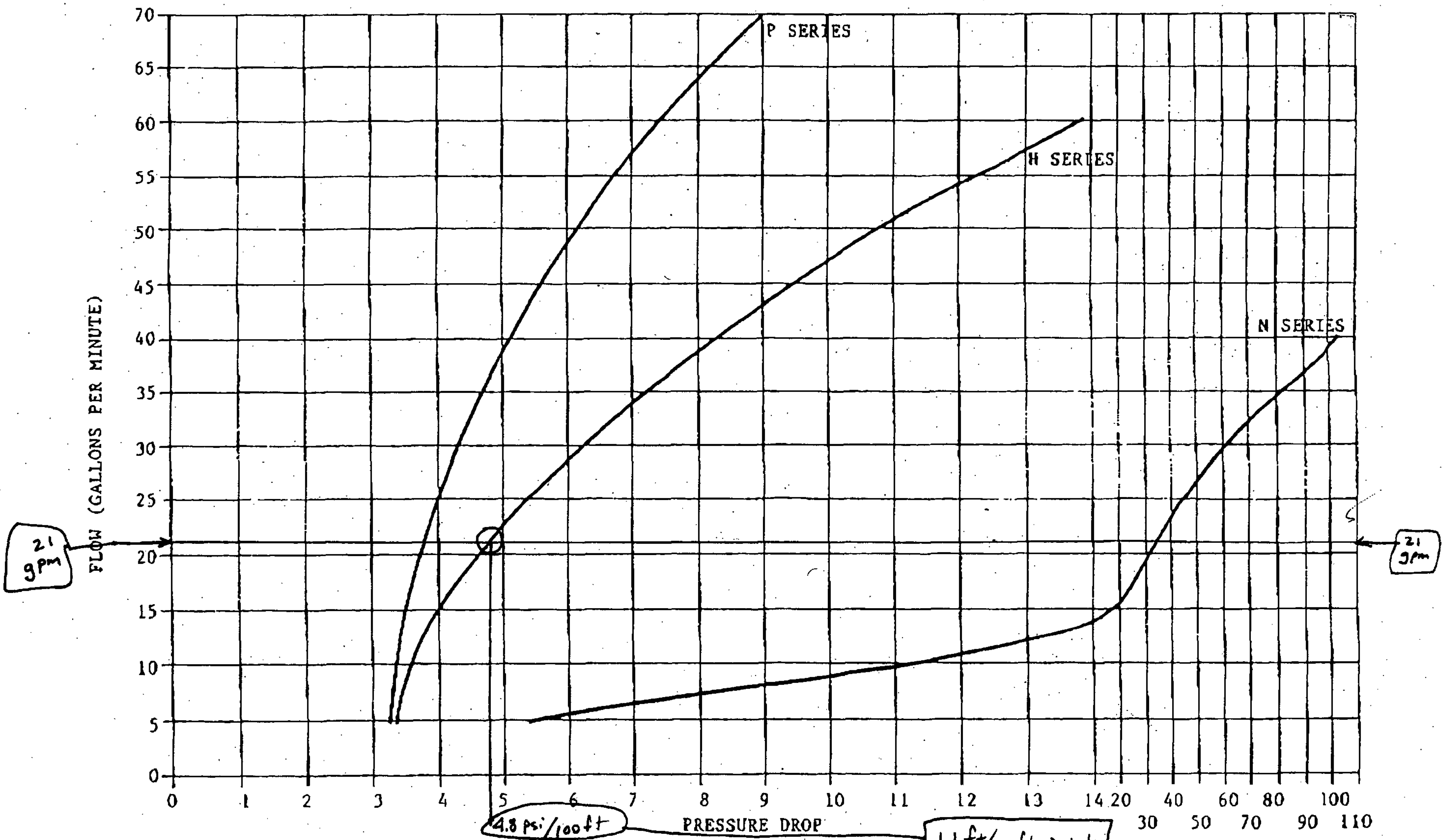
$\frac{T_u}{l} = \frac{134\text{ ft}}{10\text{ ft}} = \boxed{13.4}$

$H = h_1 + h_2 - L = 43.8\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{43.8\text{ ft}}{134\text{ ft}} = \boxed{0.33} = \boxed{33\%}$

A-15

PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From : WIRELINE TYPE II service manual, Boart Longyear.

Borehole 211
Depth 20-30 ft
pressure 5psi (est.) (Actual)
1-30-06

Borehole 211
Depth 20-30 ft
Pressure: 5 psi (ret
1-30-06

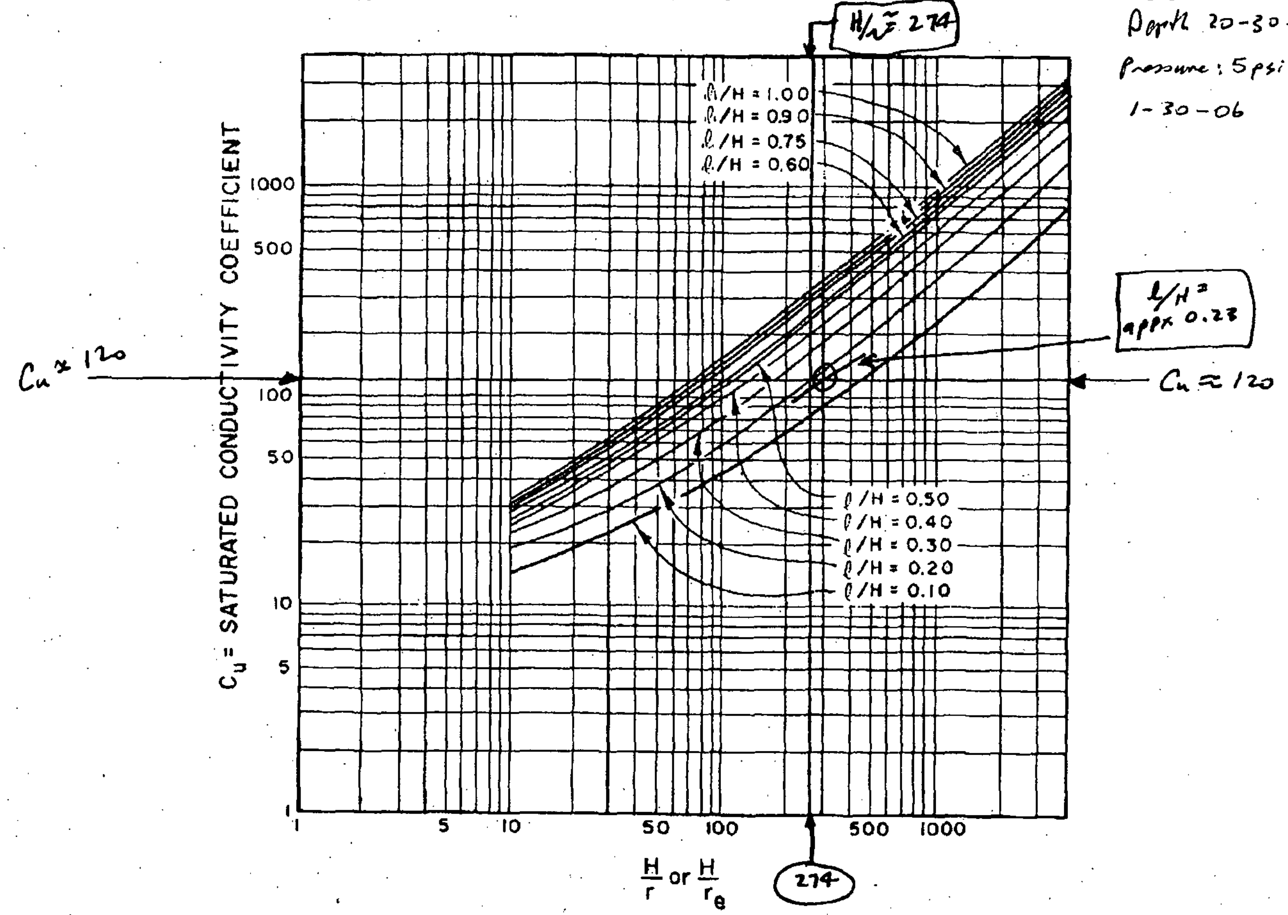


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, $D = 65$ feet, and $h_1 = 72$ feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

$H = 72 + 57.8 - 4.7 = 125.1$ feet

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 211
Depth : 20-30 ft
Pressure (h_2) : 5 psi retest
1-30-06

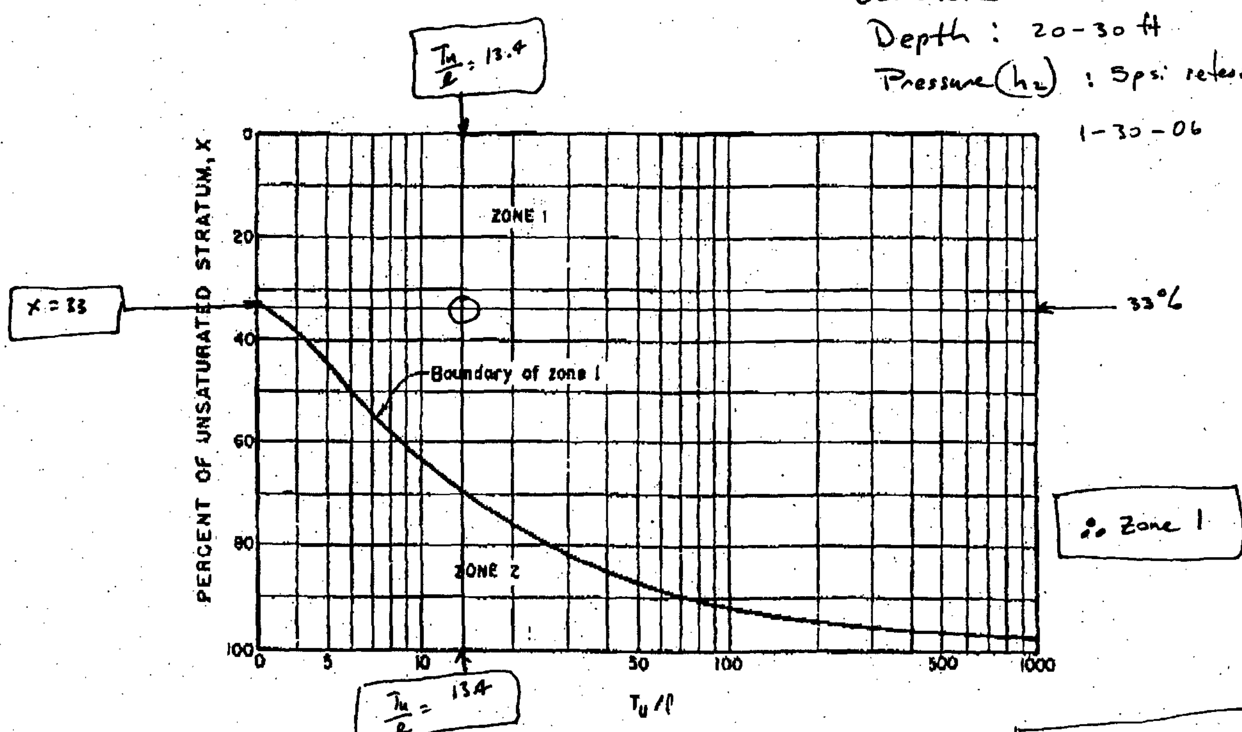


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 13.4$

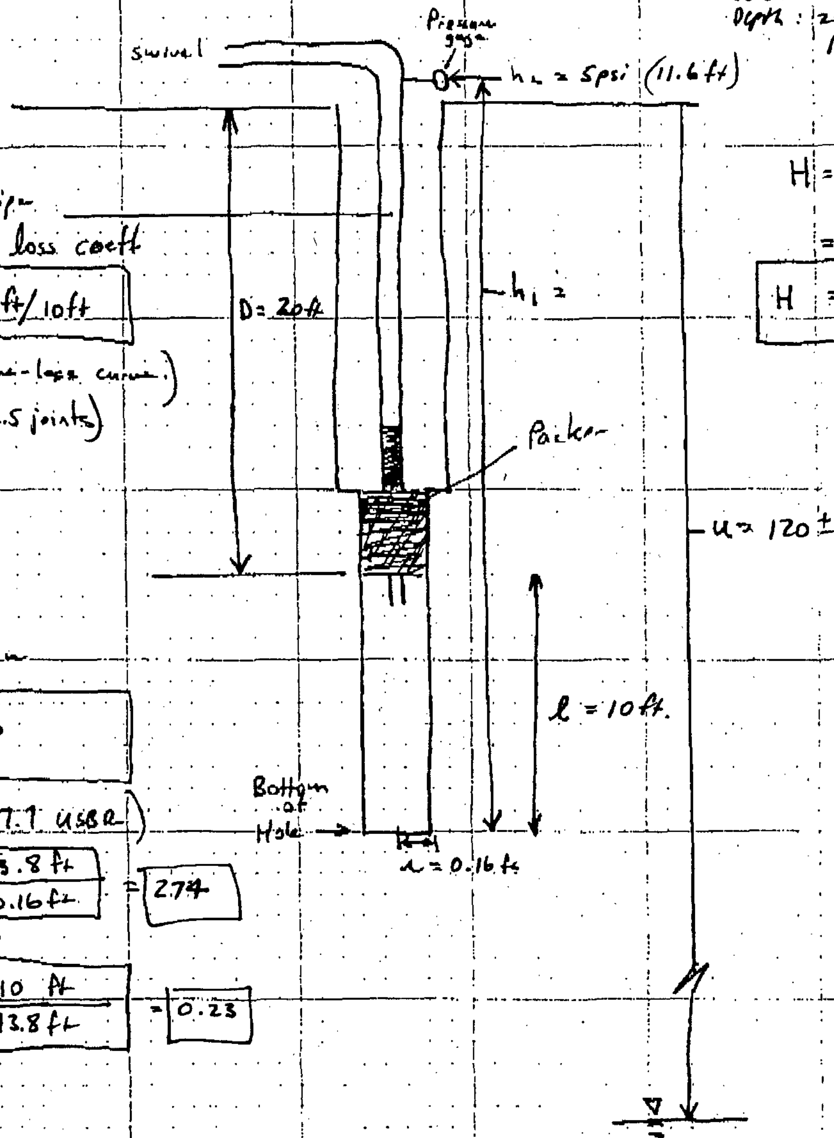
$X = 33$

Stoller

JOB NO.:	DATE: 1-30-06
JOB NAME: Crescent Junction Site	
PREPARED: Mark Kautsky	REVIEWED:
SHEET NO.: 1	OF

PACKER TEST SET-UP SHEET
Zone 1

Borehole 211
Depth : 20 – 30 ft
Pressure : 5 psi (retest)



Injection pipe

Obtain L = head loss coeff

$\boxed{L = 1.1 \text{ ft}/10 \text{ ft}}$

(from pressure-loss curve)

$L = \left(\frac{1.1 \text{ ft}}{\text{joint}}\right)(2.5 \text{ joints})$

$\boxed{L = 2.8 \text{ ft}}$

$H = h_1 + h_2 - L$

$= (35 + 11.6 - 2.8) \text{ ft}$

$\boxed{H = 43.8 \text{ ft}}$

Obtain C_u

$\boxed{C_u \cong 120}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{43.8 \text{ ft}}{0.16 \text{ ft}}} = \boxed{274}$

$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{43.8 \text{ ft}}} = \boxed{0.23}$

Calculate K:
Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u \, r \, H} = \frac{\left(\frac{21 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{day}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(120)(0.16 \text{ ft})(43.8 \text{ ft})}$$

$$\boxed{\begin{array}{l} K = 4.8 \text{ ft/d} \\ K = 1.7 \times 10^{-3} \text{ cm/s} \end{array}}$$

RECORD COPY

Stoller

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization Date: 11-22-05

Field Representative: Mark Kautsky Borehole No. 211 Total Depth : 40 ft

Depth to Water (TOC): 120 ± Borehole Cleaned? Yes X No____ Date: 11-22-05

Test Interval (BGL): from 30 to 40 ft. Swivel/Elbow Height (AGL) 5 ft.

Conductor Pipe, Type and Size: HX pipe / ~~Ack~~ Boart wireline Type II Packer inflated to 100 psi

Time	Gauge Pressure	Flow Meter Reading	Flow (gpm)
09:05	5 PSI	35515	12.5 gpm
09:06	5 PSI	35527.5	16
09:07	5 PSI	35543.5	17
09:08	5 PSI	35560.5	21
09:09	5 PSI	35581.5	24
09:10	5 PSI	35605.5	25
09:11	5 PSI	35630.5	25.5
09:12	5 PSI	35656	24.5
09:13	5 PSI	35680.5	26.5
09:14	5 PSI	35707	26
09:15	5 PSI	35733	26
09:16	5 PSI	35759	26
09:17	5 PSI	35785	

1-23-06

Crescent Junction

M. Kautsky

PACKER TEST ANALYSES

BOREHOLE : 211

Depth : 30-40 ft

Pressure (h_2) : 5 psi: $\boxed{11.6 ft}$

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10 ft$

$T_u = U - D + H = 120 - 30 + 52.1 = 142.1 ft$

$\frac{T_u}{l} = \frac{142.1 ft}{10 ft} = \boxed{14.2}$

$H = h_1 + h_2 - L = 52.1 ft$

$X = \frac{H}{T_u}(100) = \frac{52.1 ft}{142.1 ft}(100) = \boxed{37 \%}$

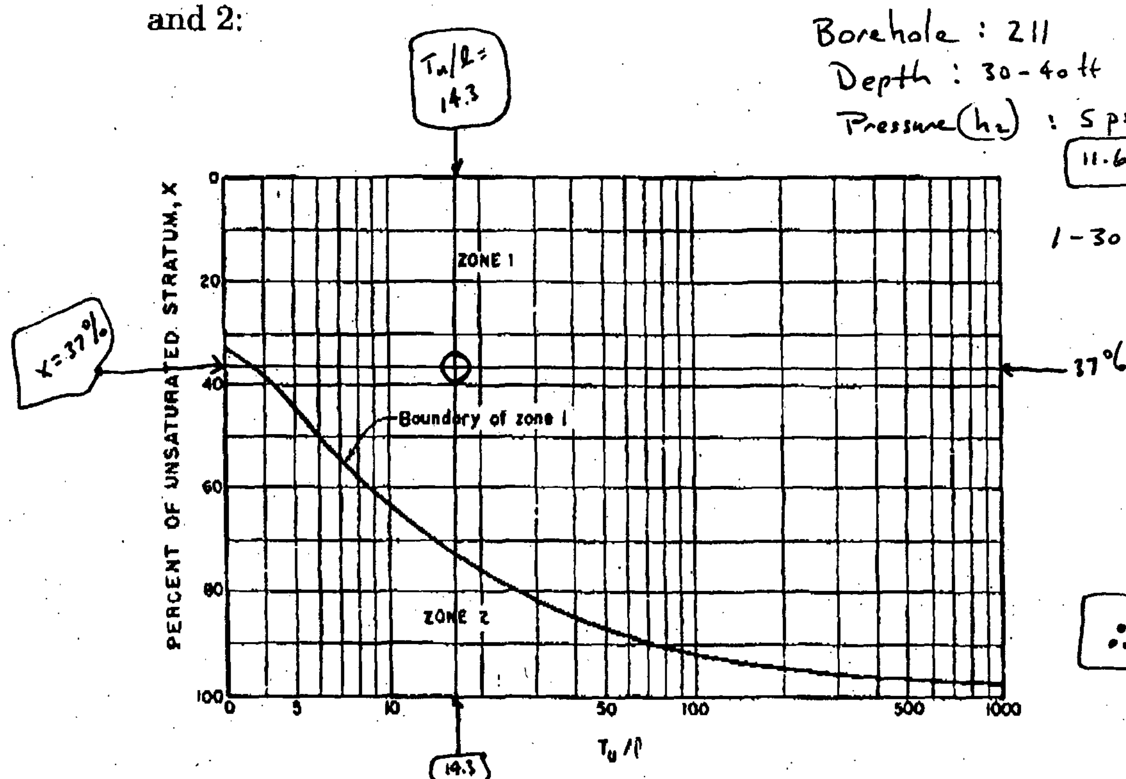
- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 211
Depth : 30 - 40 ft
Pressure (h_2) : 5 psi
$\boxed{11.6 \text{ ft}}$

1-30-06



∴ Zone 1

Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

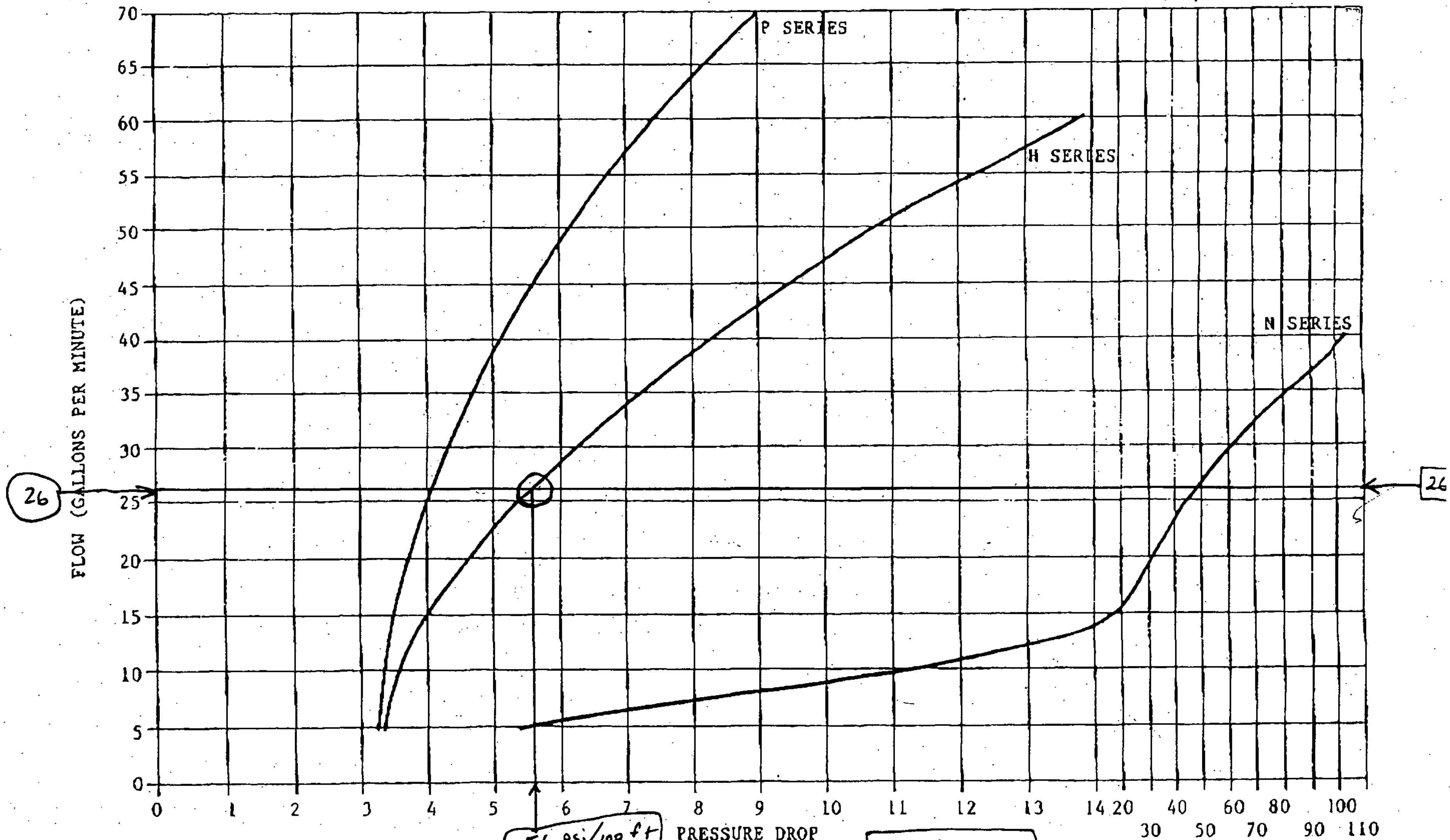
$\frac{T_u}{l} = \boxed{14.3}$

$X = \boxed{37\%}$

A-32

Borehole 211
Depth 30-40 ft
P = 5 psi

PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From: WIRELINE TYPE II service manual, Boart Longyear.

Borehole 211
Depth: 30-40 ft.
pressure: 5 psi
1-30-06

Stoller

PACKER TEST SET-UP SHEET

Zone 1

JOB NO.:

DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

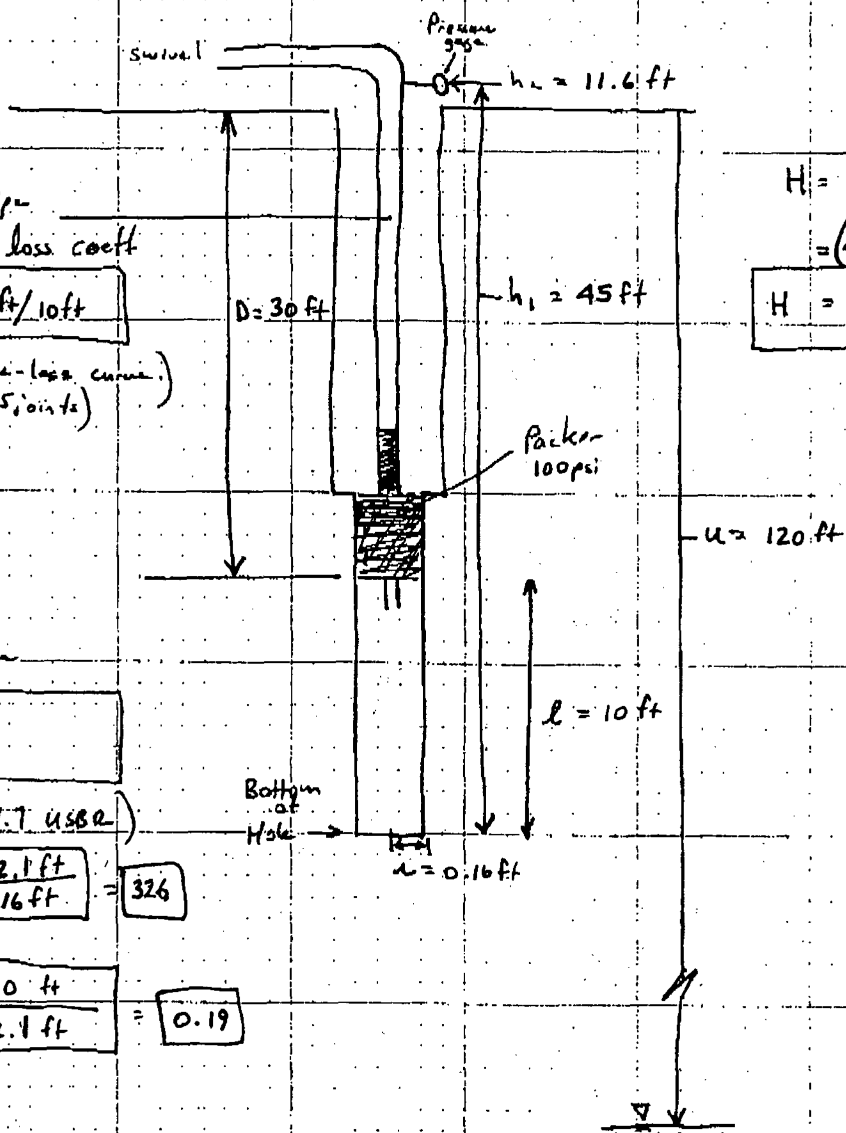
REVIEWED:

SHEET NO.: 1 OF

Corehole 211

Depth 30-40 ft

pressure: 5 psi



Obtain L = head loss coeff

$\boxed{L = 1.29 \text{ ft}/10 \text{ ft}}$

(from pressure-loss curve)

$L = 1.29 \text{ ft}/10 \text{ ft}$ (3.5 joints)

$L = 4.5$ ft

$H = h_1 + h_2 - L$

$= (45 + 11.6 - 4.5)$ ft

$\boxed{H = 52.1 \text{ ft}}$

Obtain C_u

$\boxed{C_u \cong 150}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{52.1 \text{ ft}}{0.16 \text{ ft}}} = \boxed{326}$

$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{52.1 \text{ ft}}} = \boxed{0.19}$

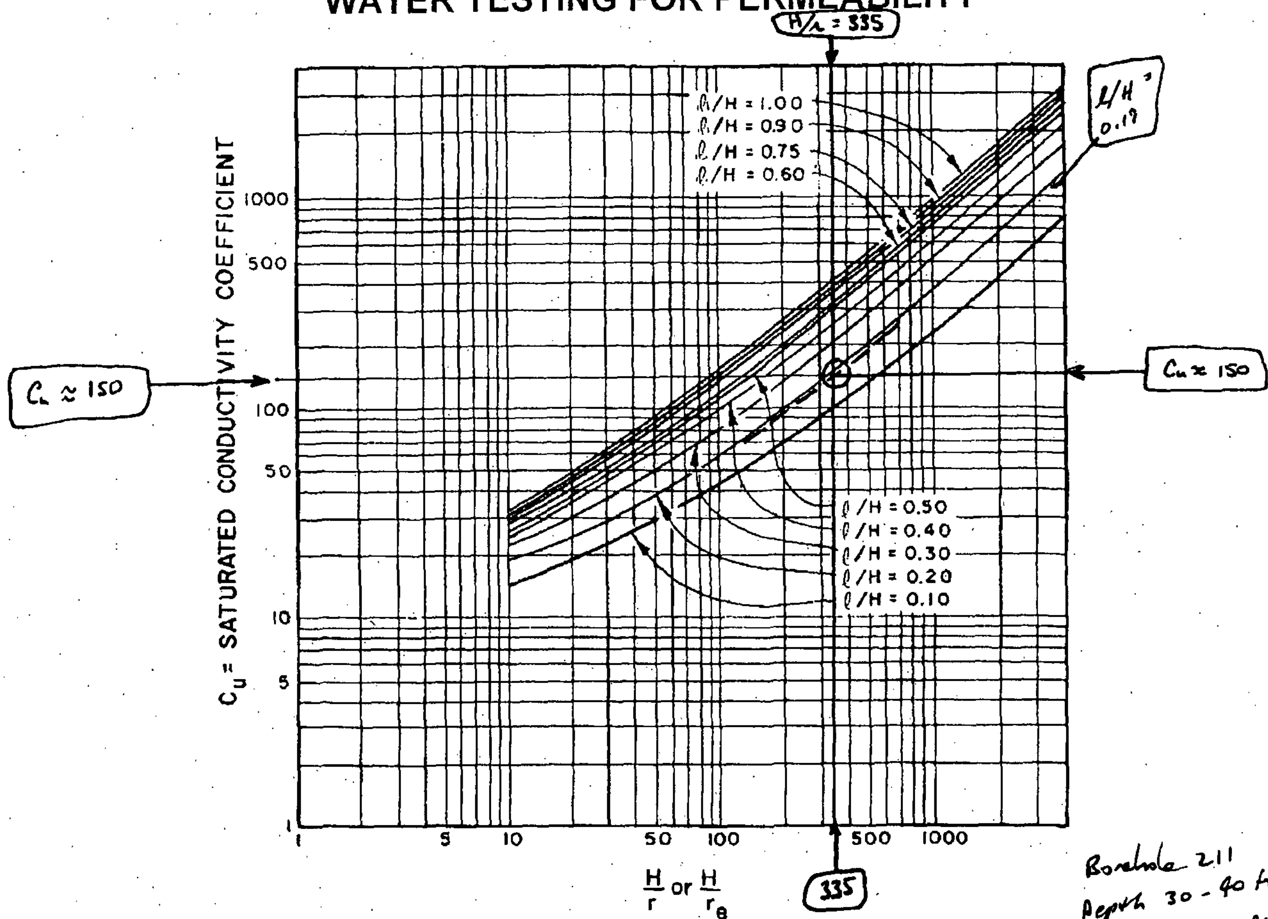
Calculate K:

Method 1, Zone 1, USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{26 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(150)(0.16 \text{ ft})(52.1 \text{ ft})}$$

$K = 4.0$ ft/d

$K = 1.4 \times 10^{-3}$ cm/sec



Borehole 211
Depth 30 - 40 ft
Pressure: 11.6 ft
1-30-06

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterizat. Date: 11-23-05

Field Representative: M. Kautsky Borehole No. 212 Total Depth: 30 ft

Depth to Water (TOC): 120 ± Borehole Cleaned? Yes ✓ No ___ Date: 11-23-05

Test Interval (BGL): from 20 to 30 ft. Swivel/Elbow Height (AGL) 5

Conductor Pipe, Type and Size: Hx

Time	Gauge Pressure	Flow Meter Reading	flow (gpm)
08:25	5 PSI	35864	
08:26	5 PSI	35884	20
08:27	5 PSI	35904	20
08:28	5 PSI	35924	20
08:29	5 PSI	359~~45~~	21
08:30	5 PSI	35966	21
08:31	5 PSI	35986	20
08:32	5 PSI	36007	21
08:33	5 PSI	36029	22
08:34	5 PSI	36051	22
08:35	5 PSI	36073	22
08:36	5 PSI	36096	23
08:37	5 PSI	36118	22
08:38	~~10 PSI~~ 5 PSI	36140	22
		final Avg Q = 22 gpm	

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterisation Date: 11-23-05

Field Representative: M. Koutsky Borehole No. 212 Total Depth : 30 ft

Depth to Water (TOC): 120± Borehole Cleaned? Yes X No____ Date: 11-23-05

Test Interval (BGL): from 20 to 30 ft. Swivel/Elbow Height (AGL) 5 ft.

Conductor Pipe, Type and Size: HX

Time	Gauge Pressure	Flow Meter Reading	
0845	10 PSI	36170	> 25
0846	10 PSI	36195	> 26
0847	10 PSI	36221	> 28
0848	10 PSI	36249	> 28
0849	10 PSI	36277	> 28
0850	10 PSI	36305	> 27
0851	10 PSI	36332	> 28
0852	10 PSI	36360	> 28
0853	10 PSI	36388	
		final Avg Q = 28 gpm	

RECORD COPY

Stoller

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization   Date: 11-23-05

Field Representative: M.Kautsky   Borehole No. 212   Total Depth: 30

Depth to Water (TOC): 120 ±   Borehole Cleaned? Yes X No ____   Date: 11-23-05

Test Interval (BGL): from 20 to 30 ft.   Swivel/Elbow Height (AGL) 5 ft.

Conductor Pipe, Type and Size: HX.

Time	Gauge Pressure	Flow Meter Reading	
09:00	5PSI	36409	
			20
09:01	5PSI	36429	
			20
09:02	5PSI	36449	
			21
09:03	5PSI	36470	
			23
09:04	5	36493	
			24
09:05	5	36517	
			26
09:06	5	36543	
			27
09:07	5	36570	
			27
09:08	5	36597	

Final Avg Q = 27

(Retest of 5psi)

Sealer

DATE 1-23-06

JOB NAME: Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO: OF

PACKER TEST ANALYSES

Borehole : 212
Depth : 20-30 ft
Pressure (h_2) : 5 psi

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = 120\text{ ft} - 20\text{ ft} + 43.8\text{ ft} = 143.8\text{ ft}$

$\frac{T_u}{l} = \frac{143.8\text{ ft}}{10\text{ ft}} = \boxed{14.4}$

$H = h_1 + h_2 - L = 43.8\text{ ft}$

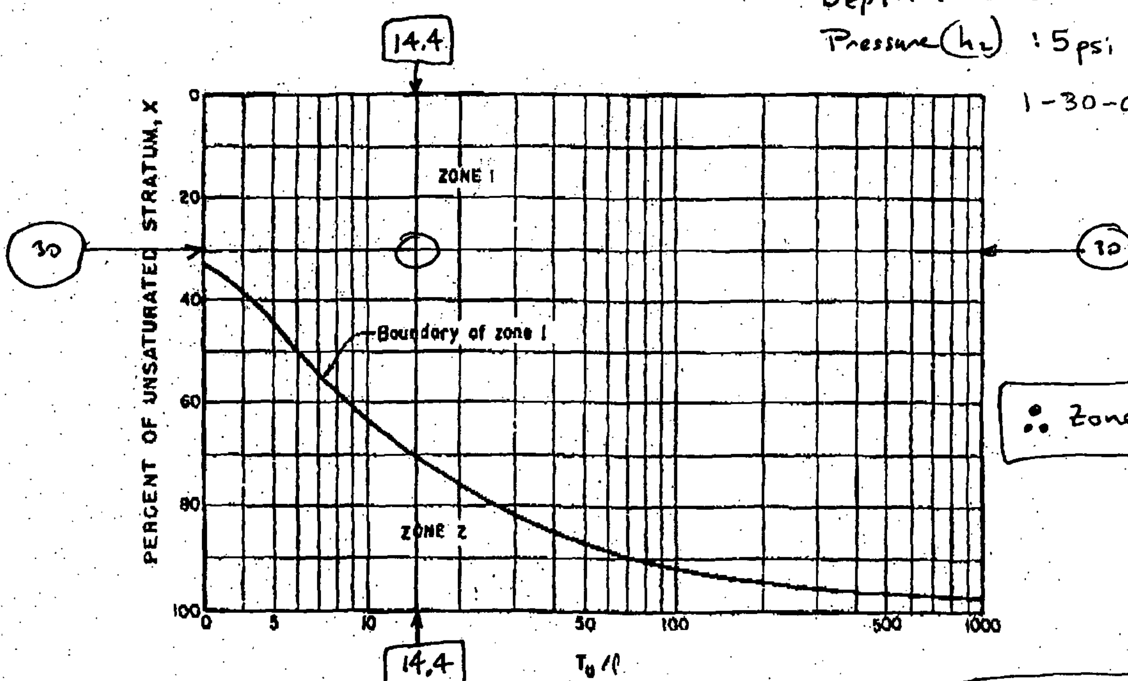
$X = \frac{H}{T_u}(100) = \frac{43.8\text{ ft}}{143.8\text{ ft}}(100) = \boxed{30}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 212
Depth : 20-30ft.
Pressure (h_2) : 5 psi
1-30-06



∴ Zone 1

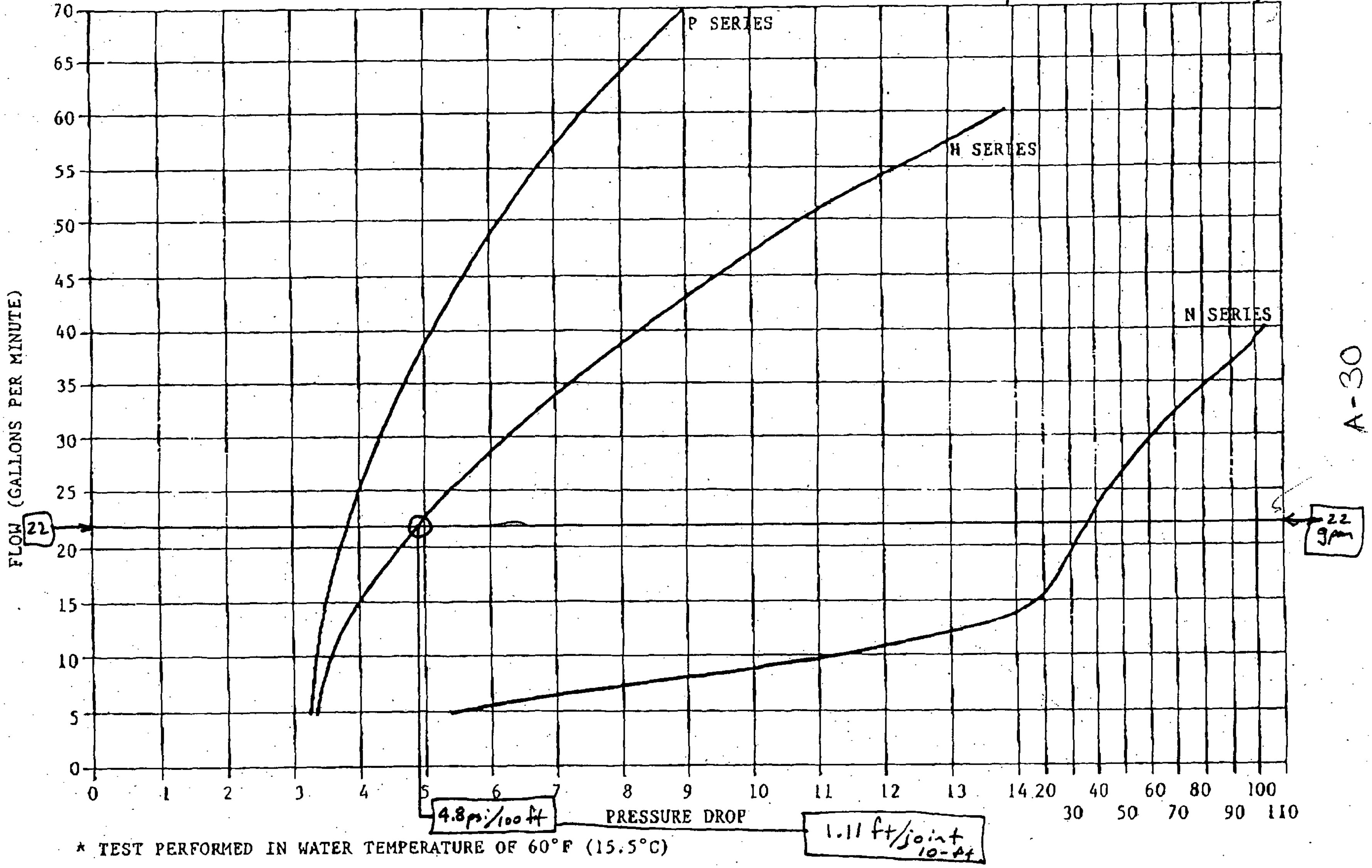
Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 14.4$

$X = 30$

PRESSURE LOSS CURVE

1-30-06
Borehole 212
Depth 20-30 ft. (5psi)

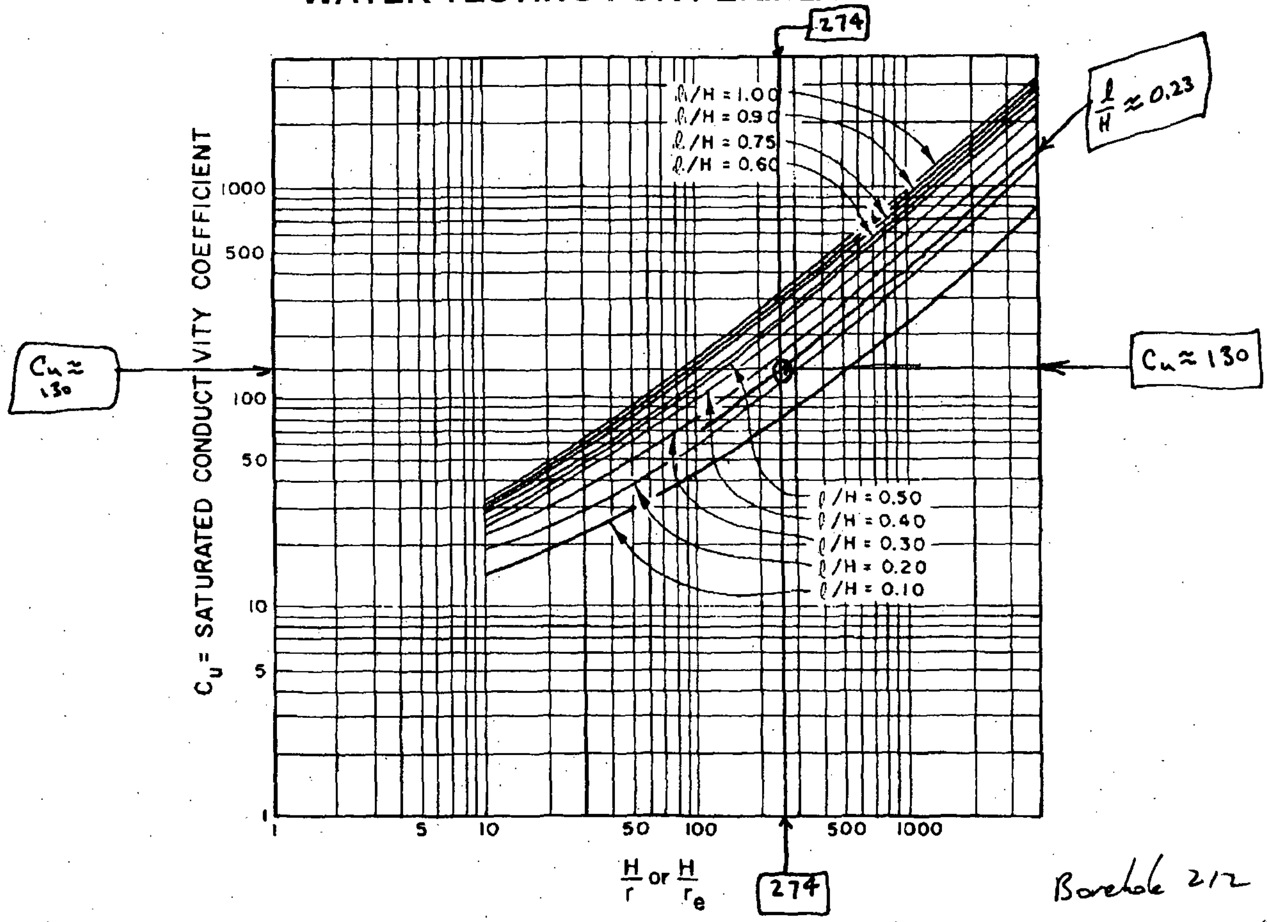


A-30

* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VARY.

From: WIRELINE TYPE II service manual, Boart Longyear.



Borehole 212
depth 20-30 ft
pressure: 5 psi
1-30-06

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Stoller

PACKER TEST SET-UP SHEET

Zone 1

JOB NO.:

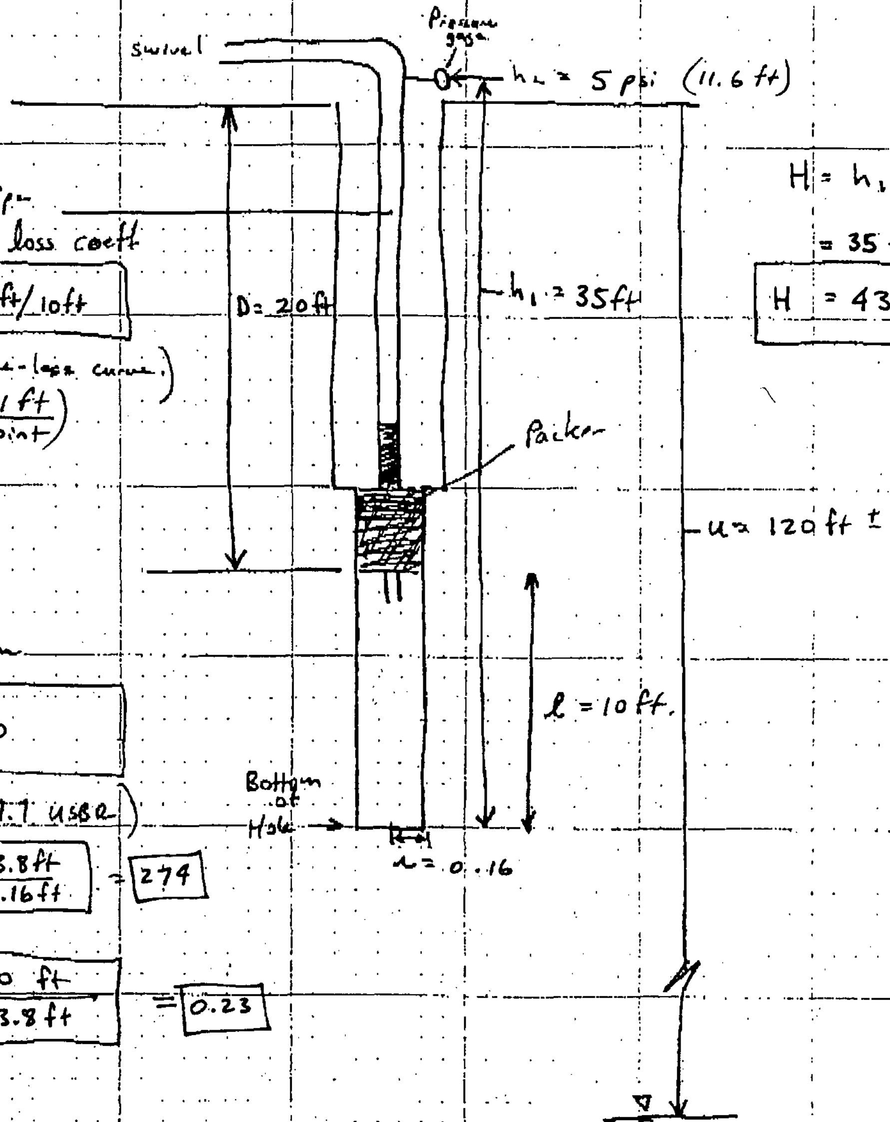
DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED:

SHEET NO.: 1 OF

Borehole 212
depth: 20-30 ft
pressure: 5 psi



Injection pipe

Obtain L = head loss coeff

$\boxed{L = 1.1 \text{ ft}/10\text{ft}}$

(from pressure-loss curve)

$L = \left(2.5\text{ joints}\right)\left(\frac{1.1\text{ ft}}{\text{joint}}\right)$

$\boxed{L = 2.8 \text{ ft.}}$

$H = h_1 + h_2 - L$

$= 35\text{ ft} + 11.6\text{ ft} - 2.8\text{ ft}$

$\boxed{H = 43.8\text{ ft.}}$

Obtain C_u

$\boxed{C_u \cong 130}$

(From fig 17.1 USBR)

$\frac{H}{r} = \boxed{\frac{43.8\text{ft}}{0.16\text{ft}}} = \boxed{274}$

$\frac{\ell}{H} = \boxed{\frac{10\text{ ft}}{43.8\text{ ft}}} = \boxed{0.23}$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{22\text{ gal}}{\text{min}}\right)\left(\frac{1440\text{ min}}{\text{day}}\right)\left(\frac{\text{ft}^3}{7.48\text{ gal}}\right)}{(130)(0.16\text{ ft})(43.8\text{ ft})}$$

$\boxed{\begin{array}{l} K = 4.6\text{ ft/day} \\ K = 1.6 \times 10^{-3}\text{ cm/s} \end{array}}$

DATE 1-23-06

JOB NAME Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO. ______ OF ______

PACKER TEST ANALYSES

Borehole : 212
Depth : 20-30 ft.
Pressure (h_2) : 10 psi

Unsaturated Zone Calculation:

Definitions : l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = (120 - 20 + 54.7)$ ft $= 154.7$ ft

$\frac{T_u}{l} = \frac{154.7 \text{ ft}}{10 \text{ ft}} = \boxed{15.5}$

$H = h_1 + h_2 - L = 54.7$ ft $+ 23.1$ ft $- 3.4$ ft $= 54.7$ ft

$X = \frac{H}{T_u}(100) = \frac{54.7 \text{ ft}}{154.7 \text{ ft}}(100) = \boxed{35}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 212
Depth : 20-30 ft
Pressure (h_2) : 10 psi
1-30-06

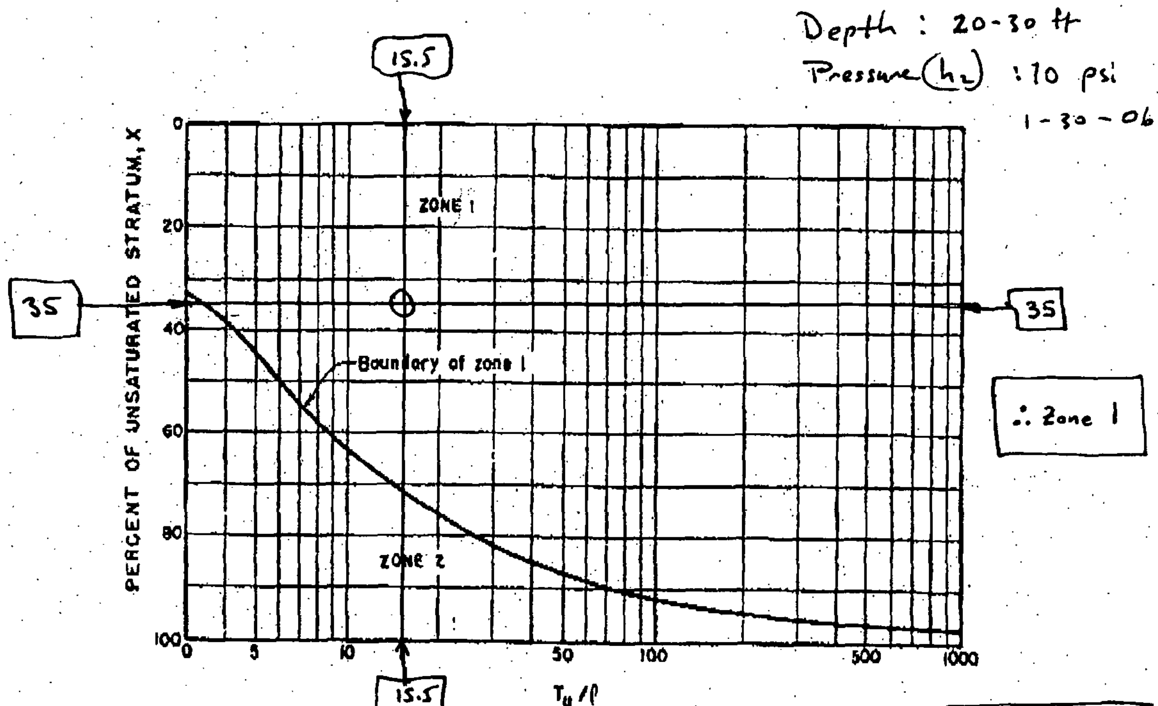


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

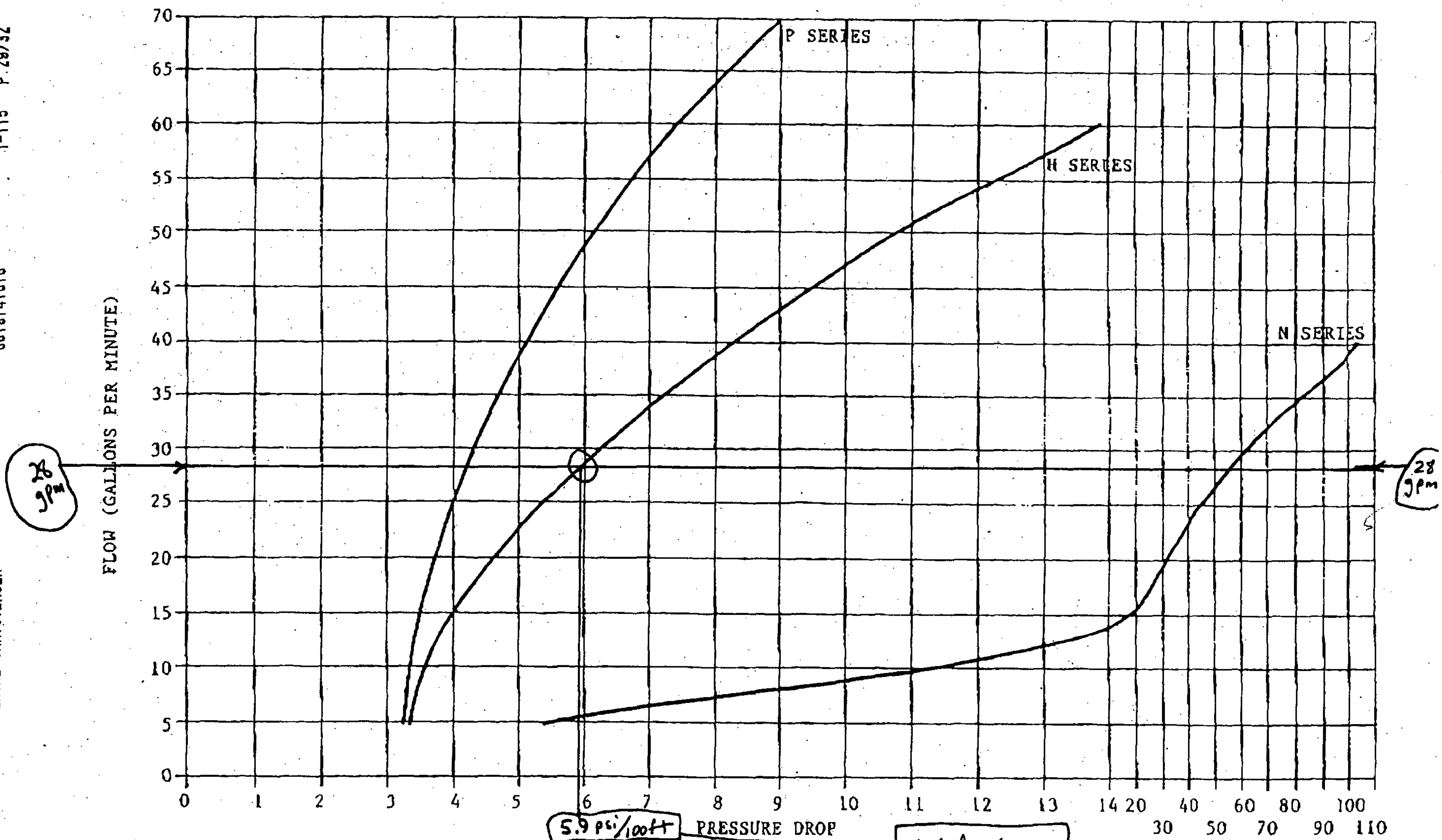
$\frac{T_u}{l} = 15.5$

$X = 35$

A-35

Borehole 212
Depth 20-30
Pressure: 10 psi (23.1 ft)

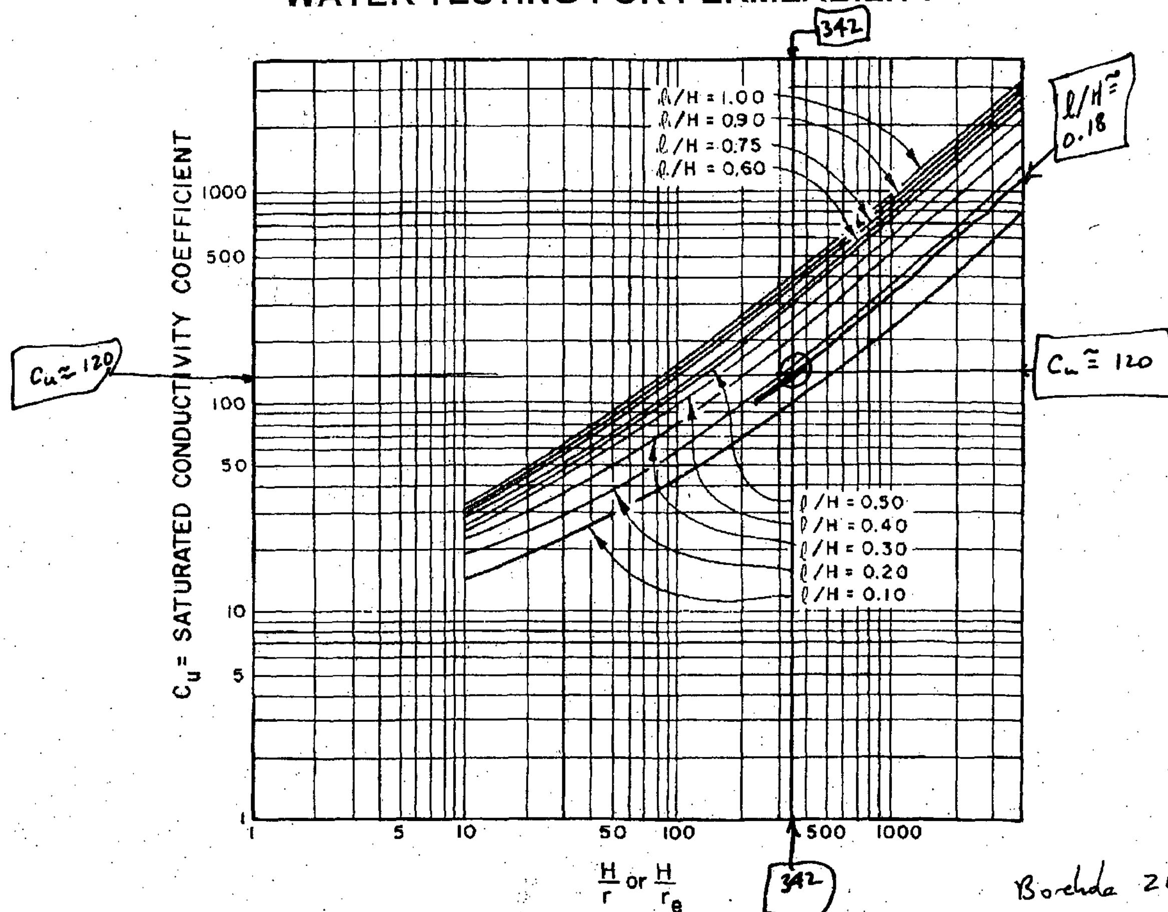
PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VARY.

From: WIRELINE TYPE II service manual, Boart Longyear.



Borehole 212
Depth 20-30 ft.
pressure 10 psi
1-30-06

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Stoller

PACKER TEST SET-UP SHEET

JOB NO.:

DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

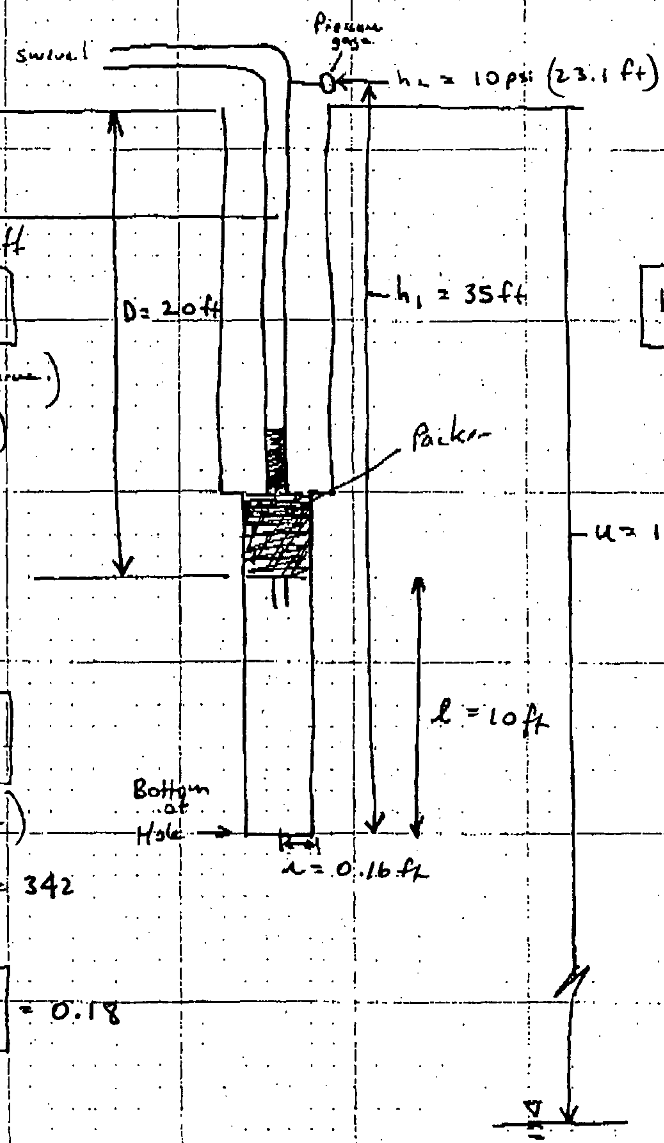
REVIEWED:

Borehole: 212

Depth: 20 - 30 ft.

Pressure: 10 psi

SHEET NO.: 1 OF



$H = h_1 + h_2 - L$

$= 35\text{ ft} + 23.1\text{ ft} - 3.4\text{ ft}$

$\boxed{H = 54.7\text{ ft}}$

Obtain L = head loss coeff

$\boxed{L = 1.4\ \text{ft}/10\text{ft}}$

(from pressure-loss curve)

$L = \frac{1.4\text{ ft}}{\text{joint}}(2.5\text{ joints})$

$\boxed{L = 3.4\text{ ft}}$

Obtain C_u

$\boxed{C_u \cong 120}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{54.7\text{ ft}}{0.16\text{ ft}}} = 342$

$\frac{\ell}{H} = \boxed{\frac{10\text{ ft}}{54.7\text{ ft}}} = 0.18$

Calculate K:

Method 1,

Zone 1,

USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{28\text{ gal}}{\text{min}}\right)\left(\frac{1440\text{ min}}{\text{day}}\right)\left(\frac{1\text{ ft}^3}{7.48\text{ gal}}\right)}{(120)(0.16\text{ ft})(54.7\text{ ft})}$$

$$\boxed{\begin{array}{l} K = 5.1\text{ ft/day} \\ K = 1.8 \times 10^{-3}\text{ cm/sec} \end{array}}$$

Stoller

PACKER TEST SET-UP SHEET

JOB NO.:

DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

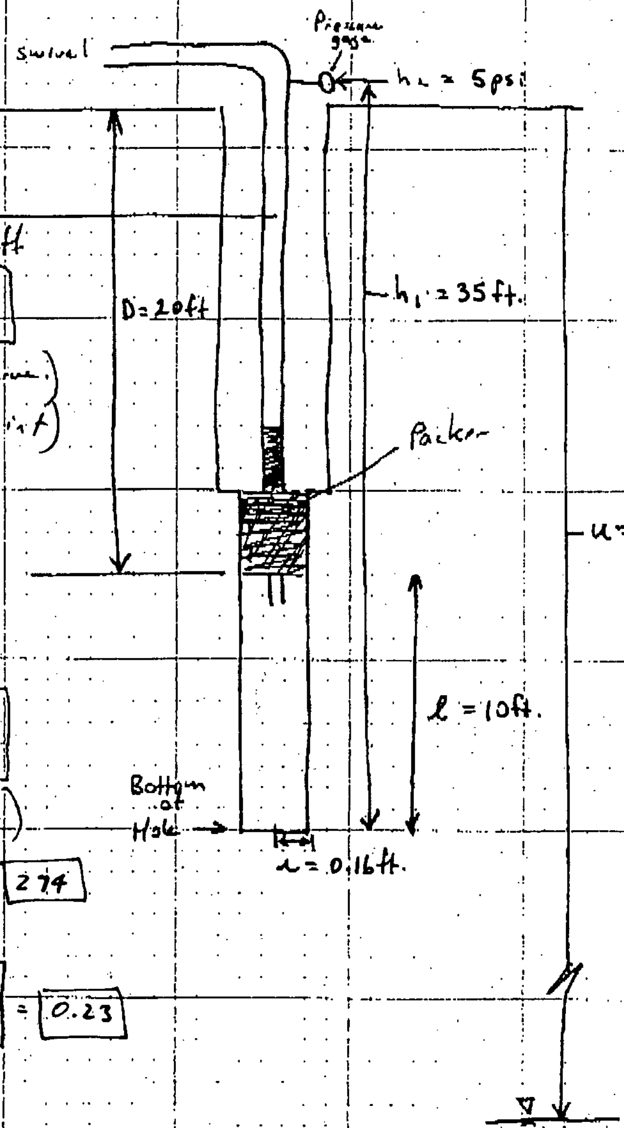
REVIEWED:

Borehole 212

SHEET NO.: 1 OF

Test Interval 20-30 ft

pressure : 5 psi (retest)



Injection pipe

Obtain L = head loss coeff

$\boxed{L = 1.4 \text{ ft}/10\text{ft}}$

(from pressure-loss curve)

$L = \left(\frac{1.4 \text{ ft}}{\text{joint}}\right)(2.5 \text{ joint})$

$\boxed{L = 3.5 \text{ ft}}$

$H = h_1 + h_2 - L$

$= (35 + 11.6 - 3.5) \text{ ft}$

$\boxed{H = 43.8 \text{ ft}}$

Obtain C_u

$\boxed{C_u = 130}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{43.8 \text{ ft}}{0.16 \text{ ft}}} = \boxed{274}$

$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{43.8 \text{ ft}}} = \boxed{0.23}$

Calculate K:

Method 1,

Zone 1,

USBR

$$K = \frac{Q}{C_u \, r \, H} = \frac{\left(\frac{27 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{day}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(130)(0.16 \text{ ft})(43.8 \text{ ft})}$$

$$\boxed{\begin{array}{l} K = 5.7 \text{ ft/d} \\ K = 2.0 \times 10^{-3} \text{ cm/sec} \end{array}}$$

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization   Date: 11-30-05

Field Representative: M. Kautsky   Borehole No.: 212   Total Depth: 40ft

Depth to Water (TOC): 120 ±   Borehole Cleaned? Yes X No ___   Date: 11-30-05

Test Interval (BGL): from 30 to 40 ft.   Swivel/Elbow Height (AGL) 5ft

Conductor Pipe, Type, and Size: HX / ~~X~~ HQ

Time		Gauge Pressure		Flow Meter Reading	Flow
12:28		5psi		36689	1
12:29		5psi		36708	19gpm
12:30		5psi		36727	19gpm
12:31		8 psi		36747	20gpm
12:33		5 psi		36802	
12:34		5 psi		36840	38gpm
12:35		5psi		36878	38gpm
12:36		5psi		36913	35gpm
12:37		5psi		36947	34gpm
12:38		5psi		36977	30gpm
12:39		5psi		37004	27gpm
12:40		5psi 4		37023	19gpm
12:41		5psi 3		37035	12gpm
12:42		5psi 0		37043	8gpm
		Ran out of water.			

Reset pressure ↓

F:\HOME\M50122\Word-2000\Crescent\PackerTest.dot   A-39

Stoller

RECORD COPY

established 1959

Packer-Test Record

Project Name: Crescent Junction Characterization Date: 11-30-05

Field Representative: Mark Kautsky Borehole No.: 212 Total Depth: 40 ft.

Depth to Water (TOC): 1202 Borehole Cleaned? Yes x No ____ Date: 11-30-05

Test Interval (BGL): from 30 to 40 ft. Swivel/Elbow Height (AGL) 5 ft.

Conductor Pipe, Type, and Size: HX / HQ

Time		Gauge Pressure		Flow Meter Reading	
14:30		5 psi		37102	
14:31		5 psi		37135	33 gal/min
14:32		5 psi		37171	36 gpm
14:33		5 psi		37208	37 gpm
14:34		5 psi		37244	36 gpm
14:35		5 psi		37282	38 gpm
14:36		5 psi		37320	38 gpm
14:37		5 psi		37358	38 gpm
14:38		10 psi		37400	
14:39		10 psi		37442	42 gpm
14:40		10 psi		37485	43 gpm
14:41		10 psi		37528	43 gpm
14:42		10 psi		37571	43 gpm
14:43		5 psi		37610	
14:44		5 psi		37648	38 gpm
14:45		5 psi		37686	38 gpm
14:46		5 psi		~~376~~ 37722	36 gpm
14:47		5 psi		37760	38 gpm

F:\HOME\M50122\Word-2000\Crescent\PackerTest.dot A-40

Stoller

DATE 1-23-06

JOB NAME Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO: ______ OF ______

PACKER TEST ANALYSES

BOREHOLE : 212

Depth : 30 - 40 ft.

Pressure (h_2) : 5 psi (11.6 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U + D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = 120 - 30 + 50.3 = 140.3$

$\frac{T_u}{l} = \frac{140.3 \text{ ft}}{10 \text{ ft}} = \boxed{14}$

$H = h_1 + h_2 - L = 50.3$ ft

$X = \frac{H}{T_u}(100) = \frac{50.3 \text{ ft}}{140.3 \text{ ft}}(100) = \boxed{36}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 212
Depth : 30-40ft
Pressure (h_2) : 5psi
1-30-06

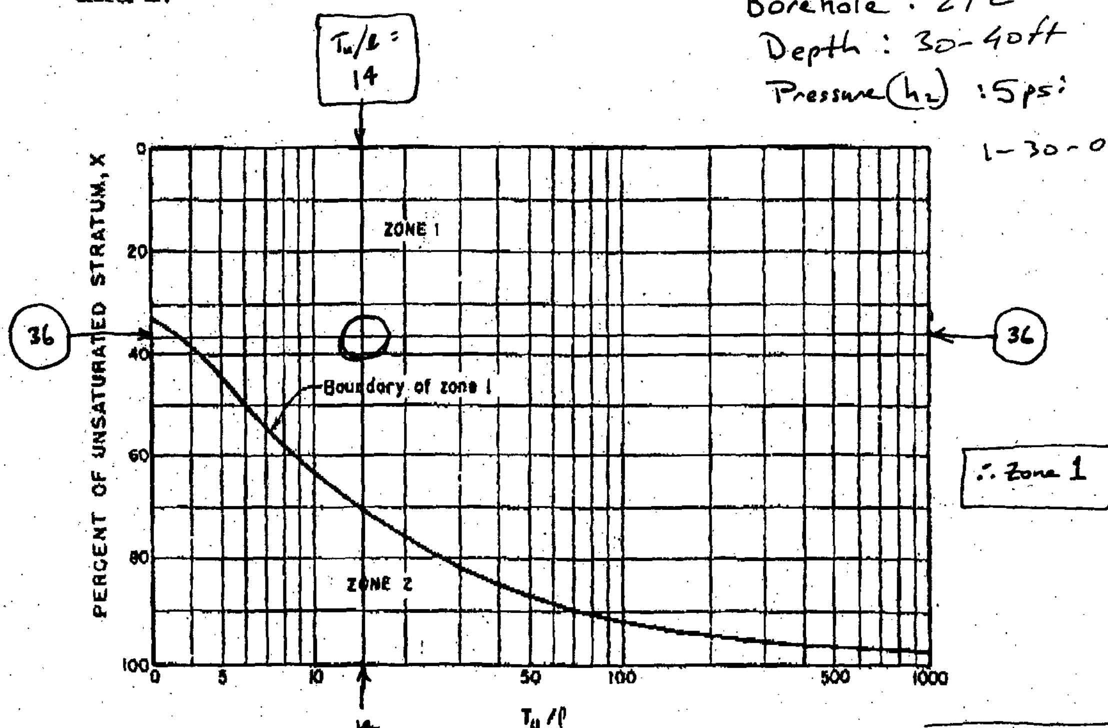


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

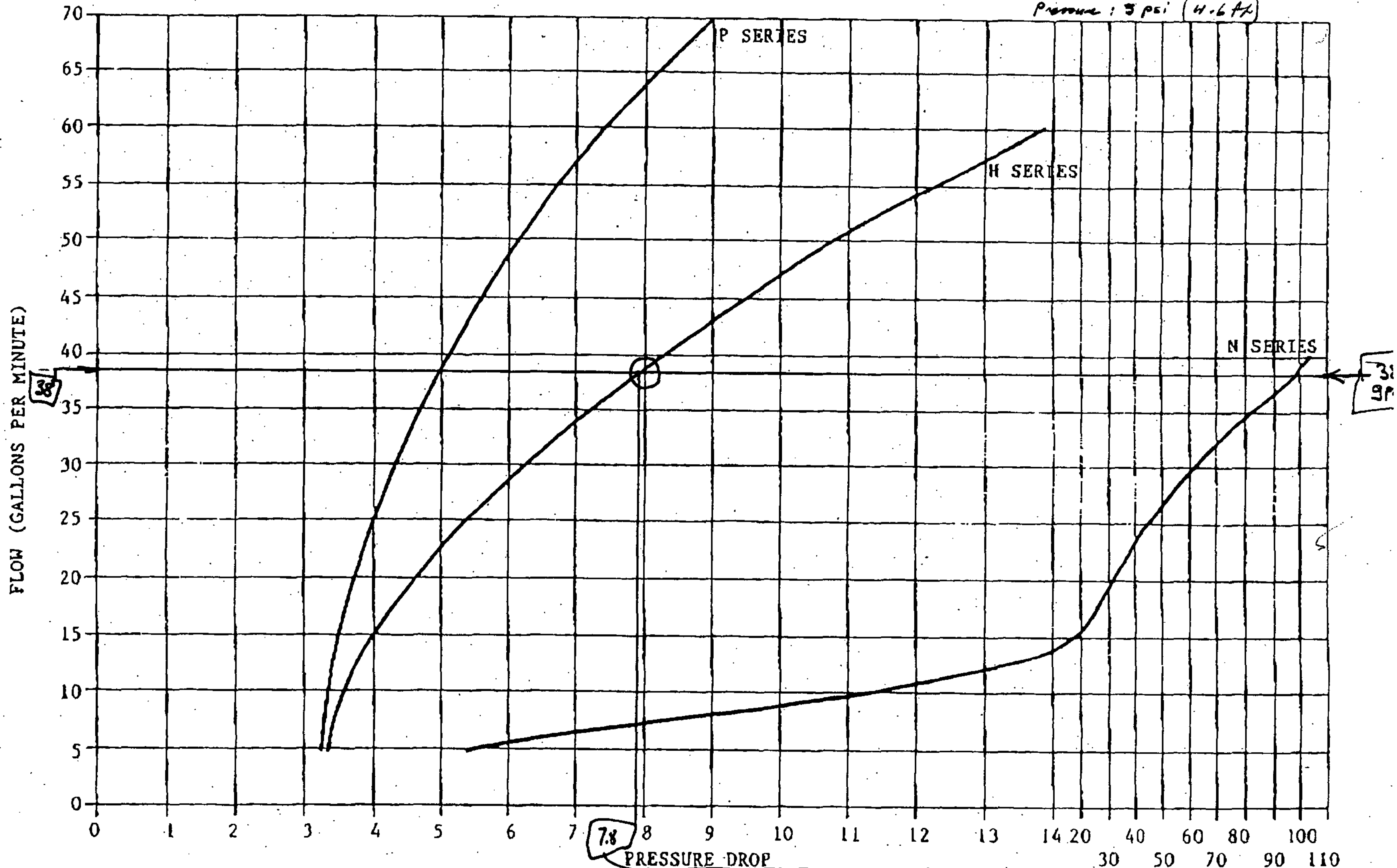
$\frac{T_u}{\ell} = 14$

$X = 36$

A-43

1-30-06
Borehole 212
Interval 30-40 ft.
Pressure : 5 psi (11.6 ft)

PRESSURE LOSS CURVE



7.8 psi/100 ft = 1.8 ft/10-ft joint

* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)
* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From : WIRELINE TYPE II service manual, Boart Longyear.

Borehole 212
Depth 30 - 40 ft
Pressure 15psi

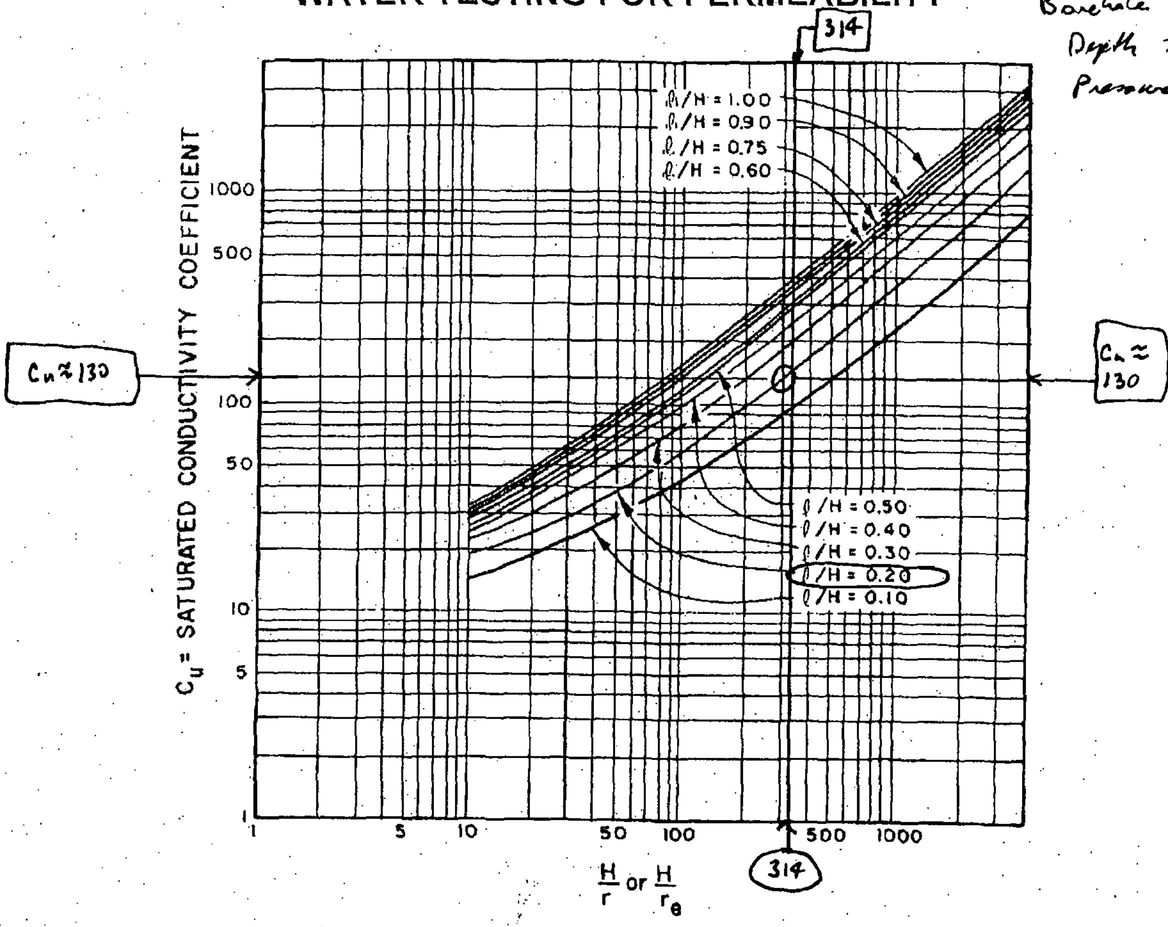


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, $D = 65$ feet, and $h_1 = 72$ feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

$H = 72 + 57.8 - 4.7 = 125.1$ feet

Stoller

PACKER TEST SET-UP SHEET

JOB NO.:

DATE: 1-30-06

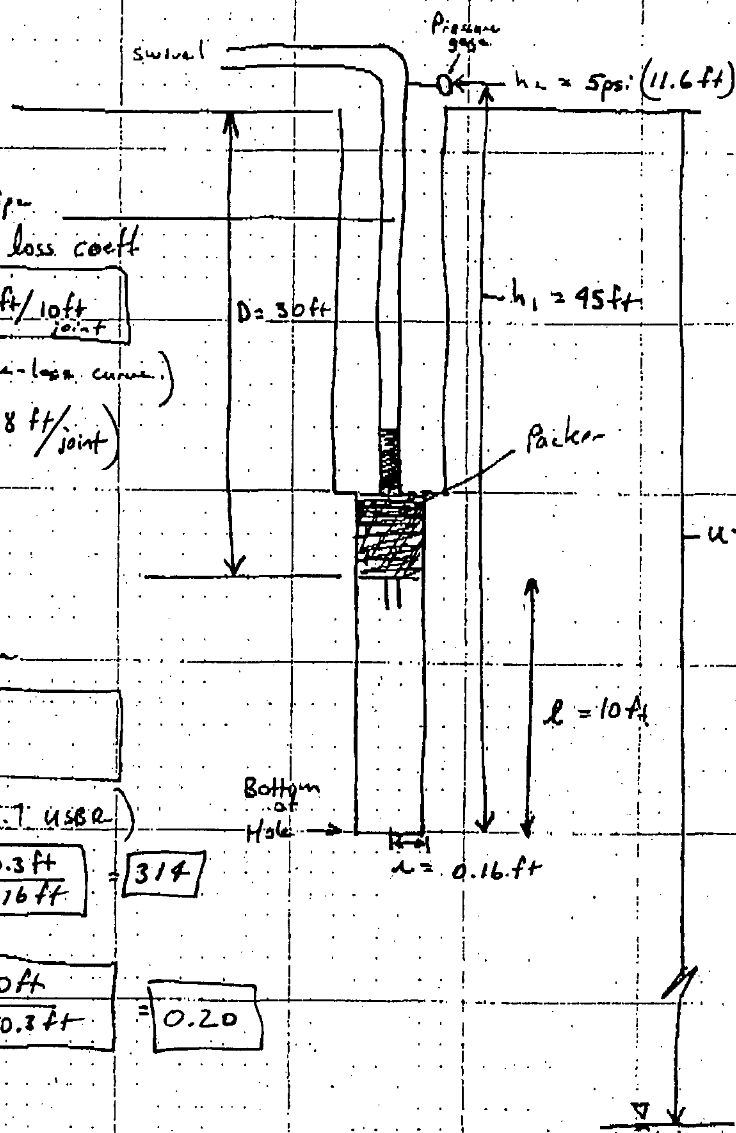
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

REVIEWED:

SHEET NO.: 1 OF

Borehole 212
Depth 30-40 ft.
pressure: 5psi (11.6 ft)



Injection pipe

Obtain: L = head loss coeff

$\boxed{L = 1.8\ ft/10ft\ joint}$

(from pressure-loss curve)

$L = (3.5\ joints)(1.8\ ft/joint)$

$\boxed{L = 6.3\ ft}$

$H = h_1 + h_2 - L$

$= 45\,ft + 11.6 - 6.3\ ft$

$\boxed{H = 50.3\ ft}$

Obtain C_u

$\boxed{C_u \cong 130}$

(From fig 17.1 USBR)

$\frac{H}{r} = \boxed{\frac{50.3\,ft}{0.16\,ft}} = \boxed{314}$

$\frac{\ell}{H} = \boxed{\frac{10\,ft}{50.3\,ft}} = \boxed{0.20}$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{38\ gal}{min}\right)\left(\frac{1440\ min}{d}\right)\left(\frac{ft^3}{7.48\ gal}\right)}{(130)(0.16\ ft)(50.3\ ft)}$$

$\boxed{K = 7\ ft/day \quad K = 2.5 \times 10^{-3}\ cm/s}$

PACKER TEST ANALYSES

BOREHOLE : 212
Depth : 30 - 40 ft.
Pressure (h_2) : 10 psi (23.1 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

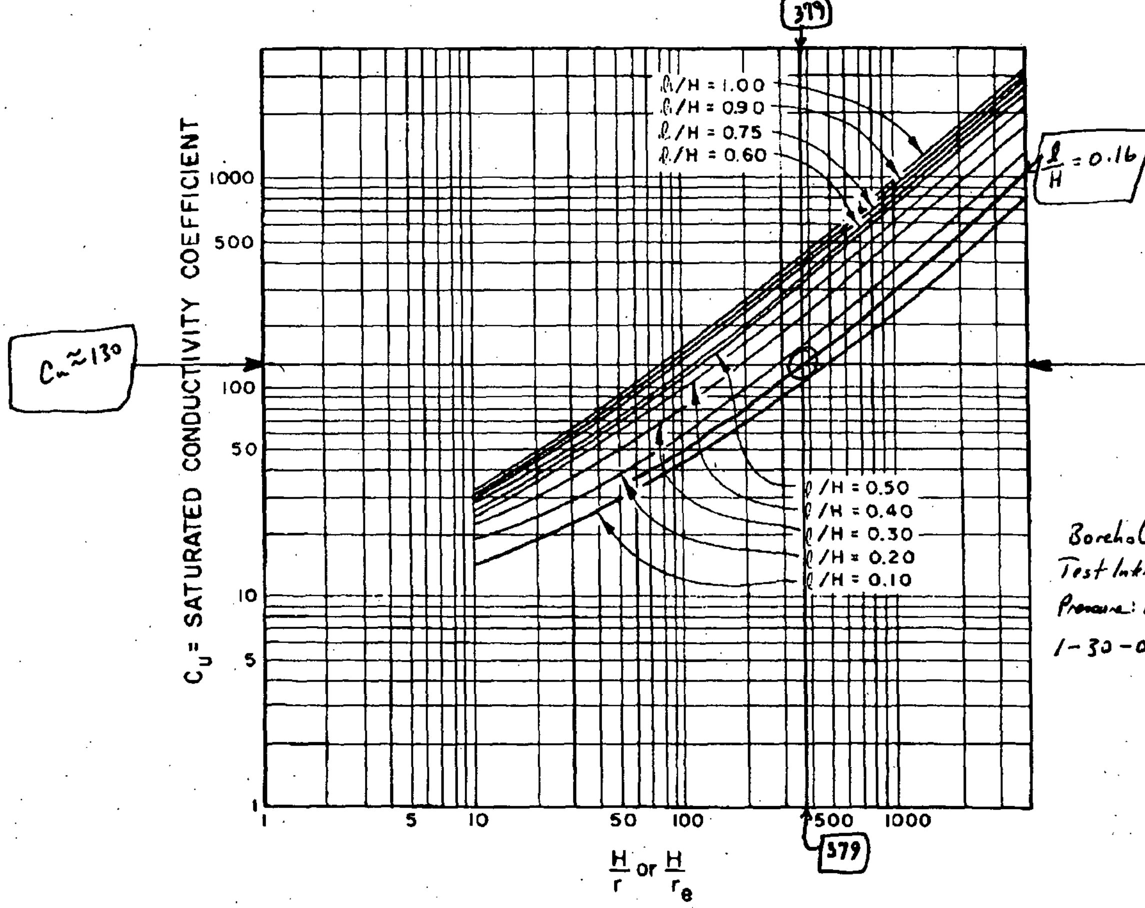
$l = 10$ ft.

$T_u = U - D + H = 120\text{ ft} - 30\text{ ft} + 60.7\text{ ft} = 150.7\text{ ft}$

$\frac{T_u}{l} = \frac{150.7\text{ ft}}{10\text{ ft}} = \boxed{15.1}$

$H = h_1 + h_2 - L = 60.7\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{60.7\text{ ft}}{150.7\text{ ft}}(100) = \boxed{40}$



Borehole 212
Test Interval: 30-40 ft
Pressure: 10 psi (23.1 ft)
1-30-06

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

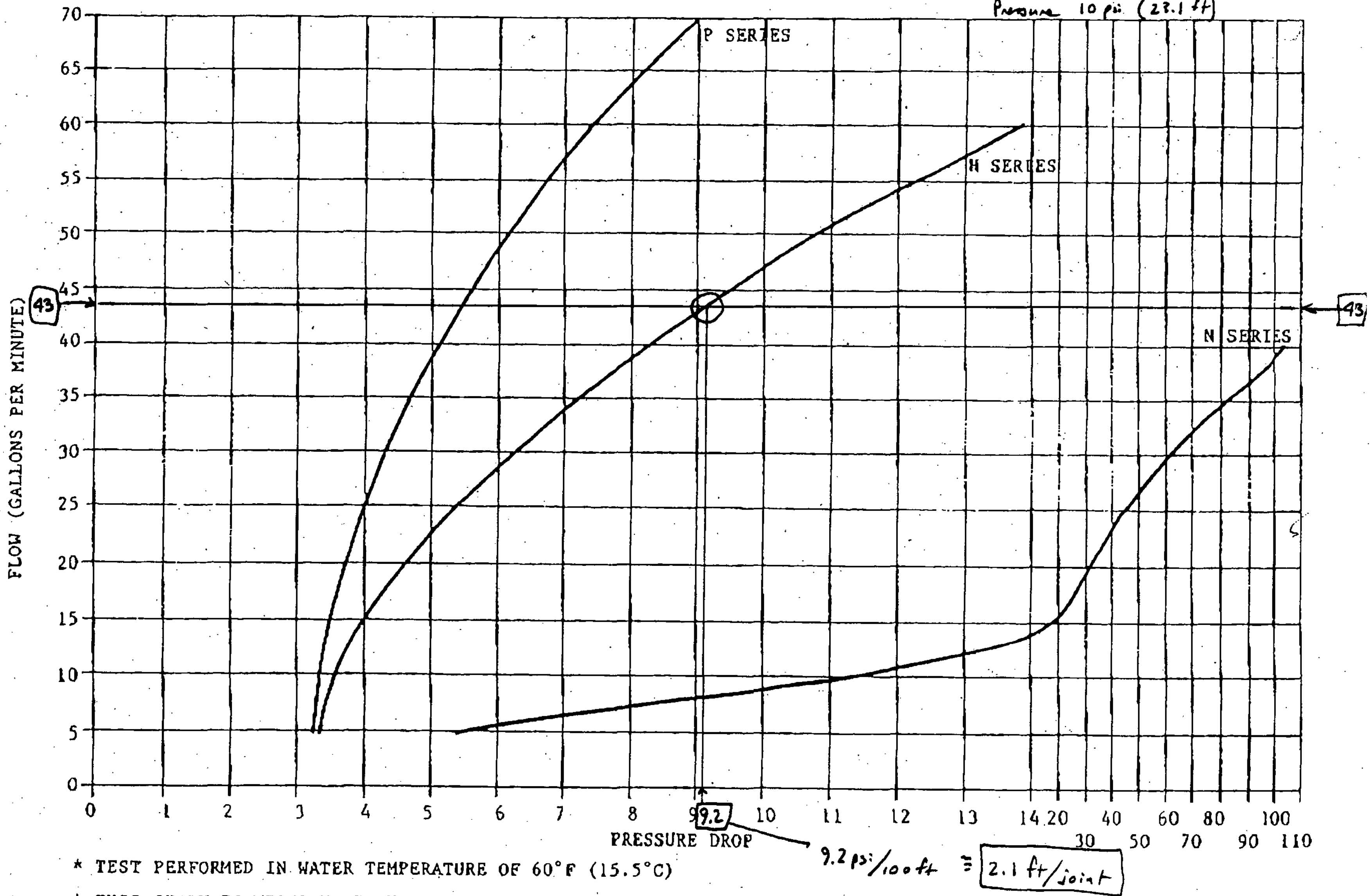
H = 72 + 57.8 - 4.7 = 125.1 feet

A-47

A-48

PRESSURE LOSS CURVE

1-30-06
Borehole 212
Test Interval 30-40 ft.
Pressure 10 psi (23.1 ft)



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VARY.

From: WIRELINE TYPE II service manual, Boart Longyear.

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 212
Depth : 30-40 ft
Pressure (h_2) : 10 psi
1-30-06

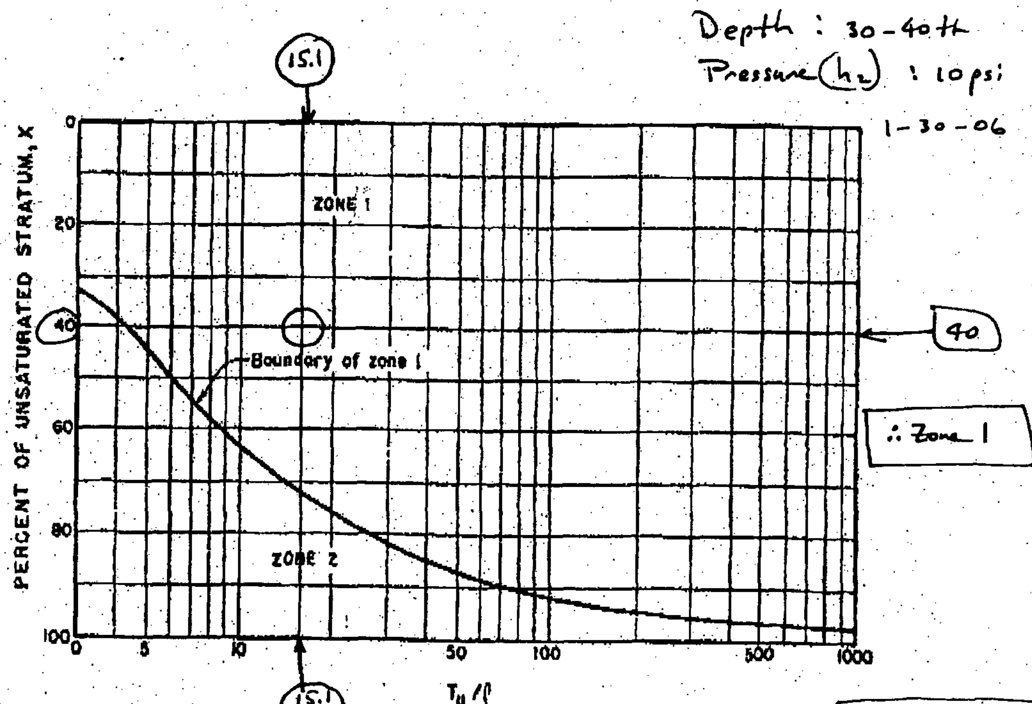


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$$\frac{T_u}{l} = 15.1$$

$$X = 40$$

Stoller

PACKER TEST SET-UP SHEET

JOB NO.: ______ DATE: 1-30-06

JOB NAME: Crescent Junction Site

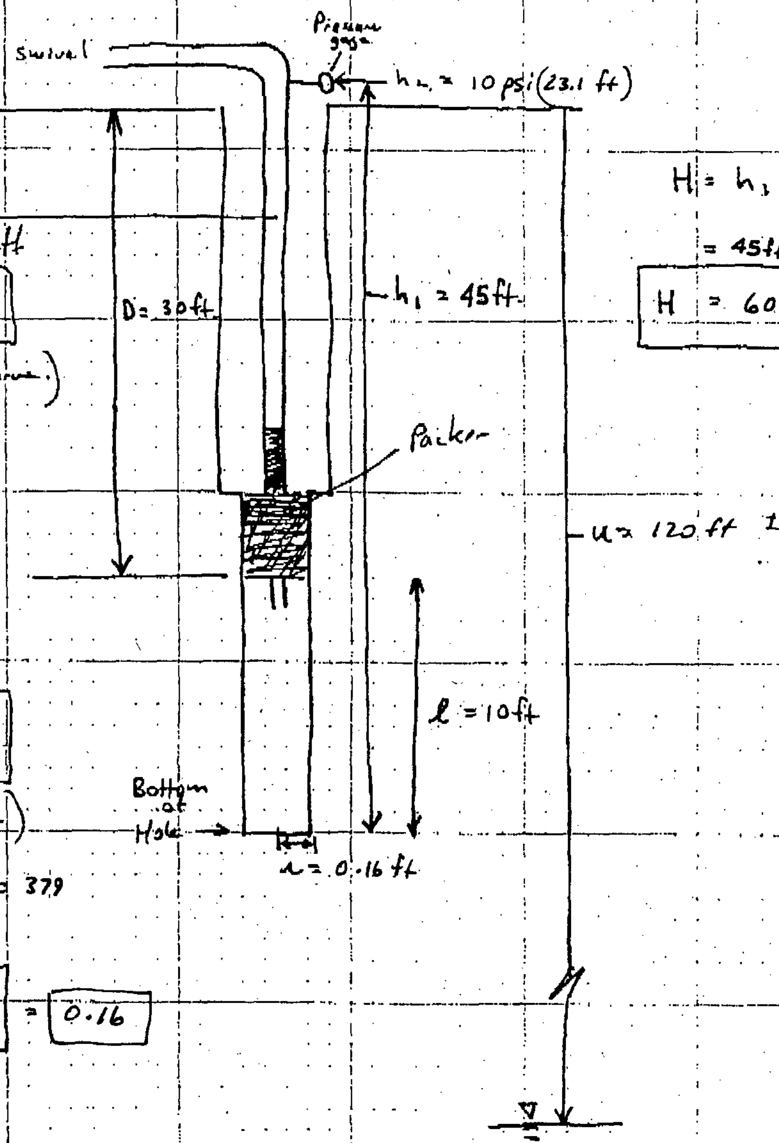
PREPARED: Mark Kautsky REVIEWED: ______

Borehole 212

Test Interval 30-40 ft.

SHEET NO.: 1 OF ______

Pressure: 10 psi (23.1 ft)



Injector pipe

Obtain L = head loss coeff

$\boxed{L = 2.1 \text{ ft}/10\text{ft}}$

(from pressure-loss curve)

$L = \left(\frac{2.1 \text{ ft}}{\text{joint}}\right)(3.5 \text{ joints})$

$\boxed{L = 7.4 \text{ ft}}$

$H = h_1 + h_2 - L$

$= 45\text{ft} + 23.1\text{ft} - 7.4\text{ft}$

$\boxed{H = 60.7 \text{ ft.}}$

Obtain C_u

$\boxed{C_u = 130}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{60.7 \text{ ft}}{0.16}} = 379$

$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{60.7 \text{ ft}}} = \boxed{0.16}$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} \;;\; K = \frac{\left(\frac{43 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)}{(130)(0.16 \text{ ft})(60.7 \text{ ft})}$$

$$\boxed{\begin{aligned} K &= 6.5 \text{ ft/d} \\ K &= 2.3 \times 10^{-3} \text{ cm/s} \end{aligned}}$$

Stoller

PACKER TEST SET-UP SHEET

JOB NO.: DATE: 1-30-06

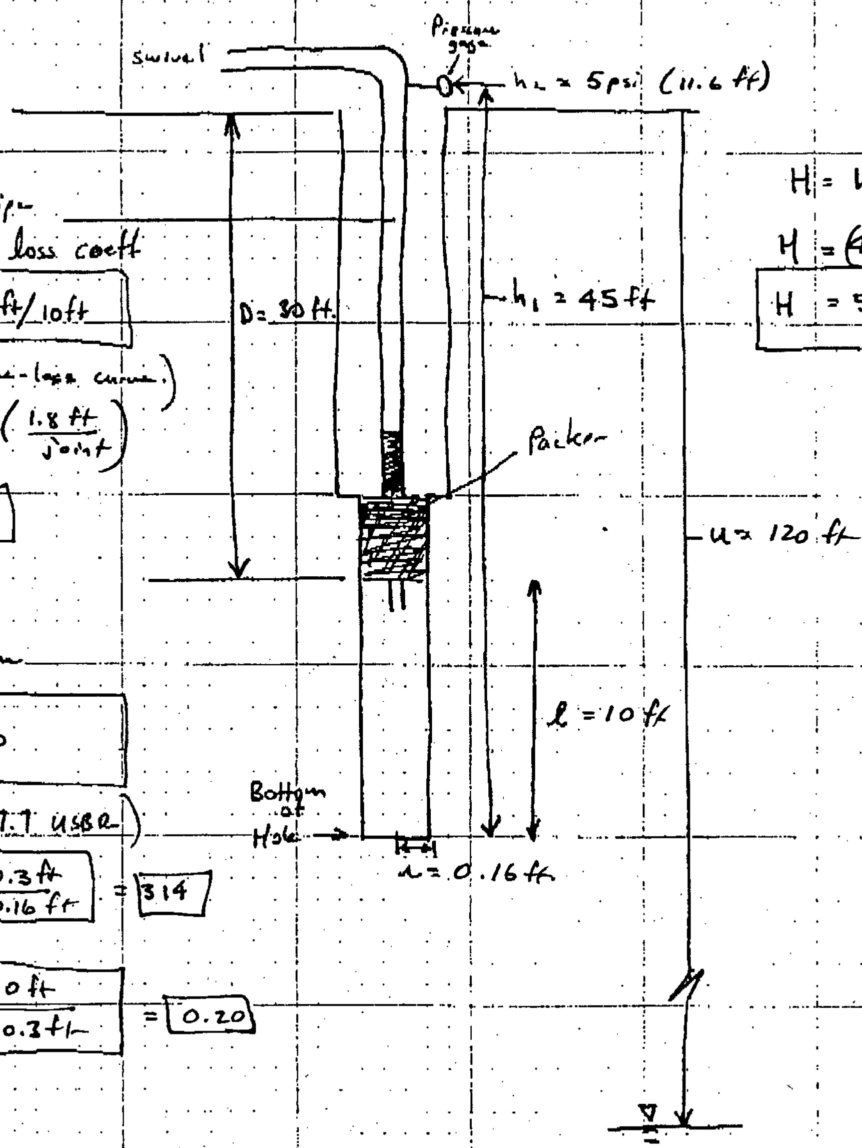
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED:

Borehole 212

SHEET NO.: 1 OF Depth 30-40 ft

pressure: 5 psi (retest)



Injection pipe

Obtain L = head loss coeff

$\boxed{L = 1.8 \text{ ft}/10\text{ft}}$

(from pressure-loss curve)

$L = 3.5 \text{ joints} \left(\frac{1.8 \text{ ft}}{\text{joint}}\right)$

$\boxed{L = 6.3 \text{ ft}}$

$H = h_1 + h_2 - L$

$H = (45 + 11.6 - 6.3)$ ft

$\boxed{H = 50.3 \text{ ft}}$

Obtain C_u

$\boxed{C_u \cong 130}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{50.3 \text{ ft}}{0.16 \text{ ft}}} = \boxed{314}$

$\frac{l}{H} = \boxed{\frac{10 \text{ ft}}{50.3 \text{ ft}}} = \boxed{0.20}$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{38 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(130)(0.16 \text{ ft})(50.3 \text{ ft})}$$

$$\boxed{\begin{aligned} K &= 7.0 \text{ ft/day} \\ K &= 2.5 \times 10^{-3} \text{ cm/s} \end{aligned}}$$

RECORD COPY

Stoller

established 1959

Packer-Test Record

Page 1 of 2

Project Name: Crescent Junction Characterization Date: 12-1-05

Field Representative: Mark Kautsky Borehole No.: 213 Total Depth: 30 ft

Depth to Water (TOC): 120 ± ft. Borehole Cleaned? Yes X No ____ Date: 12-1-05

Test Interval (BGL): from 20 to 30 ft. ft. Swivel/Elbow Height (AGL) 6 ft.

Conductor Pipe, Type, and Size: HQ/HX

Time	Gauge Pressure	Flow Meter Reading
13:01	5 psi	37784.7
13:02	5 psi	37786.3
13:04	5 psi	37792.8
13:05	5 psi	37800.5
13:06	5 psi	37811.0
13:07	5 psi	37825.0
13:08	5 psi	37842.5
13:09	5 psi	37863.3
13:10	5 psi	37887.6
13:11	5 psi	37915.0
13:12	5 psi	37944.0
13:13	5 psi	37974.3
13:14	5 psi	38005.0
13:15	5 psi	38036.5 31.5 gpm
13:16	5 psi	38068.5 32 gpm
13:17	5 psi	38100.5 32 gpm
13:18	5 psi	38132.5 32 gpm

F:\HOME\M50122\Word-2000\Crescent\PackerTest.dot A-52

RECORD COPY

Stoller

established 1959

Packer-Test Record

Project Name: Crescent Jct. Characterization   Date: 12-1-05

Field Representative: Mark Kautsky   Borehole No.: 213   Total Depth: 30

Depth to Water (TOC): 120 t   Borehole Cleaned? Yes x No ___   Date: 12-1-05

Test Interval (BGL): from 20 to 30 ft.   Swivel/Elbow Height (AGL) 6 ft.

Conductor Pipe, Type, and Size: HQ/HX

Time		Gauge Pressure		Flow Meter Reading
13:20		10 psi		38203.0
13:21		10 psi		38243.0 40 gpm
13:22		10 psi		38283.0 40 gpm
13:23		10 psi		38323.0 40 gpm
~~x x~~		~~x x~~		~~x x x~~
~~13:24~~		~~5 psi~~		~~38~~ out of water.
15:09		5 psi		38409
15:10		5 psi		38439 30 gpm
15:11		5 psi		38468 29 gpm
15:12		5 psi		38497 29 gpm
15:13		5 psi		38527 30 gpm
15:14		5 psi		38557 30 gpm
15:15		5 psi		38587 30 gpm
		end of test Corehole 213 20-30 ft.		
		MK		

F:\HOME\M50122\Word-2000\Crescent\PackerTest.dot

The S.M. Stoller Corporation   2597 B ¾ Road   Grand Junction, Colorado 81503   (970) 248-6601   Fax: (970) 248-7636

Stoller

DATE 1-23-06

JOB NAME: Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO.: OF

PACKER TEST ANALYSES

BOREHOLE : 213

Depth : 20-30 ft

Pressure (h_2) : 5 psi $\boxed{11.6 ft}$

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if Q < 4 gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S. Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = 120\text{ ft} - 20 + 43.7\text{ ft} = 143.7\text{ ft}$

$\frac{T_u}{l} = \frac{143.7\text{ ft}}{10\text{ ft}} = \boxed{14.4}$

$H = h_1 + h_2 - L = 36\text{ ft} + 11.6\text{ ft} - 3.9\text{ ft} = 43.7\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{43.7\text{ ft}}{143.7\text{ ft}}(100) = \boxed{30}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 2/3
Depth : 20-30 ft.
Pressure (h_2) : 5psi (11.6 ft)
1-30-06

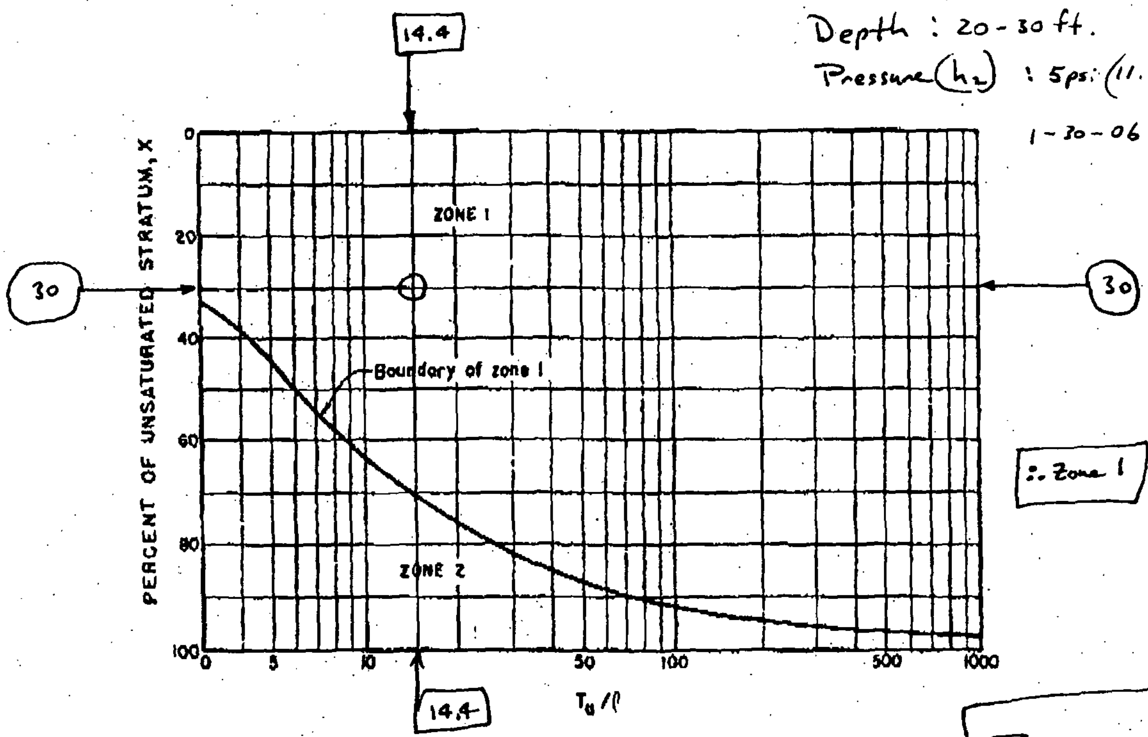


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

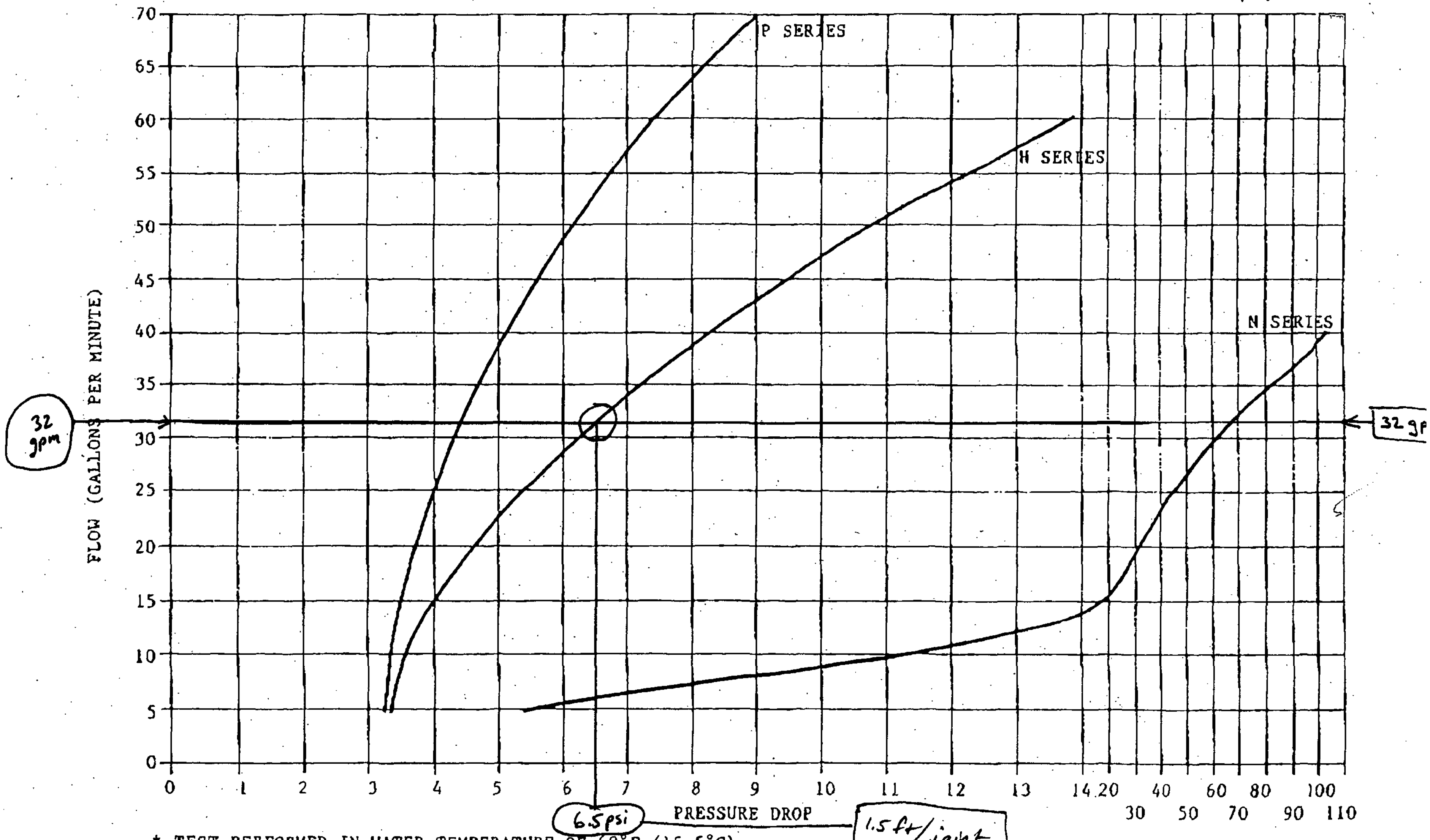
$$\frac{T_u}{\ell} = 14.4$$

$$X = 30$$

A-56

Borehole 213
Depth: 20-30 ft
Pressure: 5 psi
1-30-06

PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From: WIRELINE TYPE II service manual, Boart Longyear.

Borehole 213
Depth 20 - 30 ft.
pressure : 5 psi
1-30-06

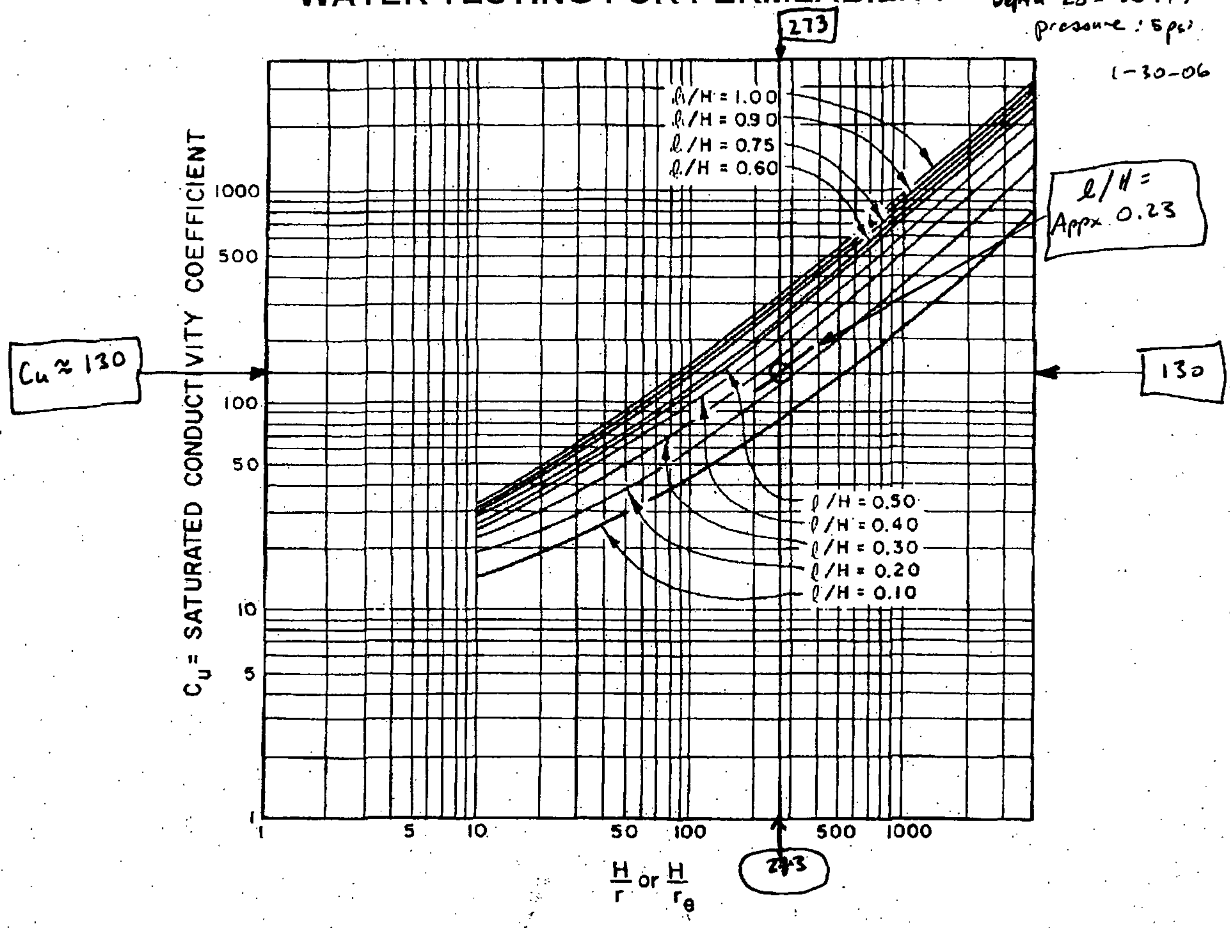


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Stoller

PACKER TEST SET-UP SHEET

JOB NO.:

DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

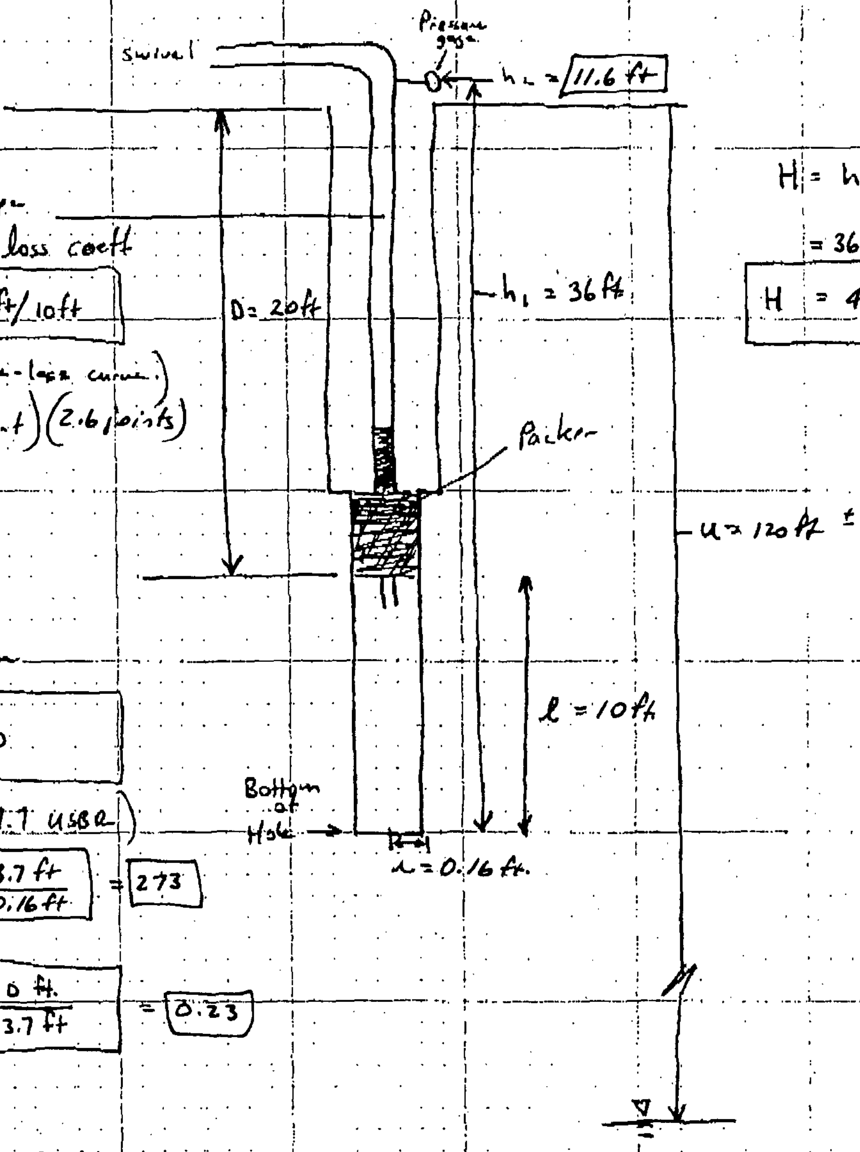
REVIEWED:

SHEET NO.: 1 OF

Borehole 213

Depth: 20 - 30 ft

pressure: 11.6 ft (5psi)



Obtain L = head loss coeff

$\boxed{L = 1.5\ ft/10\ ft}$

(from pressure-loss curve)

$L = (1.5\ ft/joint)(2.6\ joints)$

$\boxed{L = 3.9\ ft}$

$H = h_1 + h_2 - L$

$= 36\ ft + 11.6\ ft - 3.9\ ft$

$\boxed{H = 43.7\ ft}$

Obtain C_u

$\boxed{C_u = 130}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{43.7\ ft}{0.16\ ft}} = \boxed{273}$

$\frac{\ell}{H} = \boxed{\frac{10\ ft}{43.7\ ft}} = \boxed{0.23}$

Calculate K:

Method 1,

Zone 1,

USBR

$K = \frac{Q}{C_u\, r\, H} \quad \frac{(32\ gal/min)\left(\frac{1440\ min}{day}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)}{(130)(0.16\ ft)(43.7\ ft)}$

$\boxed{\begin{array}{l} K = 6.8\ ft/d \\ K = 2.4 \times 10^{-3}\ cm/s \end{array}}$

PACKER TEST ANALYSES

BOREHOLE : 213
Depth : 20-30 ft.
Pressure (h_2) : 10 psi (23.1 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$ ft

$T_u = U - D + H = 120\text{ ft} - 20\text{ ft} + 54.2\text{ ft} = 154.2\text{ ft}$

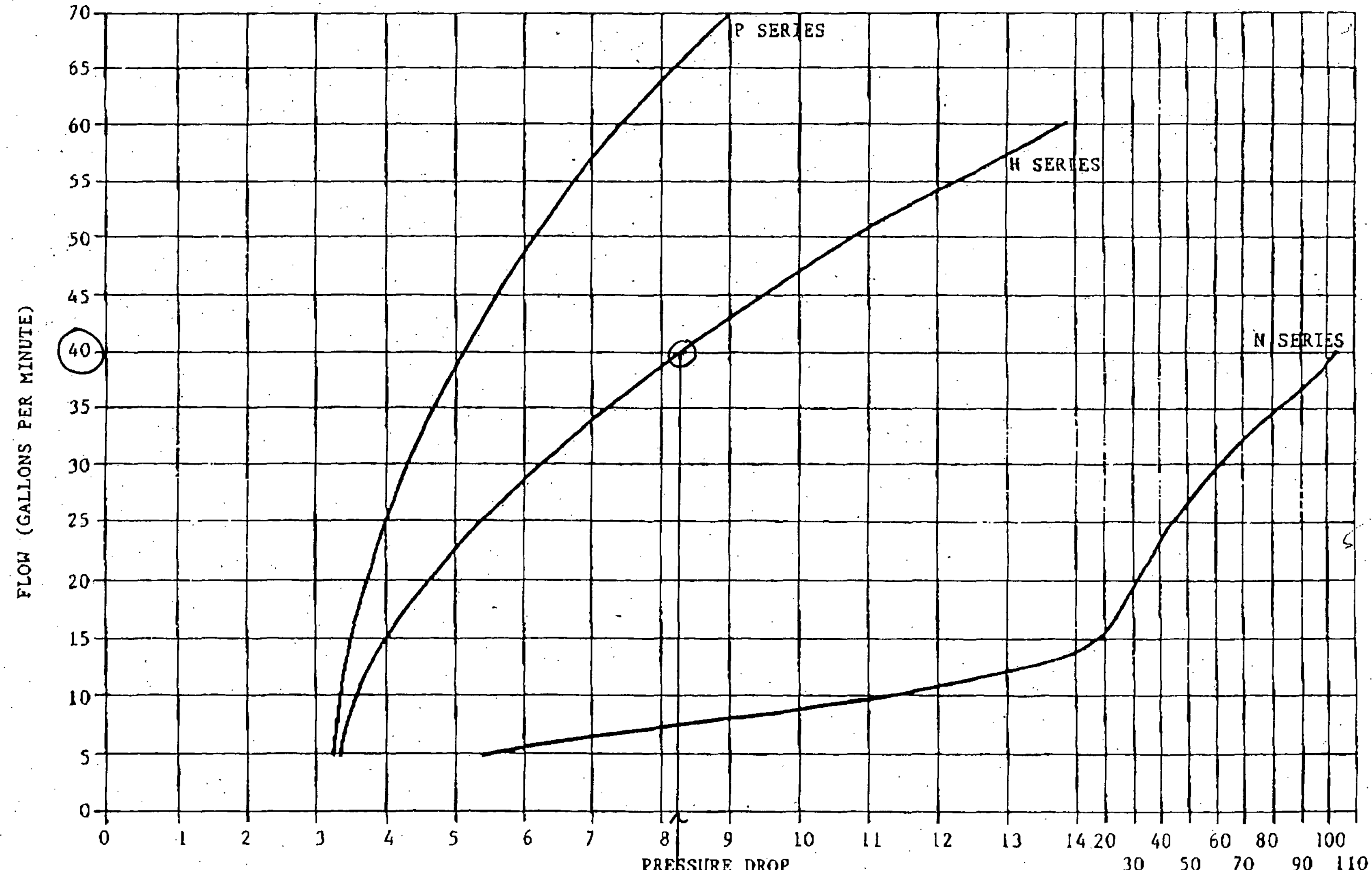
$\frac{T_u}{l} = \frac{154.2\text{ ft}}{10\text{ ft}} = \boxed{15.4}$

$H = h_1 + h_2 - L = 54.2$ ft

$X = \frac{H}{T_u}(100) = \frac{54.2\text{ ft}}{154.2\text{ ft}} \times (100) = \boxed{35}$

A-60

PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From : WIRELINE TYPE II service manual, Boart Longyear.

8.2 psi/100 ft = $\boxed{1.9 \text{ ft/joint}}$

Borehole 213
Depth: 20-30 ft
Pressure: 10 psi
1-30-06

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 213
Depth : 20-30ft
Pressure(h_2) : 10 psi
1-30-06

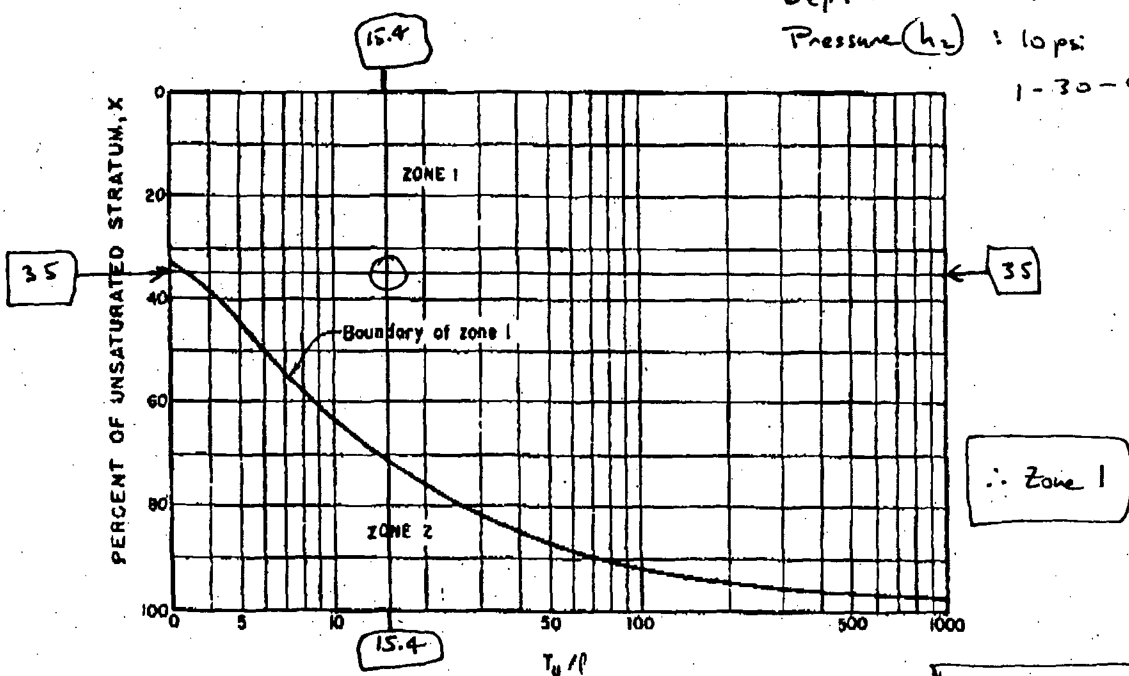


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{l} = 15.4$

$X = 35$

Borehole 213
Depth 20-30 ft.
Pressure : 10 psi
1-30-06

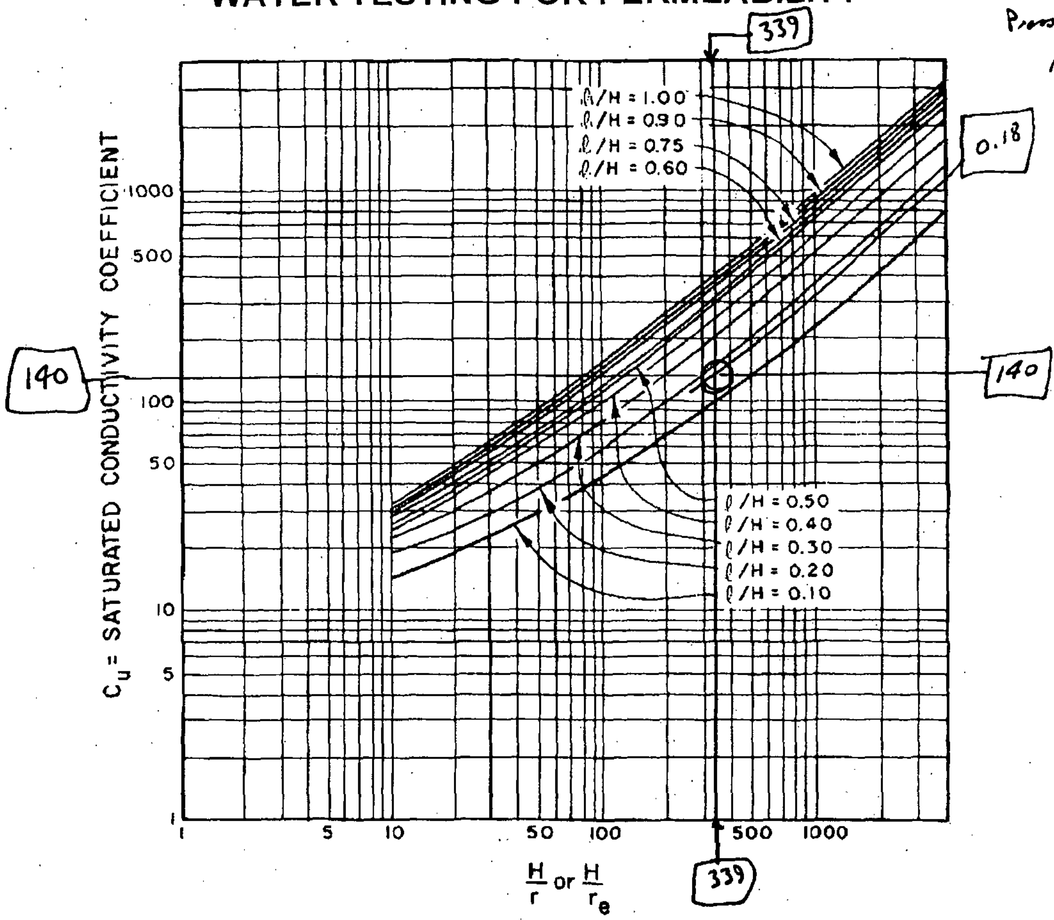


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: *U*, *ℓ*, *r*, h_2, *Q*, and *L* are as given in example 1, *D* = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total *L* is (6.2) (0.76) = 4.7 feet.

$H = 72 + 57.8 - 4.7 = 125.1$ feet

Stoller

PACKER TEST SET-UP SHEET

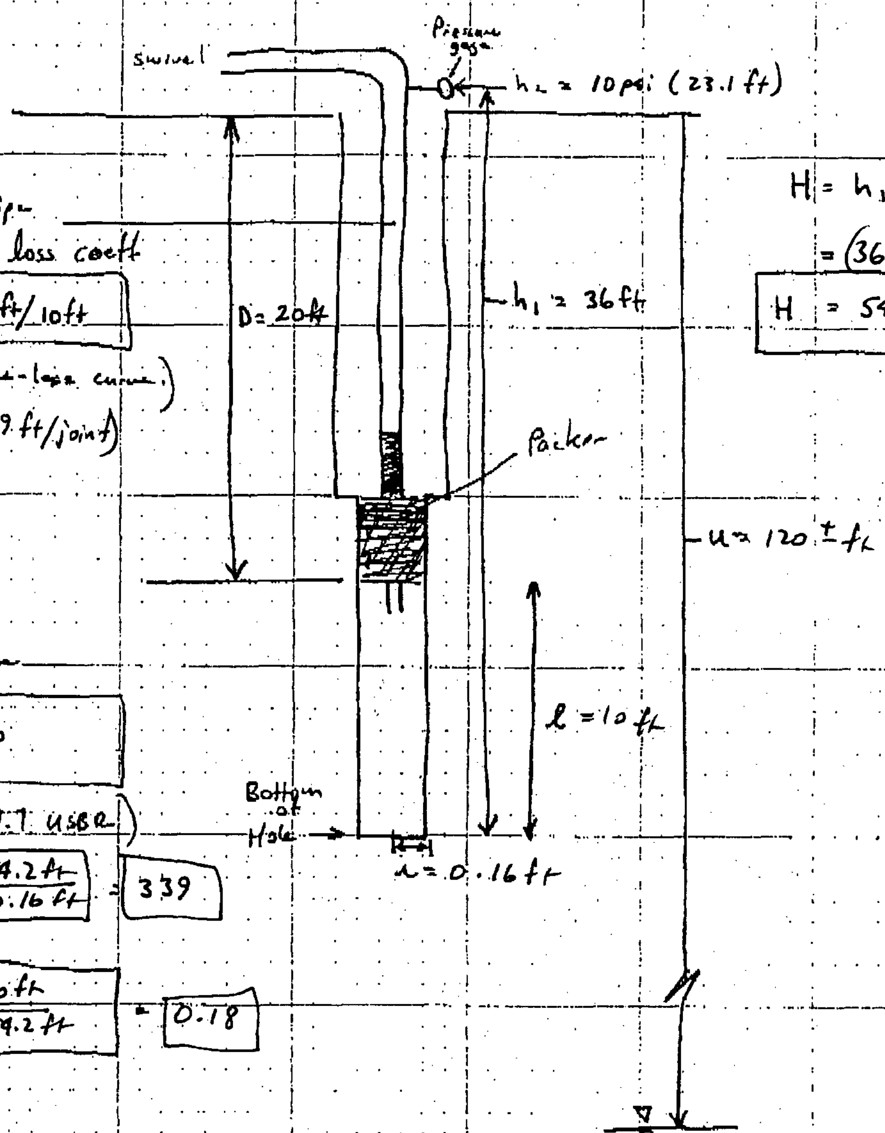
JOB NO.: DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED:

SHEET NO.: 1 OF

Borehole 213
20-30 ft.
pressure: 10 psi



Obtain L = head loss coeff

$\boxed{L = 1.9 \text{ ft}/10\text{ft}}$

(from pressure-loss curve)

$L = 2.6$ joint (1.9 ft/joint)

$L = 4.9$ ft.

$H = h_1 + h_2 - L$

$= (36 + 23.1 - 4.9)$ f

$\boxed{H = 54.2 \text{ ft}}$

Obtain C_u

$\boxed{C_u \cong 140}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{54.2\text{ ft}}{0.16\text{ ft}}} = \boxed{339}$

$\frac{\ell}{H} = \boxed{\frac{10\text{ ft}}{54.2\text{ ft}}} = \boxed{0.18}$

Calculate K:

Method 1,
Zone 1,
USBR

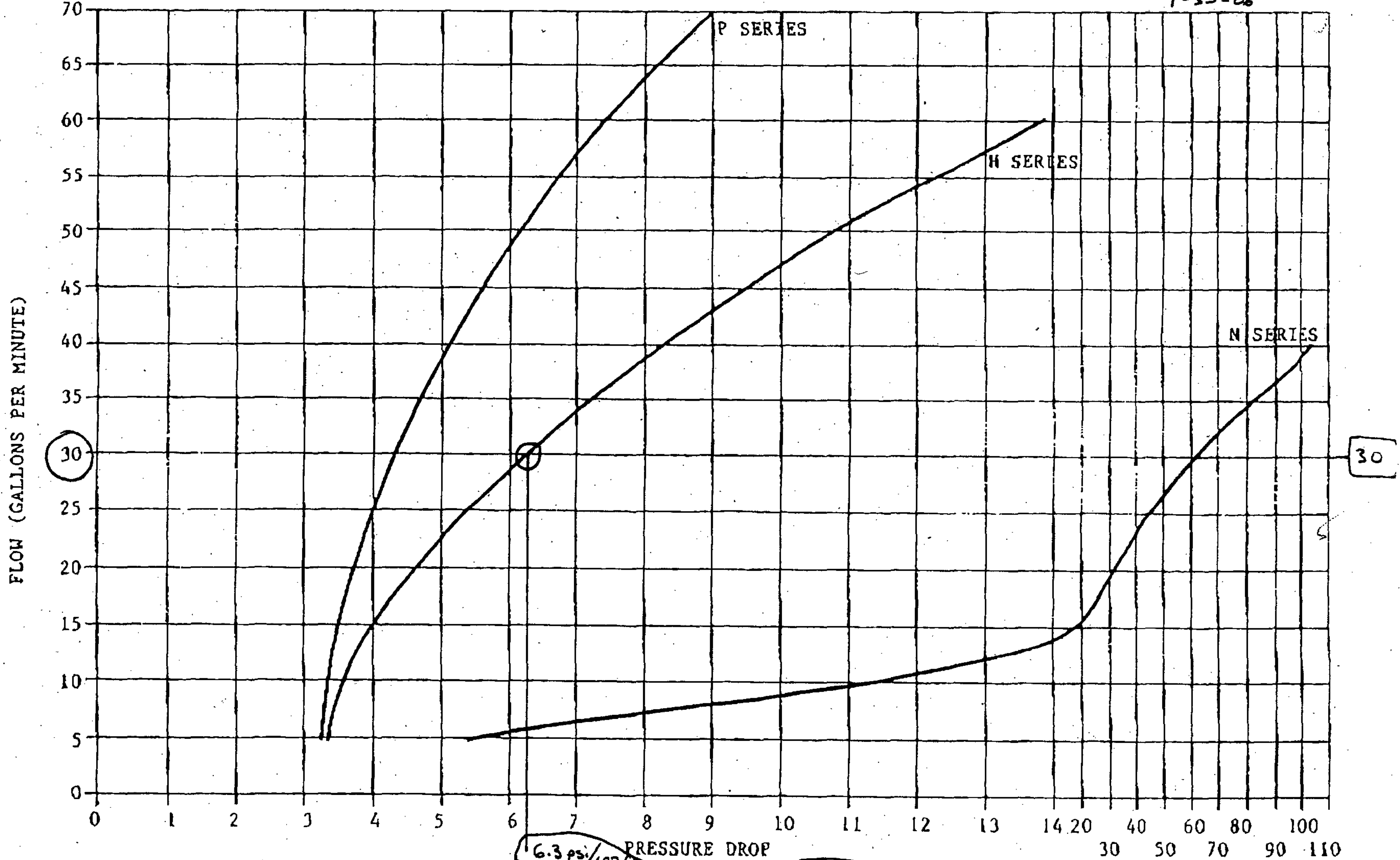
$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{40\text{ gal}}{\text{min}}\right)\left(\frac{1440\text{ min}}{\text{day}}\right)\left(\frac{1\text{ ft}^3}{7.48\text{ gal}}\right)}{(140)\,(0.16\text{ ft})\,(54.2\text{ ft})}$$

$$\boxed{\begin{array}{l} K = 6.3 \text{ ft/d} \\ K = 2.2 \times 10^{-3} \text{ cm/s} \end{array}}$$

A-64

Borehole 213
Depth : 20-30 ft
Pressure 5 psi (retest)
1-30-06

PRESSURE LOSS CURVE



1.5ft/10ft joint

* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From : WIRELINE TYPE II service manual, Boart Longyear.

Borehole 213
Depth : 20-3
pressure : 5 psi retest
1-30-06

Stoller

PACKER TEST SET-UP SHEET

JOB NO.:

DATE: 1-30-06

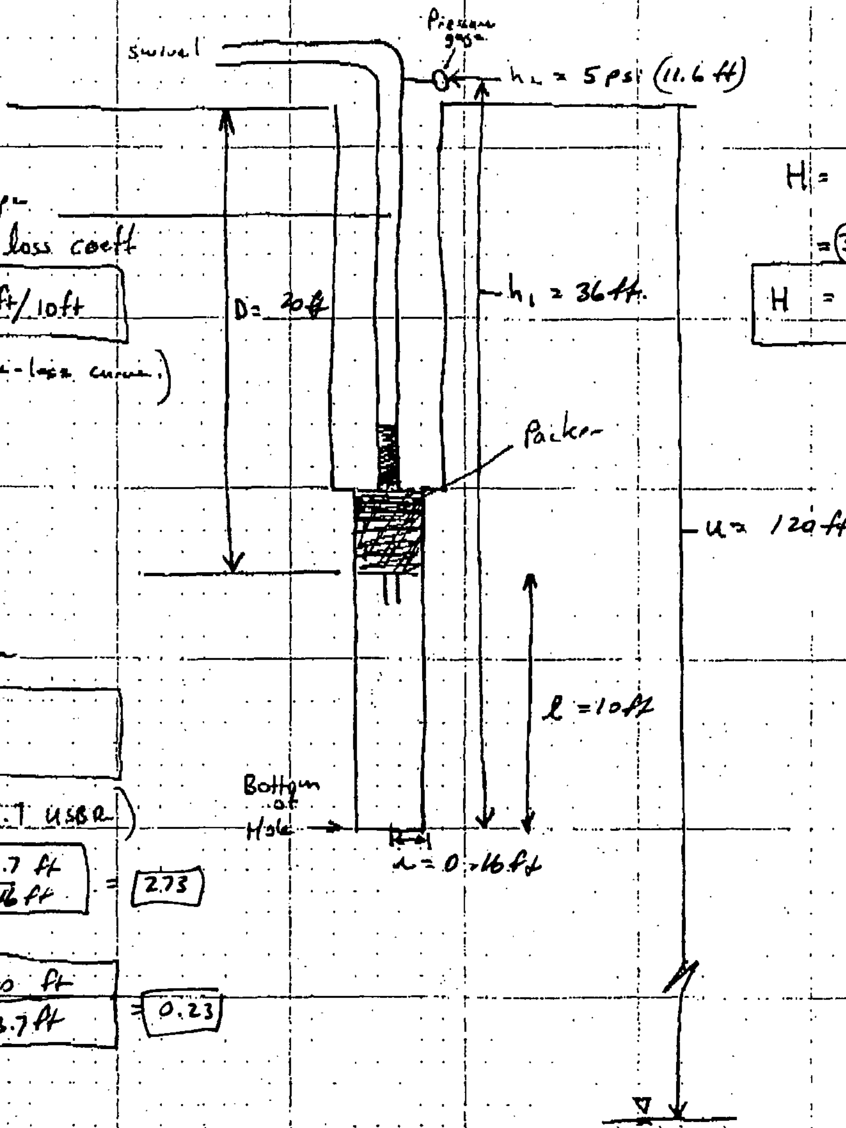
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

REVIEWED:

SHEET NO.: 1 OF

Borehole 213
Depth: 20-30 ft.
Pressure 5 psi (retest)



Obtain L = head loss coeff

$\boxed{L = 1.5 \text{ ft}/10 \text{ ft}}$

(from pressure-loss curve)

$\boxed{L = 3.9 \text{ ft}}$

$H = h_1 + h_2 - L$

$= (36 + 11.6 - 3.9)$ ft

$\boxed{H = 43.7 \text{ ft}}$

Obtain C_u

$\boxed{C_u = 130}$

(From fig 17.7 USBR)

$$\frac{H}{r} = \boxed{\frac{43.7 \text{ ft}}{0.16 \text{ ft}}} = \boxed{273}$$

$$\frac{l}{H} = \boxed{\frac{10 \text{ ft}}{43.7 \text{ ft}}} = \boxed{0.23}$$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{30 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(130)\,(0.16 \text{ ft})\,(43.7 \text{ ft})}$$

$$\boxed{\begin{aligned} K &= 6.4 \text{ ft/d} \\ K &= 2.2 \times 10^{-3} \text{ cm/s} \end{aligned}}$$

RECORD COPY

Stoller

established 1959

Packer-Test Record

Page 1 of 1

Project Name: Crescent Junction Characterization Date: 12-02-05

Field Representative: Mark Koutsky Borehole No.: 213 Total Depth: 40

Depth to Water (TOC): 120 ± Borehole Cleaned? Yes × No ____ Date: 12-02-05

Test Interval (BGL): from 30 to 40 ft. Swivel/Elbow Height (AGL) 6 ft

Conductor Pipe, Type, and Size: HQ/HX

Time	Gauge Pressure (psi)	Flow Meter Reading
09:30	5	38660
09:31	5	38697 37 gpm
09:32	5	38736 39 gpm
09:33	5	38775 39 gpm
~~09:44~~ 0934	5	38815 40 gpm
~~09:45~~ 0935	5	38854 39 gpm
0936	5	38893 39 gpm
0937	10	38934
0938	10	38979 45 gpm
0939	10	39023 44 gpm
0940	10	39068 45 gpm
09:41	10	~~390~~ 39113 45 gpm
09:42	10	39158 45 gpm
0943	5	39198
0944	5	39236 38 gpm
0945	5	39275 39 gpm
0946	5	39314 39 gpm
0947	5	end test ∴ out of water

F:\HOME\M50122\Word-2000\Crescent\PackerTest.dot

The S.M. Stoller Corporation 2597 B ¾ Road Grand Junction, Colorado 81503 (970) 248–6601 Fax: (970) 248–7636

Stoller

DATE 1-23-06

JOB NAME Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO: OF

PACKER TEST ANALYSES

BOREHOLE : 213
Depth : 30-40ft
Pressure (h_2) : 5psi (11.6 ft)

Unsaturated Zone Calculation:

Definitions: ℓ = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if Q < 4gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S. Bureau of Rec. Earth Manual

$\ell = 10\ ft$

$T_u = U - D + H = 120\ ft - 30\ ft + 50.8\ ft = \boxed{141\ ft}$

$\frac{T_u}{\ell} = \frac{141}{10} = \boxed{14.1}$

$H = h_1 + h_2 - L = (46 + 11.6 - 6.8)\ ft = 50.8\ ft$

$X = \frac{H}{T_u}(100) = \frac{50.8\ ft}{141}(100) = \boxed{36}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 213
Depth : 30 - 40 ft.
Pressure (h_2) : 5 psi (11.6 ft)

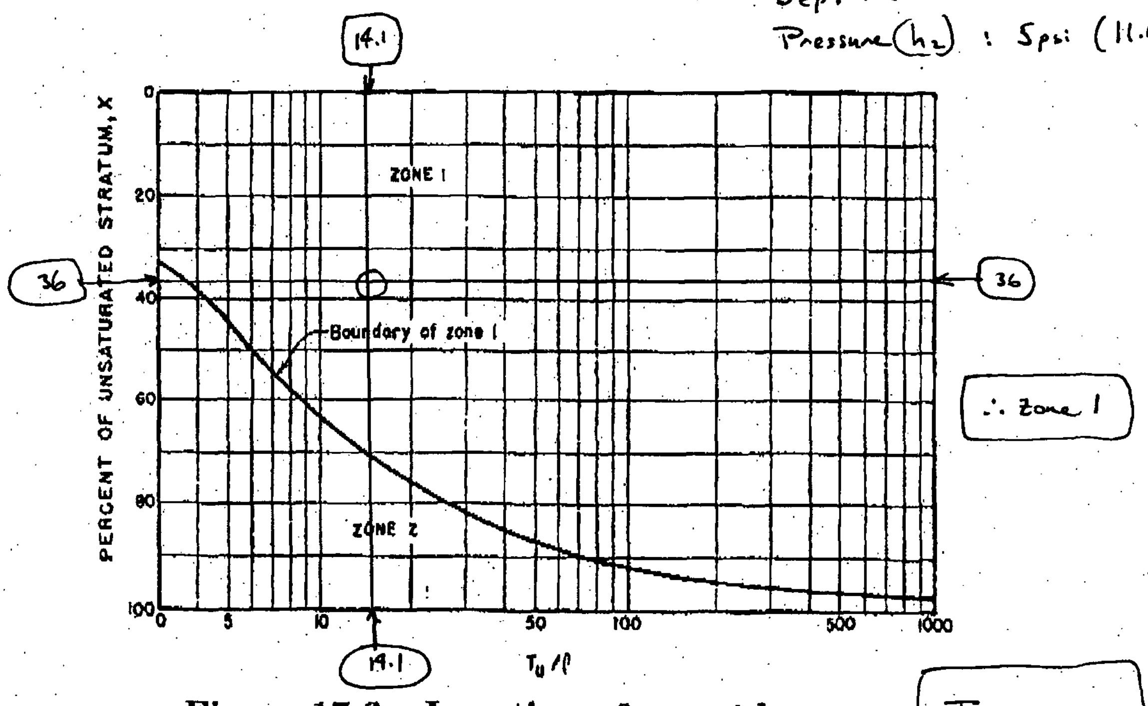


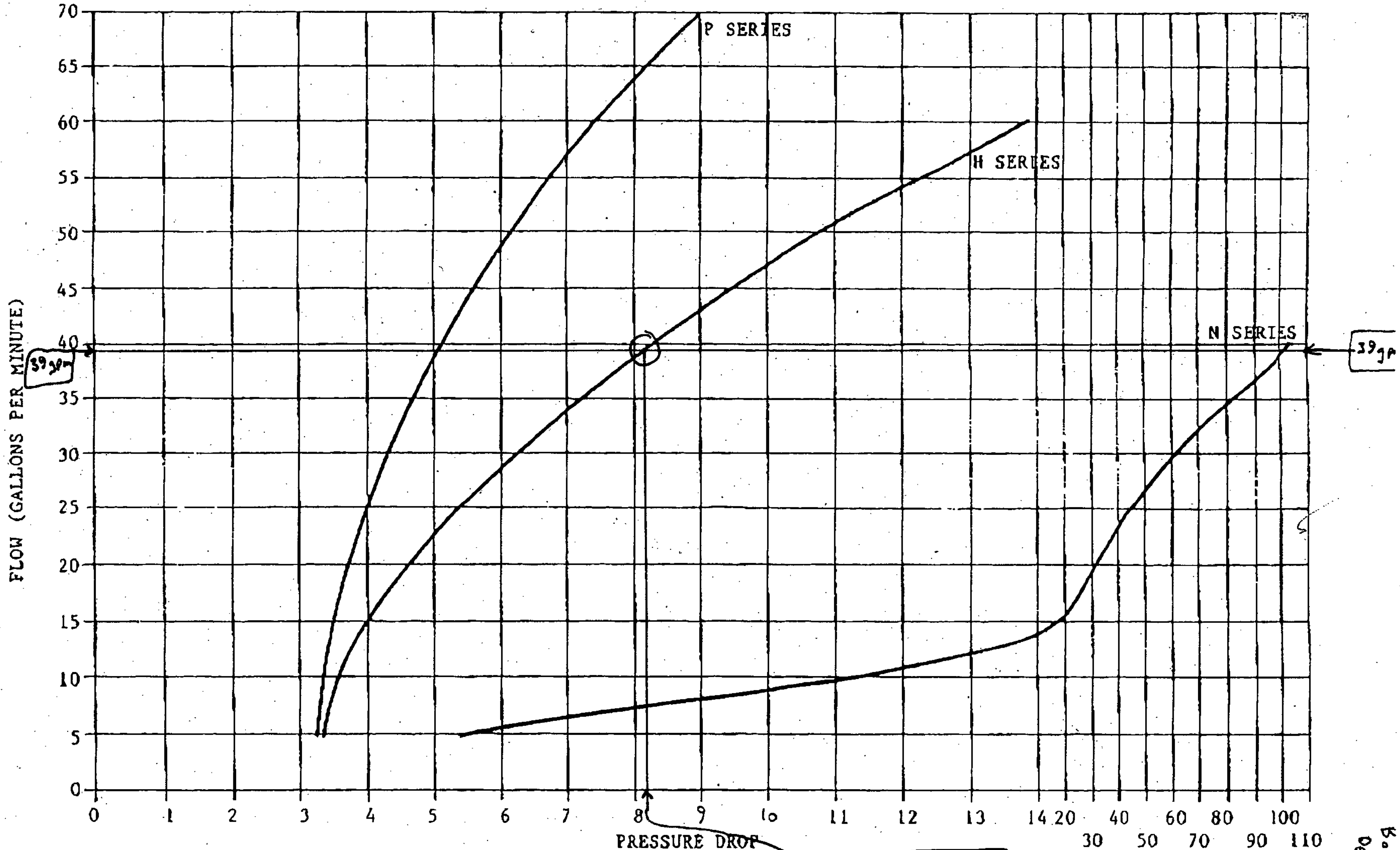
Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{l} = 14.1$

$X = 36$

A-69

PRESSURE LOSS CURVE



8.2 psi/100 ft → 1.9 ft/10-ft joint

* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From: WIRELINE TYPE II service manual, Boart Longyear.

Borehole 213
Depth: 30-40 ft.
Pressure: 5 psi
1-30-06

1-30-06
Borehole 213
pressure: 5psi
depth: 30-40 ft

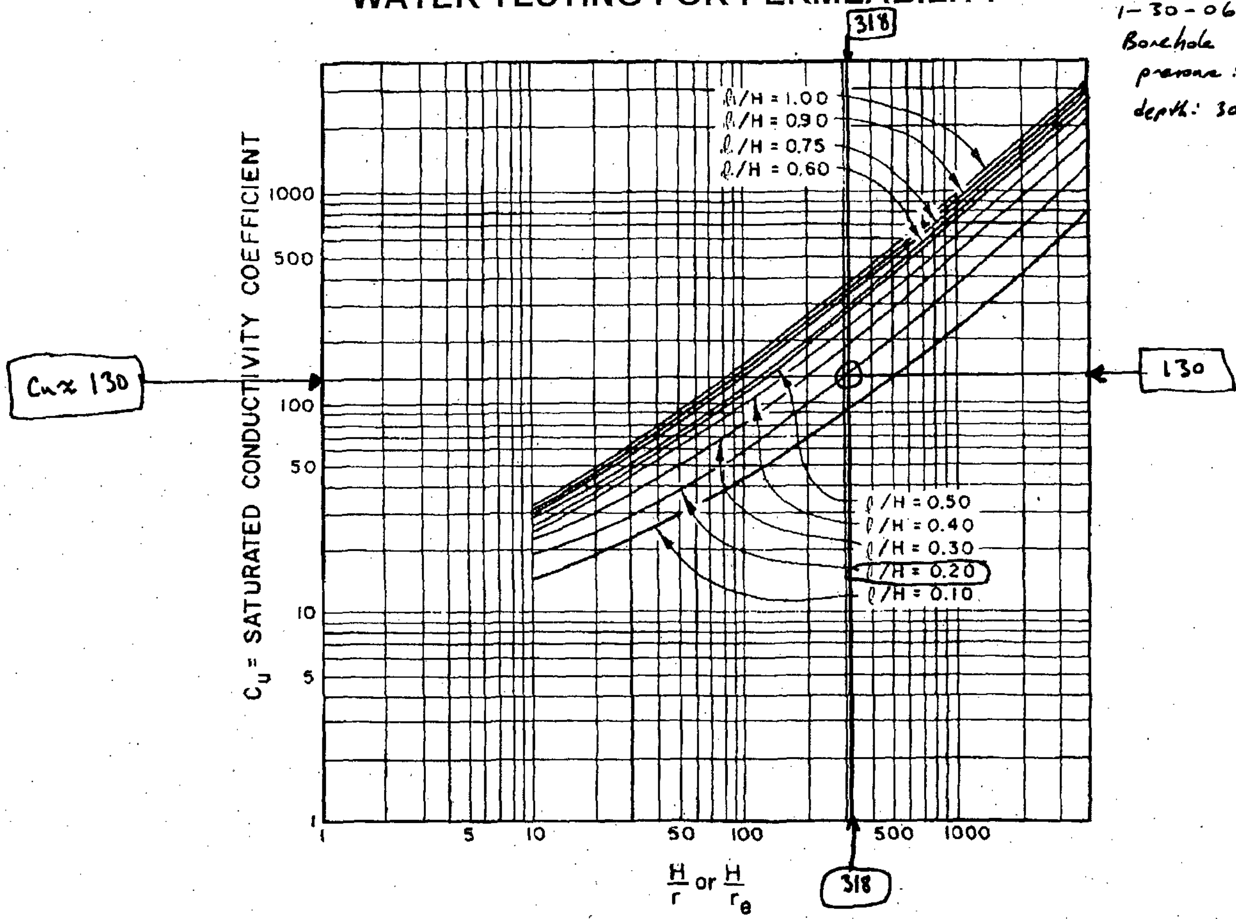


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

A-70

Stoller

PACKER TEST SET-UP SHEET

JOB NO.: DATE: 1-30-06

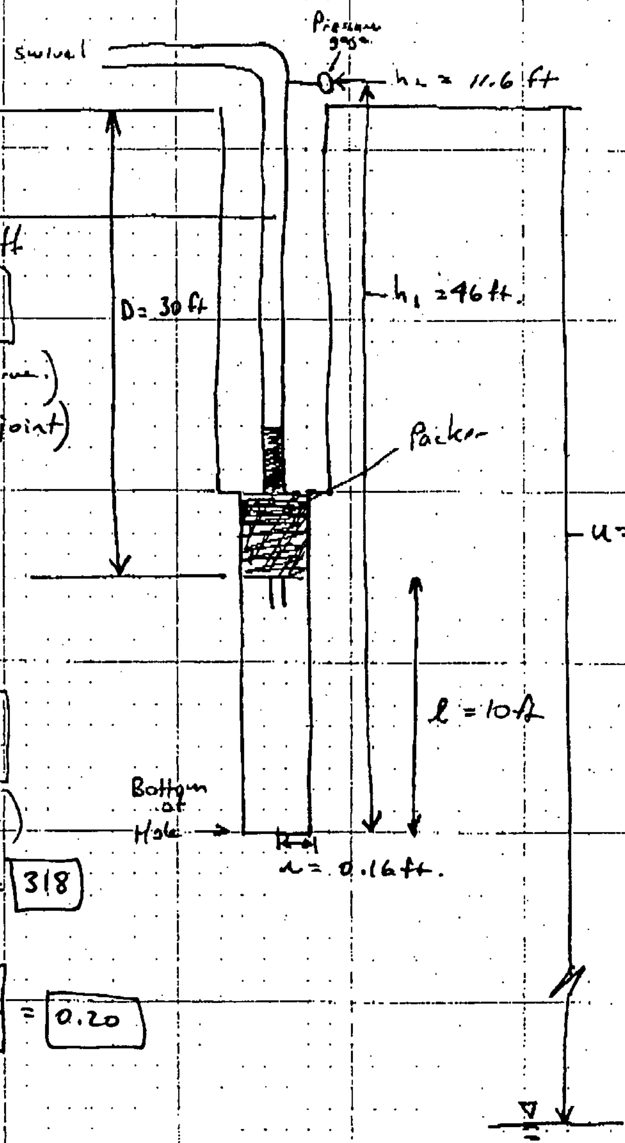
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED:

SHEET NO.: 1 OF Borehole 213

Depth: 30 - 40 ft.

Pressure: 11.6 ft (5 psi)



Injector pipe

Obtain L = head loss coeff

$\boxed{L = 1.9 \text{ ft}/10\text{ ft}}$

(from pressure-loss curve)

$L = (1.9 \text{ ft/joint})(3.6 \text{ joint})$

$\boxed{L = 6.8 \text{ ft}}$

$H = h_1 + h_2 - L$

$= (46 + 11.6 - 6.8)\text{ ft}$

$\boxed{H = 50.8 \text{ ft}}$

Obtain C_u

$\boxed{C_u \cong 130}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{50.8 \text{ ft}}{0.16 \text{ ft}}} = \boxed{318}$

$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{50.8 \text{ ft}}} = \boxed{0.20}$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u r H} = \frac{\left(\frac{39 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(130)(0.16 \text{ ft})(50.8 \text{ ft})}$$

$K = 7.1$ ft/d

$K = 2.5 \times 10^{-3}$ cm/s

DATE 1-23-06

PROJECT Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO ______ OF ______

PACKER TEST ANALYSES

BOREHOLE : 213

Depth : 30 – 40 ft

Pressure (h_2) : 10 psi (23.1 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 10$

$T_u = U - D + H = (120 - 30 + 61.3)\text{ ft} = 151$

$\frac{T_u}{l} = \left(\frac{151\text{ ft}}{10\text{ ft}}\right) = \boxed{15.1}$

$H = h_1 + h_2 - L = \boxed{61.3\text{ ft}}$

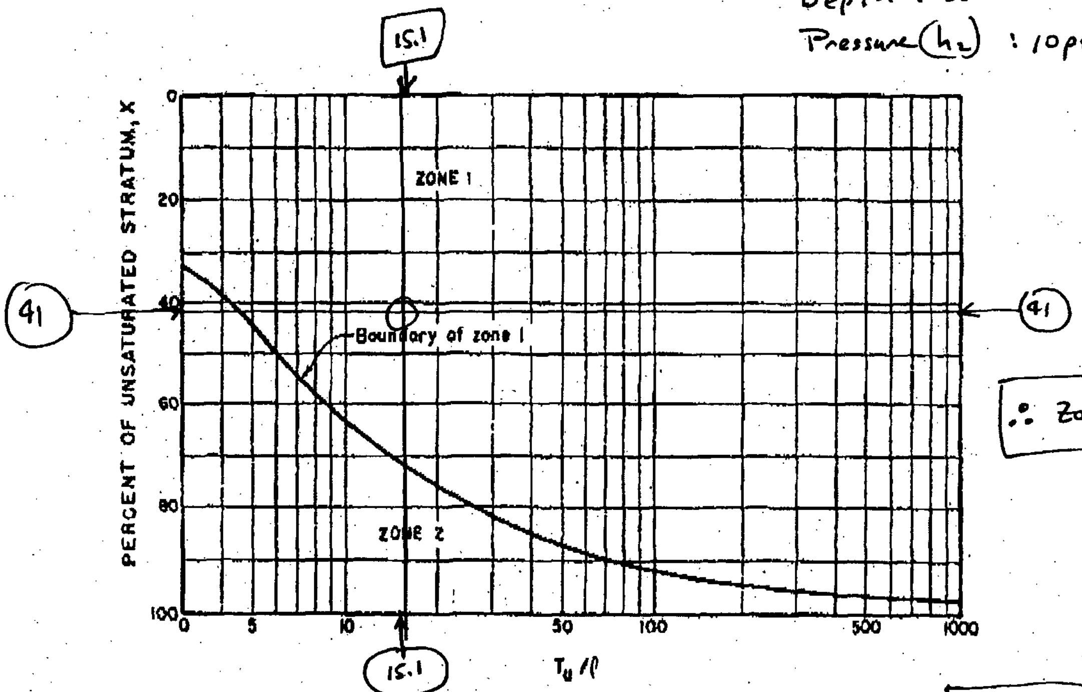
$X = \frac{H}{T_u}(100) = \frac{61.3\text{ ft}}{151\text{ ft}} \times 100\% \cong \boxed{41}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 213
Depth : 30-40 ft.
Pressure (h_2) : 10psi (23.1 ft)



∴ Zone 1

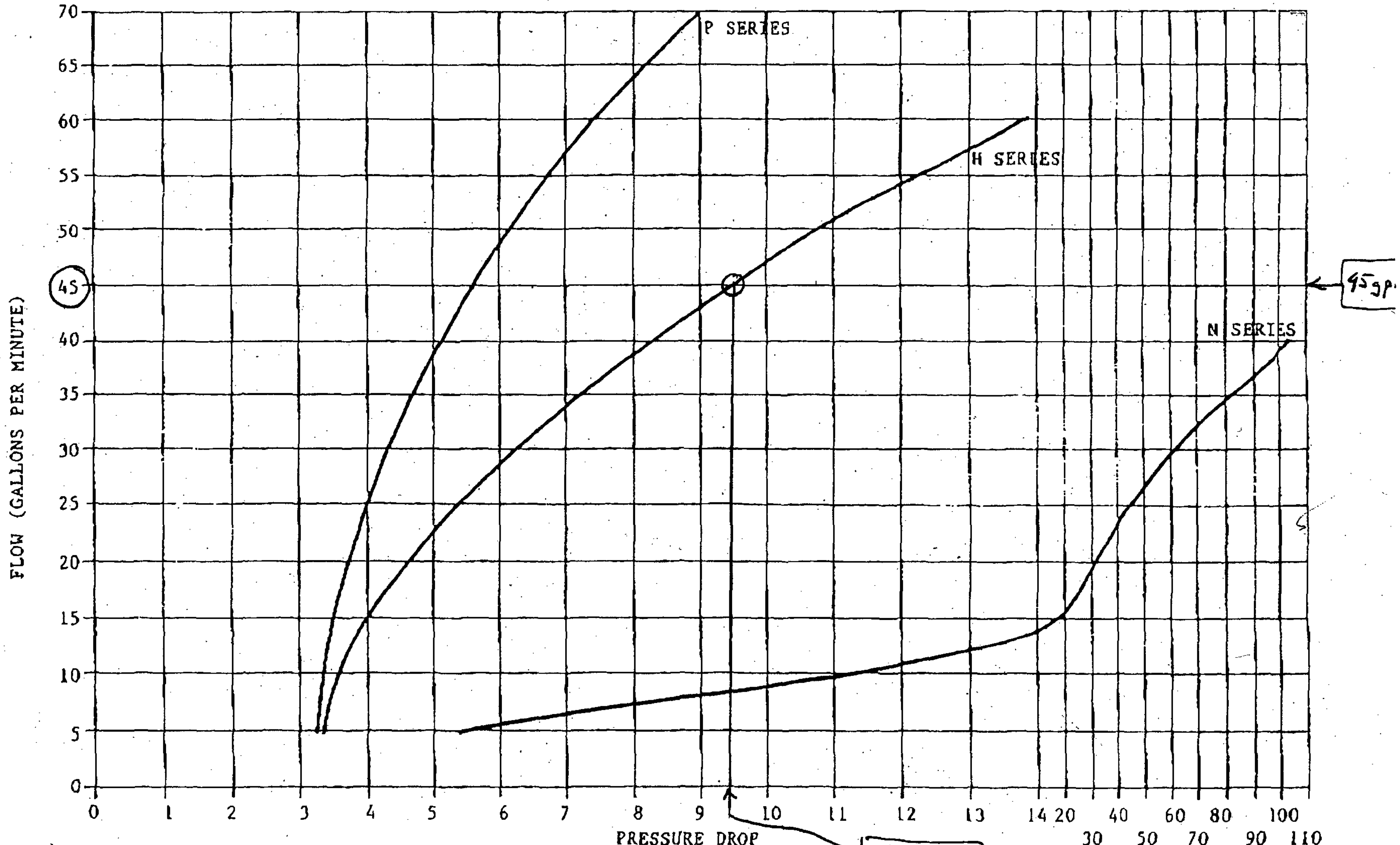
Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$$\frac{T_u}{\ell} = 15.1$$

$$X = 41$$

A-74

PRESSURE LOSS CURVE



* TEST PERFORMED IN WATER TEMPERATURE OF 60°F (15.5°C)

* THIS CHART IS MEANT TO BE USED HAS A GUIDE ONLY. THE MEASUREMENTS WERE OBTAINED UNDER CONTROLLED LAB CONDITIONS AND ACTUAL FIELD CONDITIONS MAY VERY.

From: WIRELINE TYPE II service manual, Boart Longyear.

Borehole 213
Depth 30-90 ft
pressure 10 psi
1-30-06

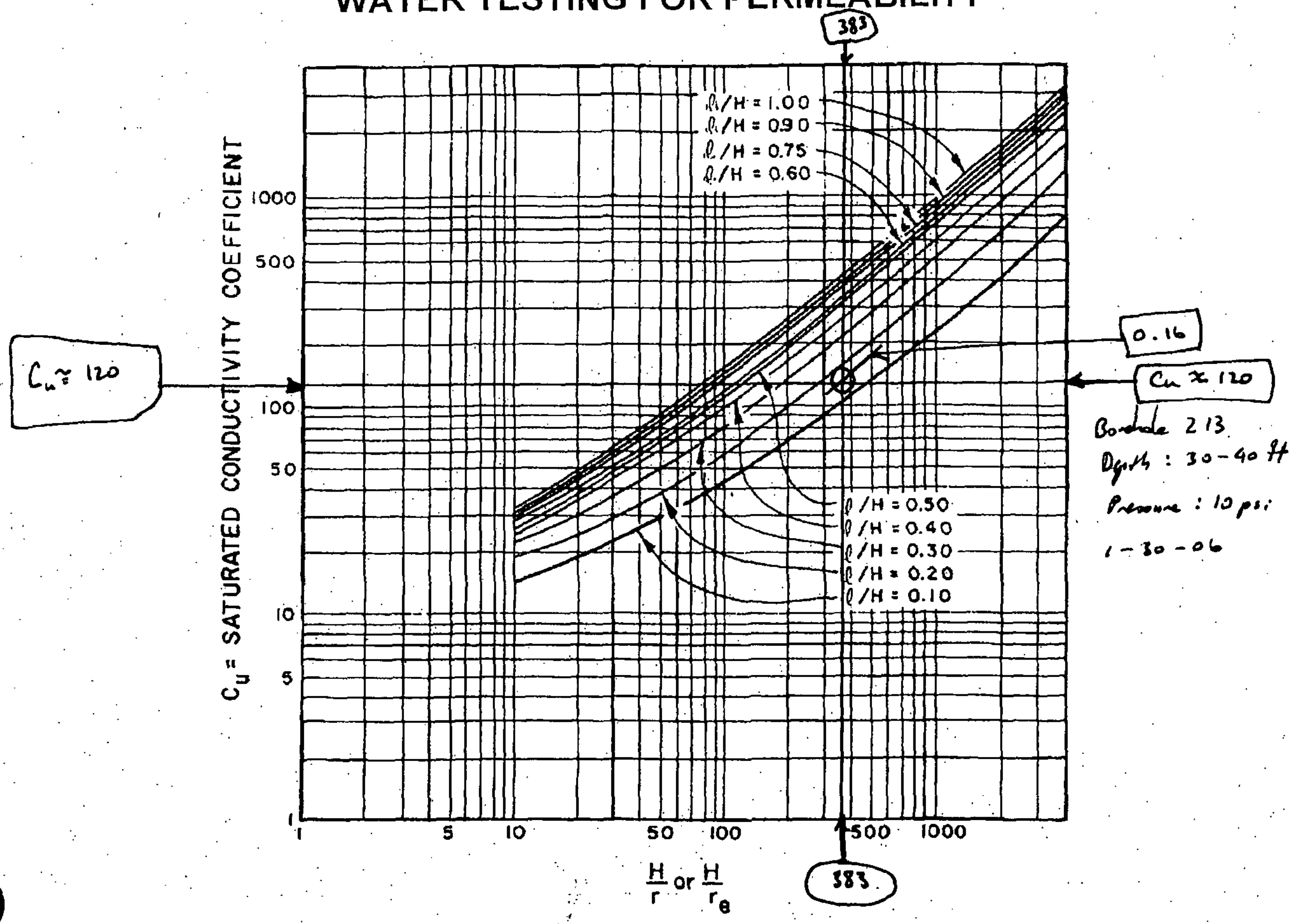


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Stoller

PACKER TEST SET-UP SHEET

Zone 1

JOB NO.: DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED:

SHEET NO.: 1 OF

Borehole 213
Depth 30-40 ft.
pressure: (10 psi)

Injection pipe

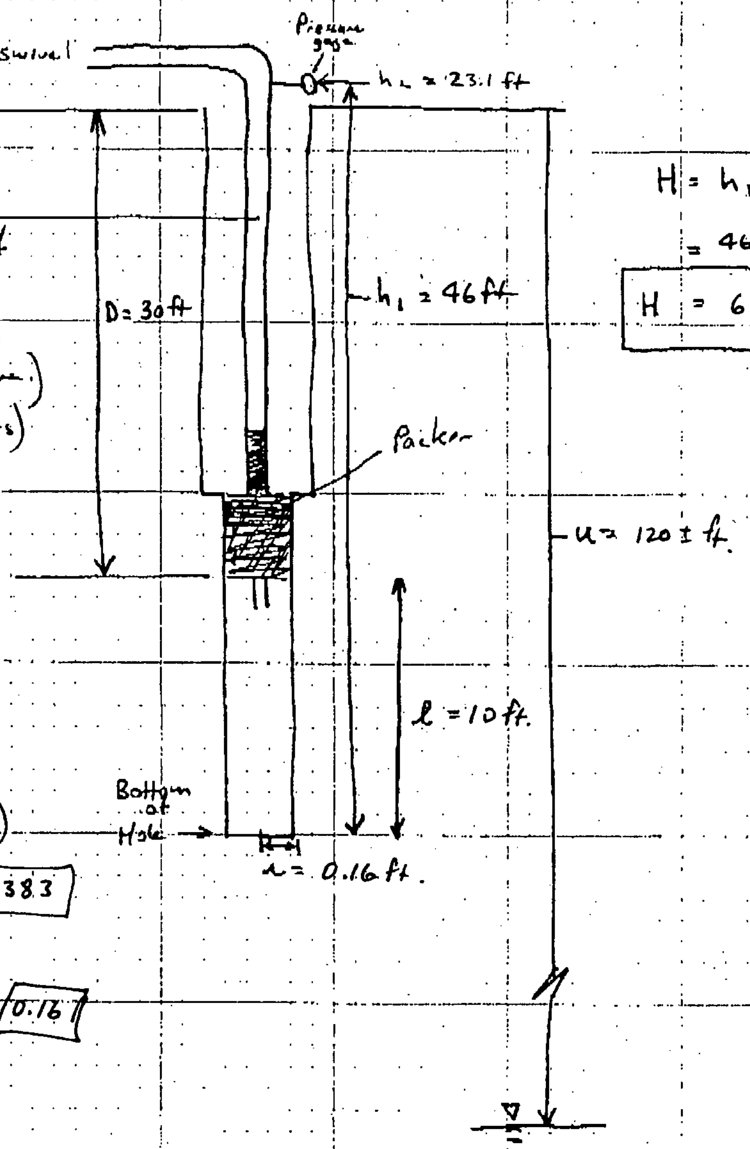
Obtain L = head loss coeff

$\boxed{L = 2.2\ ft/10ft}$

(From pressure-loss curve)

$L = \left(2.2\ ft/joint\right)\left(3.6\ joints\right)$

$\boxed{L = 7.8\ ft}$



$H = h_1 + h_2 - L$

$= 46 + 23.1 - 7.8\ ft$

$\boxed{H = 61.3\ ft}$

Obtain C_u

$\boxed{C_u = 120}$

(From fig 17.7 USBR)

$\frac{H}{r} = \boxed{\frac{61.3\ ft}{0.16\ ft}} = \boxed{383}$

$\frac{l}{H} = \boxed{\frac{10\ ft}{61.3\ ft}} = \boxed{0.16}$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{45\ gal}{min}\right)\left(\frac{1440\ min}{d}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)}{(120)(0.16\ ft)(61.3\ ft)}$$

$\boxed{K = 7.4\ ft/d \quad K = 2.6 \times 10^{-3}\ cm/sec}$

Stoller

PACKER TEST SET-UP SHEET

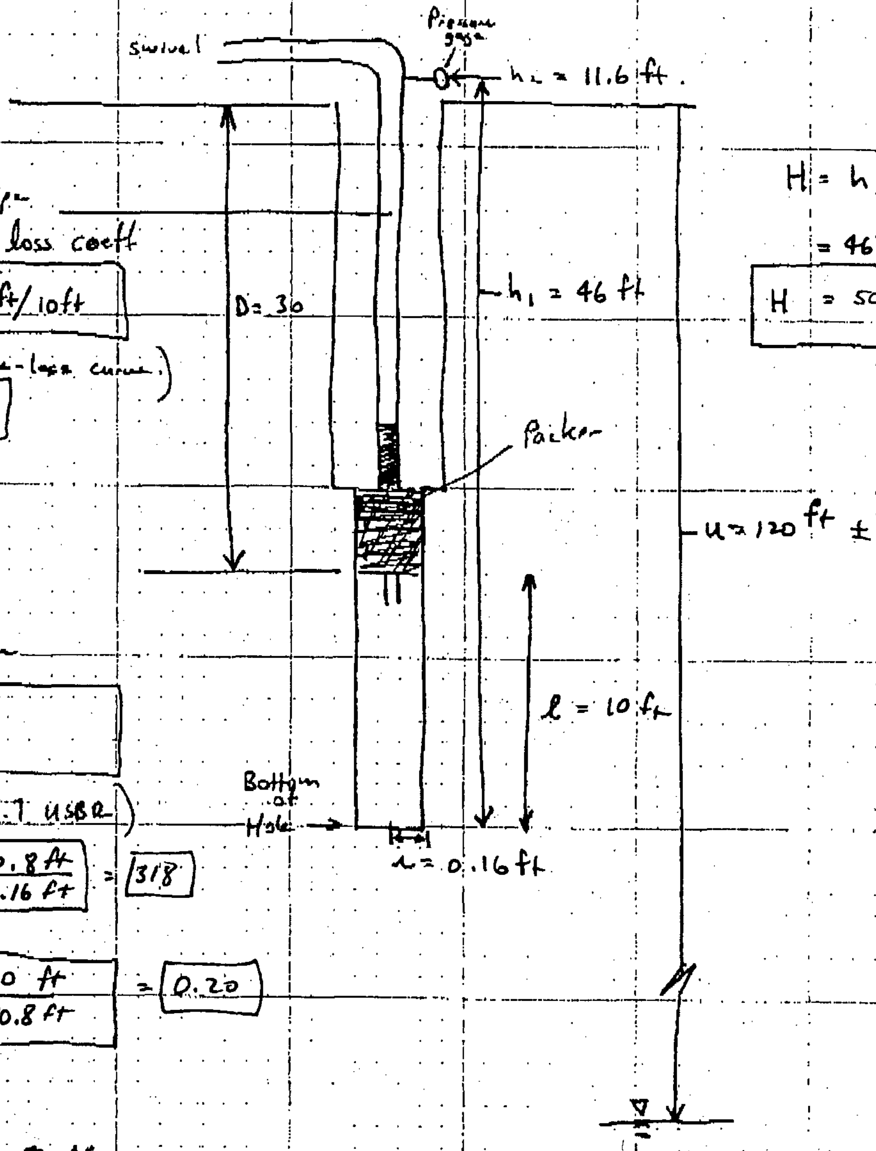
JOB NO.: ______ DATE: 1-30-06

JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky REVIEWED: ______

SHEET NO.: 1 OF ____

Borehole 213
Depth: 30 - 40 ft
pressure: 5 psi (refect)



Obtain L = head loss coeff

$\boxed{L = 1.9 \text{ ft}/10\text{ft}}$

(from pressure-loss curve)

$\boxed{L = 6.8 \text{ ft}}$

$$H = h_1 + h_2 - L$$
$$= 46 \text{ ft} + 11.6 - 6.8 \text{ ft}$$
$$\boxed{H = 50.8 \text{ ft.}}$$

Obtain C_u

$\boxed{C_u \doteq 130}$

(From fig 17.7 USBR)

$$\frac{H}{r} = \boxed{\frac{50.8 \text{ ft}}{0.16 \text{ ft}}} = \boxed{318}$$

$$\frac{\ell}{H} = \boxed{\frac{10 \text{ ft}}{50.8 \text{ ft}}} = \boxed{0.20}$$

Calculate K:

Method 1,
Zone 1,
USBR

$$K = \frac{Q}{C_u\, r\, H} = \frac{\left(\frac{39 \text{ gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{day}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(130)\,(0.16 \text{ ft})\,(50.8 \text{ ft})}$$

$$\boxed{\begin{aligned} K &= 7.1 \text{ ft/d} \\ K &= 2.5 \times 10^{-3} \text{ cm/s} \end{aligned}}$$

Stoller

established 1959

Packer-Test Record

Project Name: Moab-Crescent Jct Characterization Date: 01/14/06

Field Representative: R. Rupp Borehole No. 0204 Total Depth: 300'

Depth to Water (TOC): 225 ft. Borehole Cleaned? Yes ✓ No____ Date: 01/12/06

Test Interval (BGL): from 80 to 92 ft. Swivel/Elbow Height (AGL) 4.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin Wall STEEL TUBING

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
1035	10 psi	39387.75	
1040	10	39387.8	0.01 gpm
1045	10	39387.8	~~0~~
1050	10	39387.8	~~0~~
1055	10	39387.8	~~0~~
1100	20 psi	39388.0	0.04 gpm
1105	20	39388.15	0.03
1110	20	39388.25	0.02
1115	20	39388.4	0.03
1120	20	39388.55	0.03
1125	20	39388.7	0.03
1130	30 psi	39389.0	0.06
1135	30	39389.25	0.05
1140	30	39389.35	0.02
1145	30	39389.35	~~0~~
1150	30	39389.35	~~0~~
1155	30	39389.35	~~0~~

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct. Characterization Date: 01/14/06

Field Representative: R. Rupp Borehole No. 0204 Total Depth : 300'

Depth to Water (TOC): 225' Borehole Cleaned? Yes ✓ No ____ Date: 01/12/06

Test Interval (BGL): from 80 to 92 ft. Swivel/Elbow Height (AGL) 4.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin Wall steel tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
1200	20 psi	39389.45	0.02 gpm
1205	20	39389.7	0.05
1210	20	39389.95	0.05
1215	20	39390.15	0.04
1220	20	39390.35	0.04
1225	20	39390.55	0.04
1230	10 psi	39390.55	-0-
1235	10	39390.6	0.01
1240	10	39390.65	0.01
1245	10	39390.65	-0-
1250	10	39390.65	-0-
1255	10	39390.65	-0-

DATE: 1-25-06

PROJECT: Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO: OF

PACKER TEST ANALYSES

BOREHOLE : 204

Depth : 80 - 92 ft

Pressure (h_2) : 10 psi (23.1 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = (225\text{ ft}) - (92\text{ ft}) + (119.1\text{ ft}) = 252.1$ ft

$\frac{T_u}{l} = \frac{252.1\text{ ft}}{12\text{ ft}} = \boxed{21}$

$H = h_1 + h_2 - L = (96\text{ ft}) + (23.1\text{ ft}) - \emptyset = 119.1$ ft

$X = \frac{H}{T_u}(100) = \frac{119.1\text{ ft}}{252.1\text{ ft}}(100) = \boxed{47}$

$h_1 = (D) + (\text{stick up height}) = (92\text{ ft}) + (4\text{ ft}) = 96$ ft

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 204
Depth : 82-94 ft
Pressure (h_2) : 10 psi

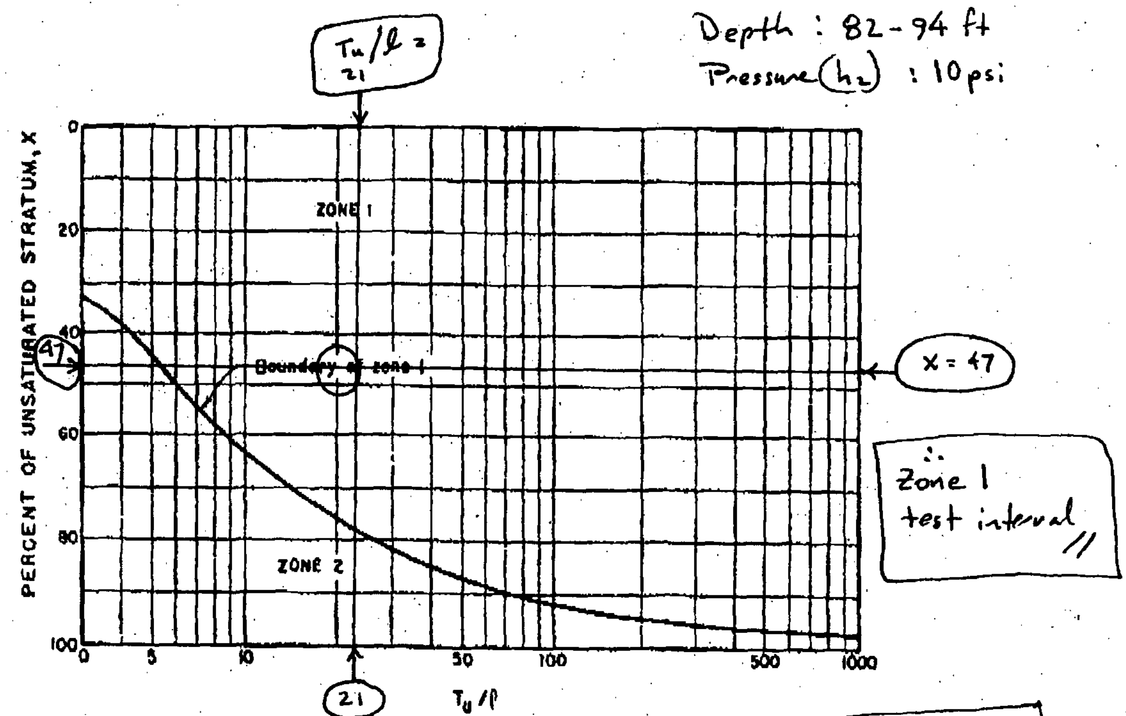


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 21$

$X = 47$

1-25-06
Borehole : 204
Depth : 80 - 92 ft.
Pressure : 10 psi

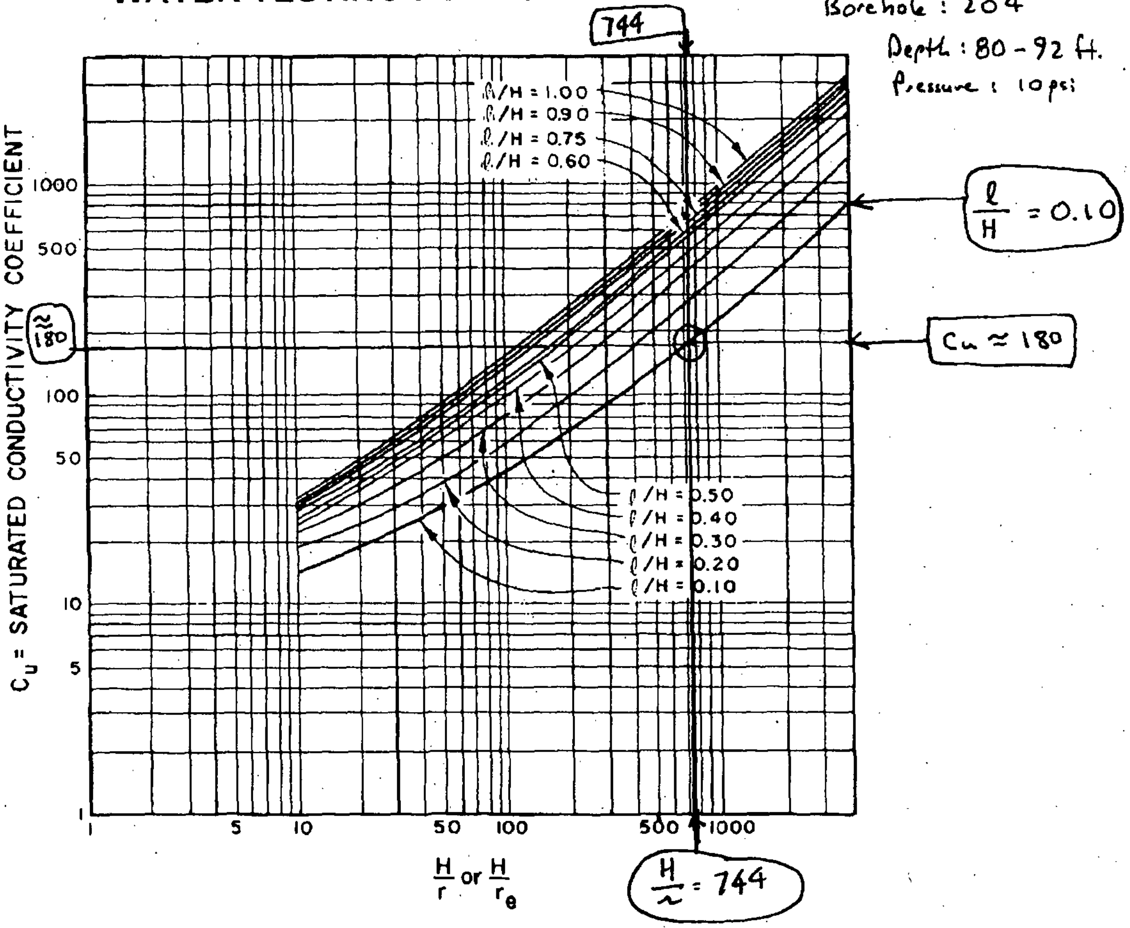


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

JOB NO. DATE: 1-25-06

JOB NAME: Crescent Junction Site

PREPARED: REVIEWED:

SHEET NO. OF

Borehole 204

Depth : 80 - 92 ft

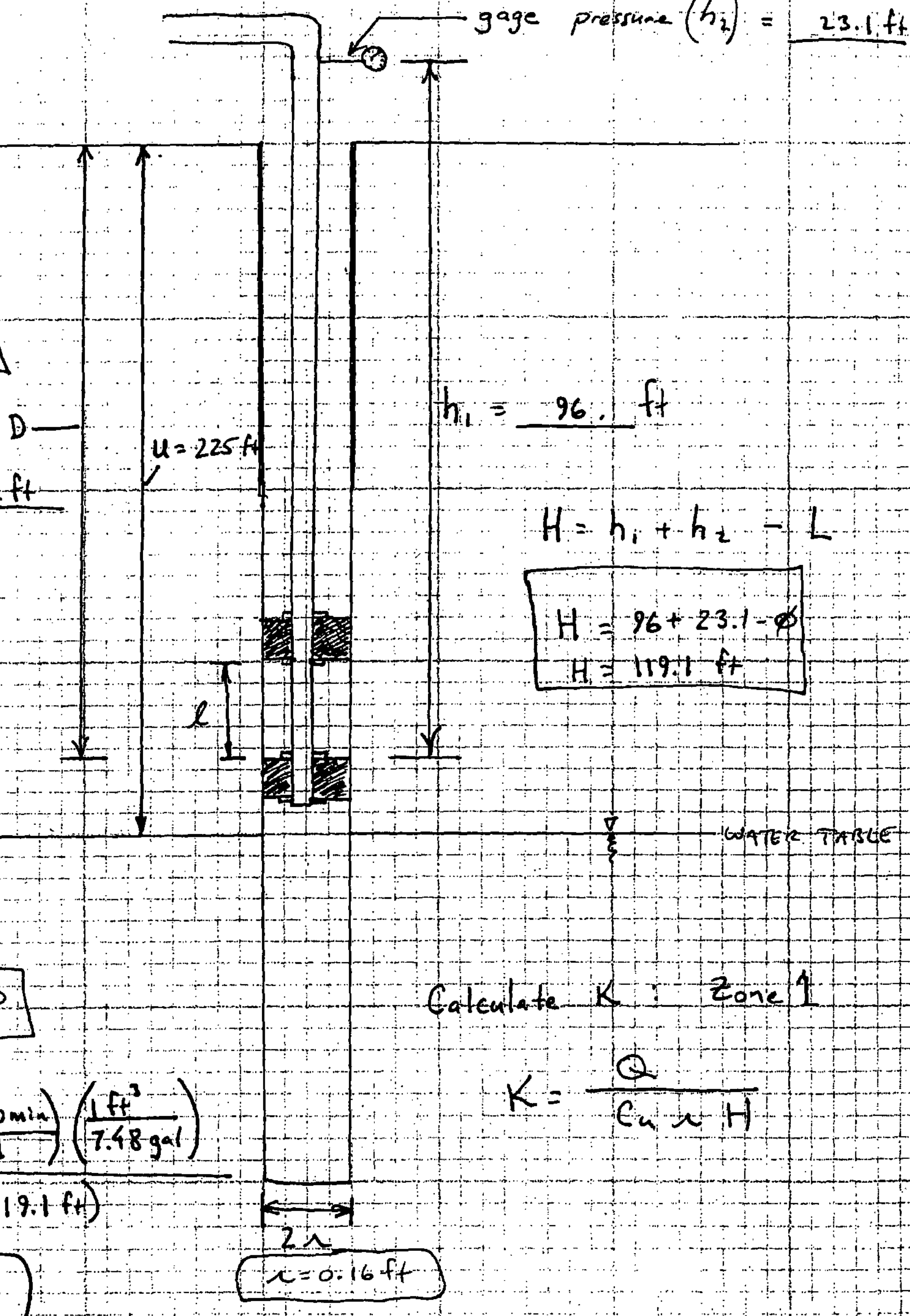
Pressure : 10 psi (23.1 ft)

Stoller

Packer Test Set-up Sheet

For straddle packer tests in Zone I

– Above water Table –



Injector Pipe

Obtain L (head loss coeff.)

$\boxed{L = \phi \text{ ft}/10 \text{ ft}}$

from pressure-loss curve $Q < 4$ gpm $\therefore L = \phi$

$Q < \frac{0.01 \text{ gal}}{15 \text{ min}}$

$\boxed{Q < 6.7 \times 10^{-4} \text{ gal/min}}$

Obtain C_u

$\boxed{C_u = 180}$

from fig 17.7 USBR

$$H = h_1 + h_2 - L$$

$$\boxed{\begin{aligned} H &= 96 + 23.1 - \phi \\ H &= 119.1 \text{ ft} \end{aligned}}$$

$$\frac{H}{r} = \boxed{\frac{119.1 \text{ ft}}{0.16 \text{ ft}}} = \boxed{744}$$

$$\frac{l}{H} = \boxed{\frac{12 \text{ ft}}{119.1 \text{ ft}}} = \boxed{0.10}$$

Calculate K : Zone 1

$$K = \frac{Q}{C_u \, r \, H}$$

$$K < \frac{\left(6.7 \times 10^{-4} \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(180)(0.16 \text{ ft})(119.1 \text{ ft})}$$

$$\boxed{\begin{aligned} K &< 3.7 \times 10^{-5} \text{ ft/d} \\ K &< 1.3 \times 10^{-8} \text{ ft/d} \end{aligned}}$$

PACKER TEST ANALYSES

BOREHOLE : 204
Depth : 80-92 ft.
Pressure (h_2) : 20 psi (46.2 ft)

Unsaturated Zone Calculation:

Definitions:

l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S. Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = (225 \text{ ft}) - (92 \text{ ft}) + (142.2 \text{ ft}) = 275.2 \text{ ft}$

$\frac{T_u}{l} = \frac{275.2 \text{ ft}}{12 \text{ ft}} \cong 23$

$H = h_1 + h_2 - L = 96 \text{ ft} + 46.2 \text{ ft} - \emptyset = 142.2 \text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{142.2 \text{ ft}}{275.2 \text{ ft}}(100) \cong 52$

$h_1 = D + \text{stickup height} = 92 \text{ ft} + 4 \text{ ft} = 96 \text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 204
Depth : 80-92 ft
Pressure (h_2) : 20 psi
(46.2 ft)

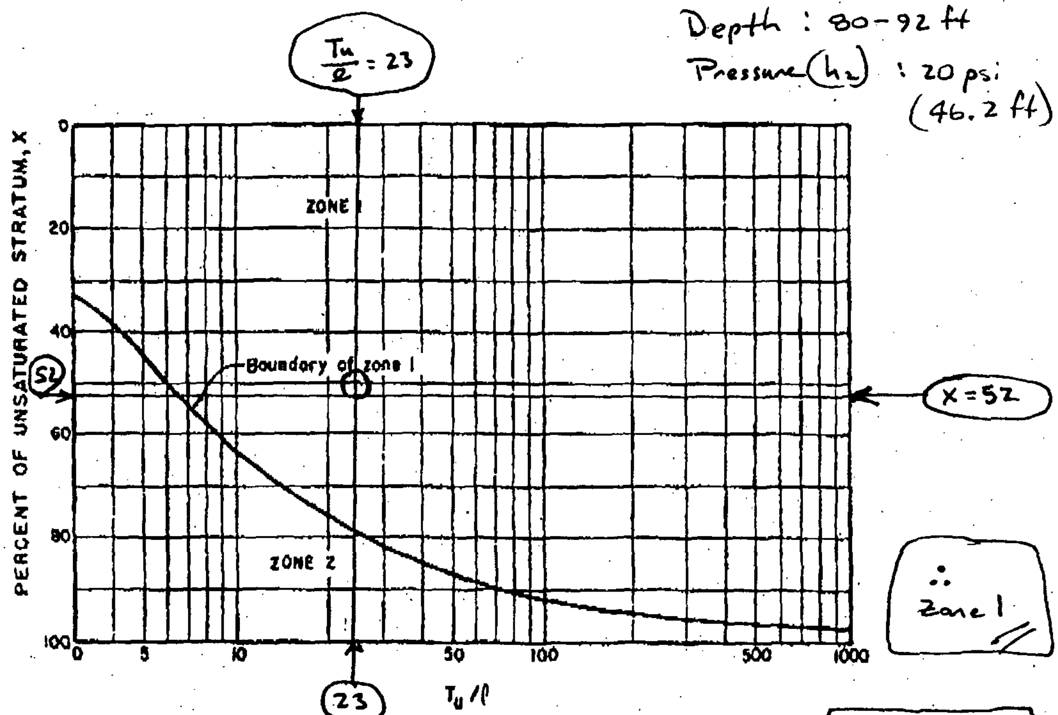


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

∴ Zone 1

$\frac{T_u}{\ell} = 23$

$X = 52$

A-85

Borehole 204
Depth : 80-92 ft
Pressure : 20 psi

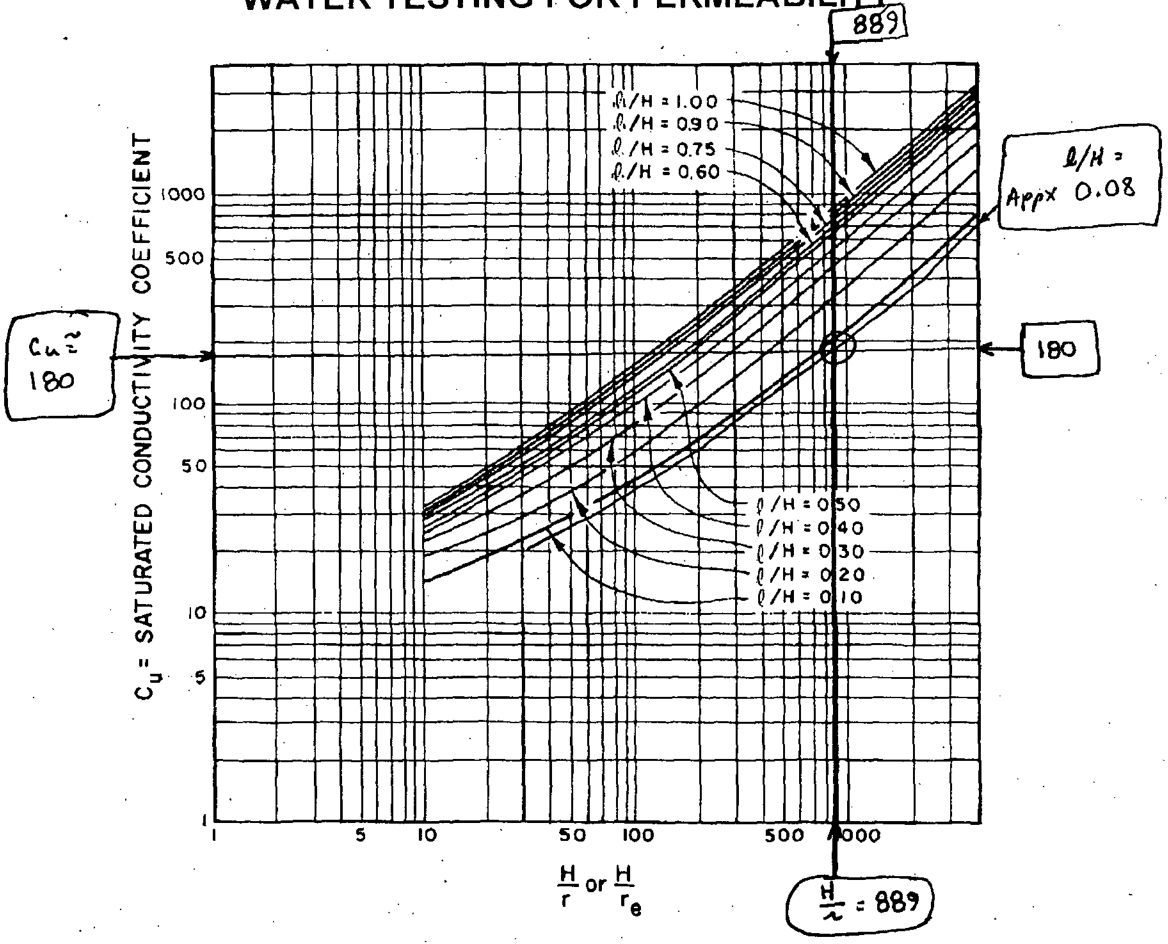


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

JOB NO.: DATE:

JOB NAME: Crescent Junction site

PREPARED: M. Kautsky REVIEWED:

SHEET NO. OF

Borehole : 204

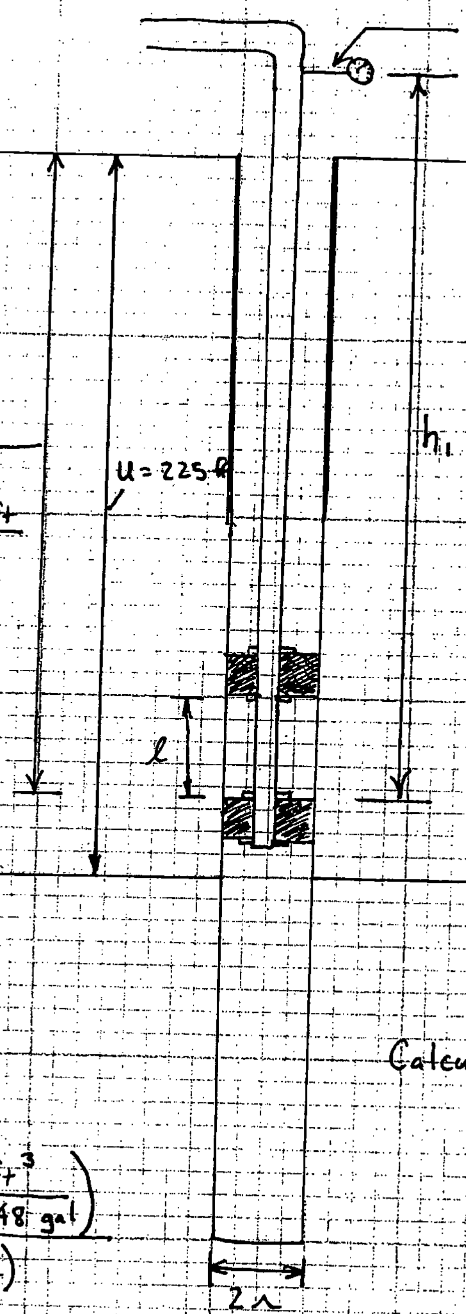
Depth : 80-92

Pressure : 20 psi

Packer Test Set-up Sheet

For straddle packer tests in Zone I

– Above water Table –



gage pressure (h_2) = 46.2 ft

Injector Pipe

Obtain L (head loss coeff.)

L = ø ft/10 ft
(Q < 4 gpm)

from Pressure-loss Curve

Q = 0.03 gal/min

from Packer-Test Record

h_1 = 96 ft

$H = h_1 + h_2 - L$

$H = 96 + 46.2 - ø$

$H = 142.2$ ft

Obtain Cu

Cu = 180

from fig 17.7 USBR

$\frac{H}{r} = \frac{142.2 \text{ ft}}{0.16 \text{ ft}} = 889$

$\frac{l}{H} = \frac{12 \text{ ft}}{142.2 \text{ ft}} = 0.08$

Calculate K : Zone 1

$K = \frac{Q}{C_u r H}$

$K = \frac{\left(0.03 \frac{gal}{min}\right)\left(\frac{1440 \text{ min}}{d}\right)\left(\frac{ft^3}{7.48 \text{ gal}}\right)}{(180)(0.16 \text{ ft})(142.2 \text{ ft})}$

$K = 1.1 \times 10^{-3}$ ft/d

$K = 3.9 \times 10^{-7}$ cm/s

PACKER TEST ANALYSES

Borehole : 204
Depth : 80 - 92
Pressure (h_2) : 30 psi (69.3 ft)

Unsaturated Zone Calculation:

Definitions: l = length of test section
$T_u = U - D + H$
U = Thickness of Unsaturated Material
D = distance from ground surface to bottom of test section
$H = h_1 + h_2 - L$
L = head loss ; ignore if $Q < 4$ gpm
$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 225\text{ ft} - 92\text{ ft} + 165.3\text{ ft} = 298.3\text{ ft}$

$\frac{T_u}{l} = \frac{298.3\text{ ft}}{12\text{ ft}} = \boxed{24.9}$

$H = h_1 + h_2 - L = 96\text{ ft} + 69.3\text{ ft} = 165.3\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{165.3\text{ ft}}{298.3\text{ ft}}(100) = \boxed{55}$

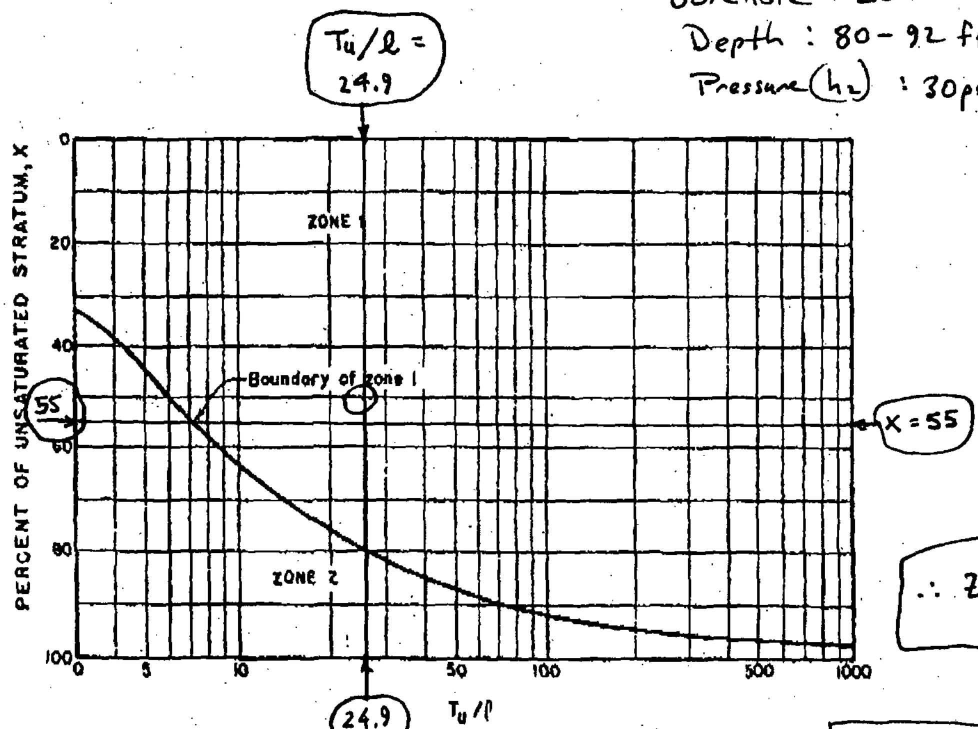
$h_1 = D$ + stick-up height $= 92\text{ ft} + 4\text{ ft} = 96\text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 204
Depth : 80 - 92 ft
Pressure (h_2) : 30psi (69.3 ft)



∴ Zone 1

Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$$\frac{T_u}{\ell} = 24.9$$

$$X = 55$$

Borehole : 204
Depth : 80 - 92 ft
Pressure : 30psi
1-23-06

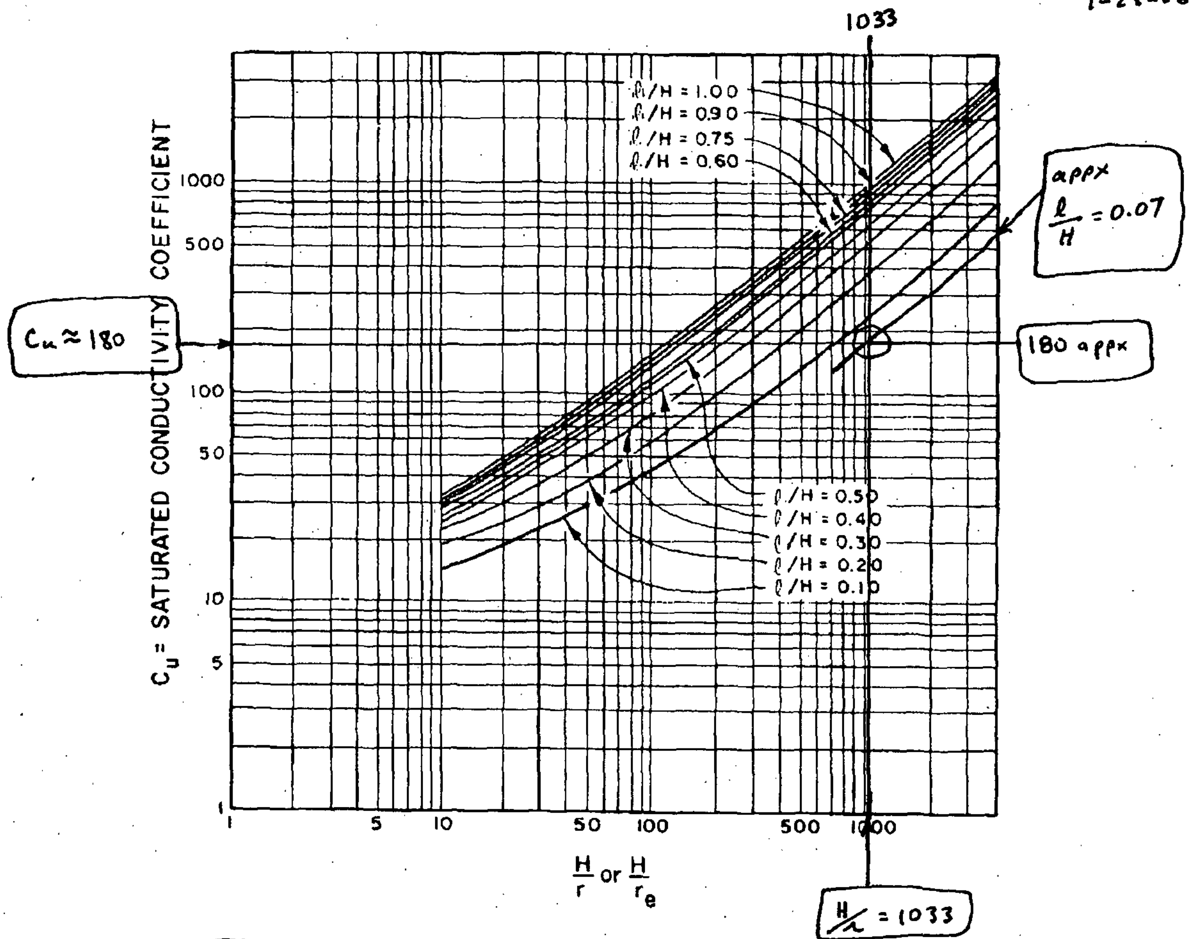


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

JOB NO. ______ DATE: 1-23-06

JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky REVIEWED: ______

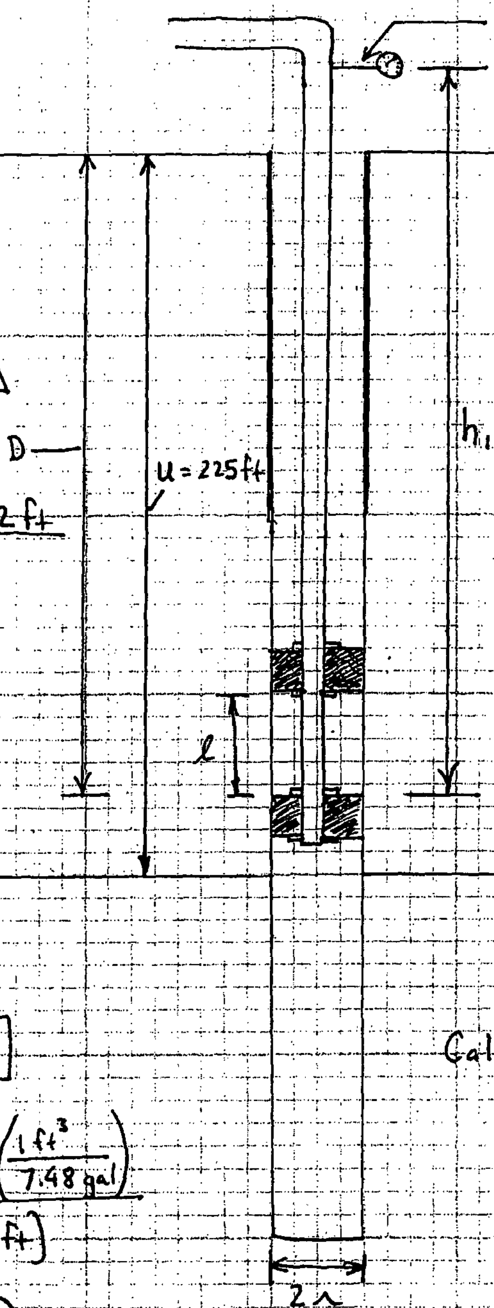
SHEET NO. ______ OF ______

Borehole : 204
Depth : 80-92
Pressure : 30 psi

Packer Test Set-up Sheet

For straddle packer tests in Zone I
– Above water Table –

gage pressure (h_2) = 69.3 ft



Injector Pipe

Obtain L (head loss coeff.)

$\boxed{L = \emptyset \text{ ft}/10\text{ ft}}$ (Q < 4 gpm)

from pressure-loss curve

$Q < \frac{0.01 \text{ gal}}{15 \text{ min}}$

$\boxed{Q < 6.7 \times 10^{-4} \text{ gal/min}}$

D = 92 ft

h_1 = 96 ft

$H = h_1 + h_2 - L$
$= 96 + 69.3 - 0$

$\boxed{H = 165.3 \text{ ft}}$

Obtain Cu

$\boxed{Cu = 180}$

from fig 17.7 USBR

WATER TABLE

$\frac{H}{r} = \boxed{\frac{165.3 \text{ ft}}{0.16 \text{ ft}}} = \boxed{1033}$

$\frac{l}{H} = \boxed{\frac{12 \text{ ft}}{165.3 \text{ ft}}} = \boxed{0.07}$

Calculate K : Zone 1

$K = \frac{Q}{Cu\, r\, H}$

$$K < \frac{\left(6.7 \times 10^{-4} \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{d}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(180)(0.16 \text{ ft})(165.3 \text{ ft})}$$

$K < 2.7 \times 10^{-5}$ ft/d

$K < 9.6 \times 10^{-9}$ cm/s //

JOB NO.: DATE: 1-25-06

JOB NAME: Crescent Junction Site

Packer Test Set-up Sheet

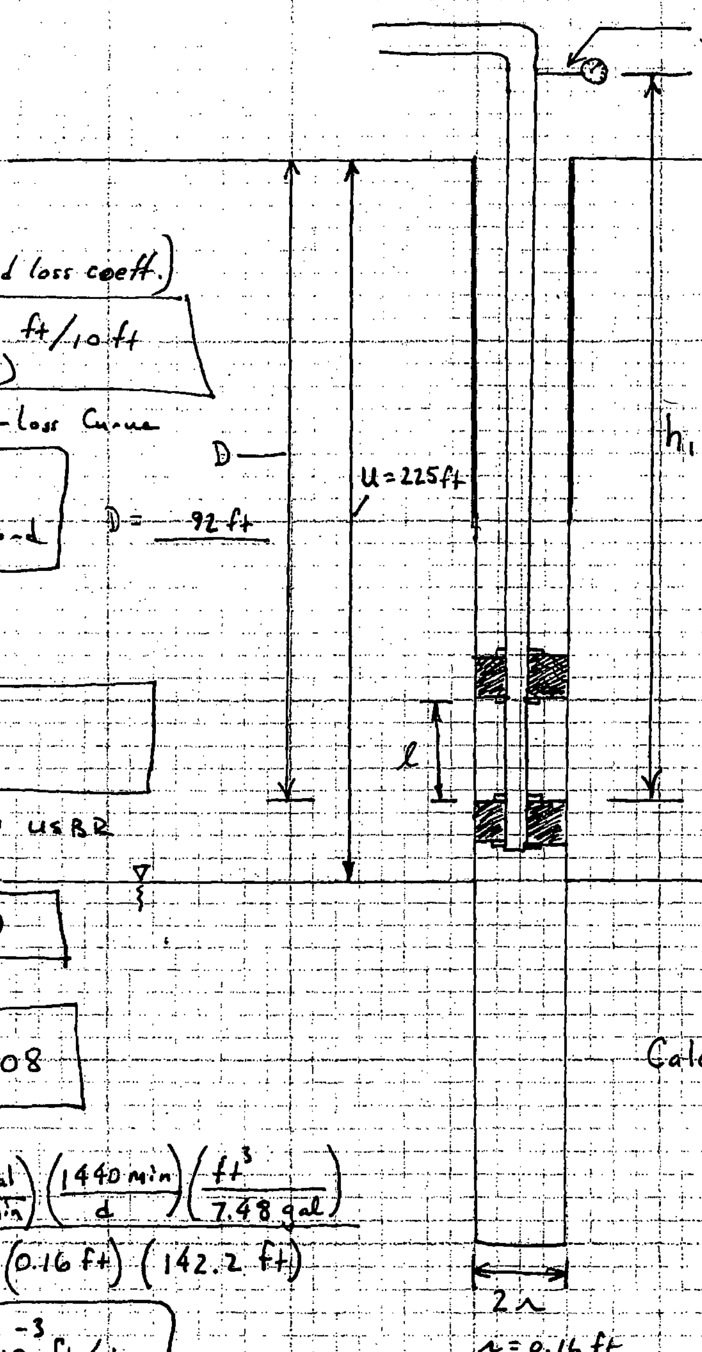
For straddle packer tests in Zone 1
– Above water Table –

PREPARED: Mark Kautsky REVIEWED:

SHEET NO. OF

Borehole 204
Depth : 80-92 ft
Pressure : 20 psi (retest)

gage pressure (h_2) = 46.2 ft



Injection Pipe

Obtain L (head loss coeff.)

$L = \varnothing$ ft/10 ft
(Q < 4 gal/min)

from Pressure-loss Curve

$Q = 0.04 \frac{gal}{min}$
per Packer Test Record

$h_1 = 96$ ft

$H = h_1 + h_2 - L$

$\boxed{H = 142.2 \text{ ft}}$

Obtain Cu

$\boxed{C_u = 180}$

from fig 17.7 USBR

$\frac{H}{r} = \boxed{889}$

$\frac{l}{H} = \boxed{0.08}$

Calculate K : Zone 1

$$K = \frac{Q}{C_u \, r \, H}$$

$$K = \frac{\left(0.04 \frac{gal}{min}\right)\left(\frac{1440 \, min}{d}\right)\left(\frac{ft^3}{7.48 \, gal}\right)}{(180)\,(0.16 \text{ ft})\,(142.2 \text{ ft})}$$

$K = 1.9 \times 10^{-3}$ ft/d

$K = 6.6 \times 10^{-7}$ cm/s

JOB NO.: DATE: 1-25-06

JOB NAME: Crescent Junction site

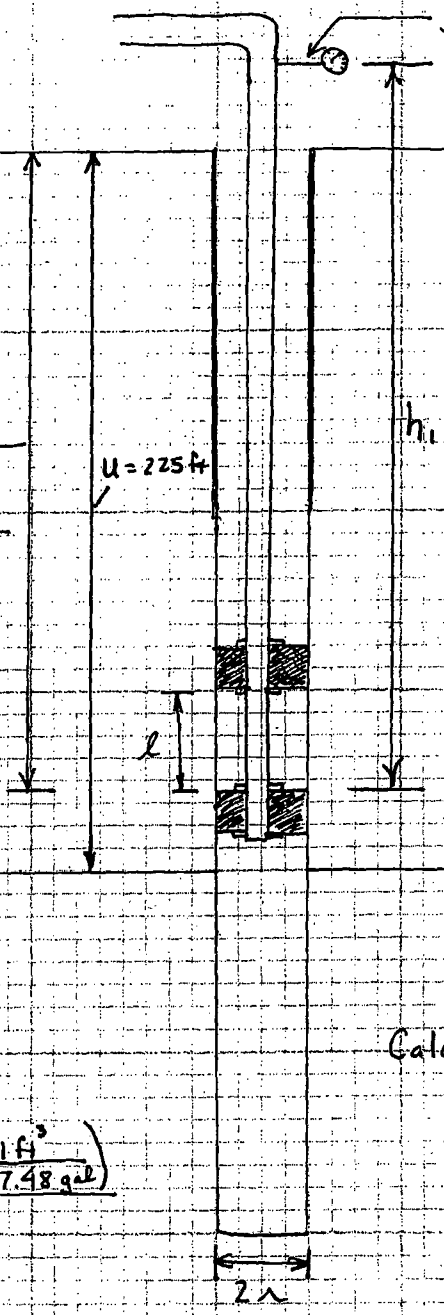
PREPARED: M. Kautsky REVIEWED:

SHEET NO. OF

Borehole : 204
Depth : 80 - 92 ft
pressure : 10 psi (retest)

Packer Test Set-up Sheet

For straddle packer tests in Zone I
– Above water Table –



Injector Pipe

Obtain L (head loss coeff.)

$\boxed{L = \emptyset \text{ ft/10 ft} \quad (Q < 4 \text{ gal/min})}$

from Pressure-loss Curve

$Q < \frac{0.01 \text{ gal}}{15 \text{ min}}$

$\boxed{Q < 6.7 \times 10^{-4} \text{ gal/min} \text{ per Packer Test Record}}$

D = 92 ft

Obtain Cu

$\boxed{Cu = 180}$

from fig 17.7 USBR

$\frac{H}{r} = \boxed{\frac{119.1 \text{ ft}}{0.16 \text{ ft}}} = 744$

$\frac{\ell}{H} = \boxed{0.10}$

$$K < \frac{(6.7 \times 10^{-4} \text{ gal/min})\left(\frac{1440 \text{ min}}{d}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(180)(0.16 \text{ ft})(119.1 \text{ ft})}$$

$\boxed{K < 3.7 \times 10^{-5} \text{ ft/d}}$

$\boxed{K < 1.3 \times 10^{-8} \text{ cm/s}}$

$H = h_1 + h_2 - L$

$\boxed{H = 119.1 \text{ ft}}$

Calculate K : Zone 1

$$K = \frac{Q}{Cu \, r \, H}$$

Stoller

established 1959

Packer-Test Record

Project Name: Moab-Crescent Jct Characterization Date: 01/13/06- 01/14/06

Field Representative: R. Rupp Borehole No. 0204 Total Depth : 300 ft.

Depth to Water (TOC): 225 ft Borehole Cleaned? Yes ✓ No____ Date: 01/12/06

Test Interval (BGL): from 110 to 122 ft. Swivel/Elbow Height (AGL) 4.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin wall steel tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
1610	10 psi	39377.1	
1615	10	39377.2	0.02 gpm
1620	10	39377.35	0.03
1625	10	39377.35	0
1630	10	39377.35	0
1635	10	39377.35	0
1640	10	39377.35	0
1641	20 psi	39378.05	
1645	20	39378.4	0.09 gpm
1650	20	39378.55	0.03
1655	20	39378.85	0.06
1700	20	~~39378.05~~ 39379.05	0.04
1705	20	39379.25	0.04
1710	20	39379.3	0.01
1715	20	39379.35	0.01
3/06 1720	20	39379.4	0.01
4/06 0800	30 psi	39379.05	
0805	30	39379.15	0.02 gpm

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct Characterization Date: 01/14/06

Field Representative: R. RUPP Borehole No. 0204 Total Depth: 300 ft

Depth to Water (TOC): 225 ft Borehole Cleaned? Yes ✓ No____ Date: 01/12/06

Test Interval (BGL): from 110 to 122 ft. Swivel/Elbow Height (AGL) 4.0 ft

Conductor Pipe, Type and Size: 1-inch ID thin wall tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
0810	30 psi	39379.5	0.07 gpm
0815	30	39379.8	0.06
0820	30	39380.1	0.06
0825	30	39380.3	0.04
0830	30	39380.5	0.04
0835	30	39380.7	0.04
0840	20 psi	39380.4	-0.06
0845	20	39380.3	~~0~~ -0.02
0850	20	39380.3	0
0855	20	39380.3	0
0900	10 psi	39379.75	-0.11
0905	10	39378.75	-0.20
0910	10	39378.85	0.02
0915	10	39378.5	-0.07
0920	10	39378.4	-0.02
0925	10	39378.15	-0.05
0930	10	39378.0	-0.03
0935	10	39377.95	-0.01
0940	10	39377.85	-0.02
0945	10	39377.85	0
0950	10	39377.85	0

Steller

DATE 1-26-06

JOB NAME: Crescent Junction

PREPARED: M. Koutsky REVIEWED:

SHEET NO. ____ OF ____

PACKER TEST ANALYSES

BOREHOLE : 204

Depth : 110 - 122 ft

Pressure (h_2) : 10 psi (23.1 ft)

Unsaturated Zone Calculation:

Definitions: ℓ = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$\ell = 12$ ft

$T_u = U - D + H = (225\text{ ft}) - (122\text{ ft}) + (149.1\text{ ft}) = 252.1$ ft

$\frac{T_u}{\ell} = \frac{252.1\text{ ft}}{12\text{ ft}} = \boxed{21}$

$H = h_1 + h_2 - L = 126\text{ ft} + 23.1\text{ ft} - \varnothing = 149.1$ ft

$X = \frac{H}{T_u}(100) = \frac{149.1\text{ ft}}{252.1\text{ ft}}(100) = \boxed{59}$

$h_1 = 122\text{ ft} + 4\text{ ft} = 126$ ft

1-26-06

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 204
Depth : 110 - 122 ft
Pressure (h_2) : 23.1 ft
(10 psi)

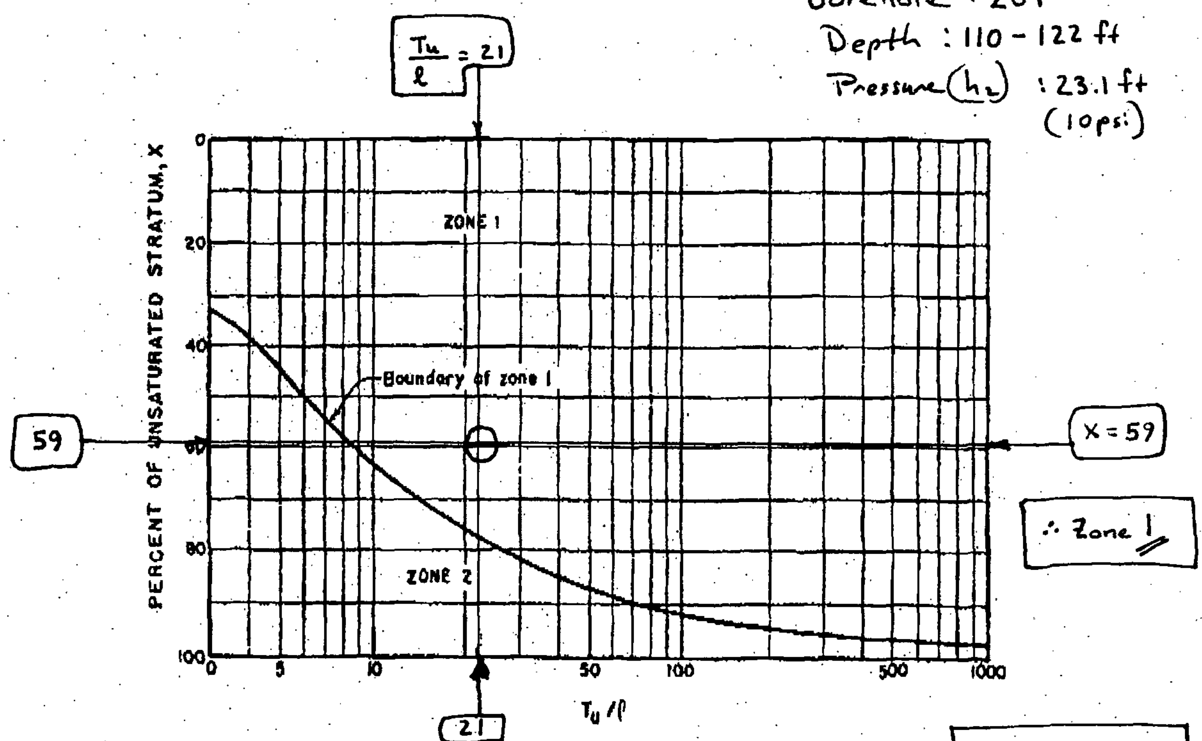
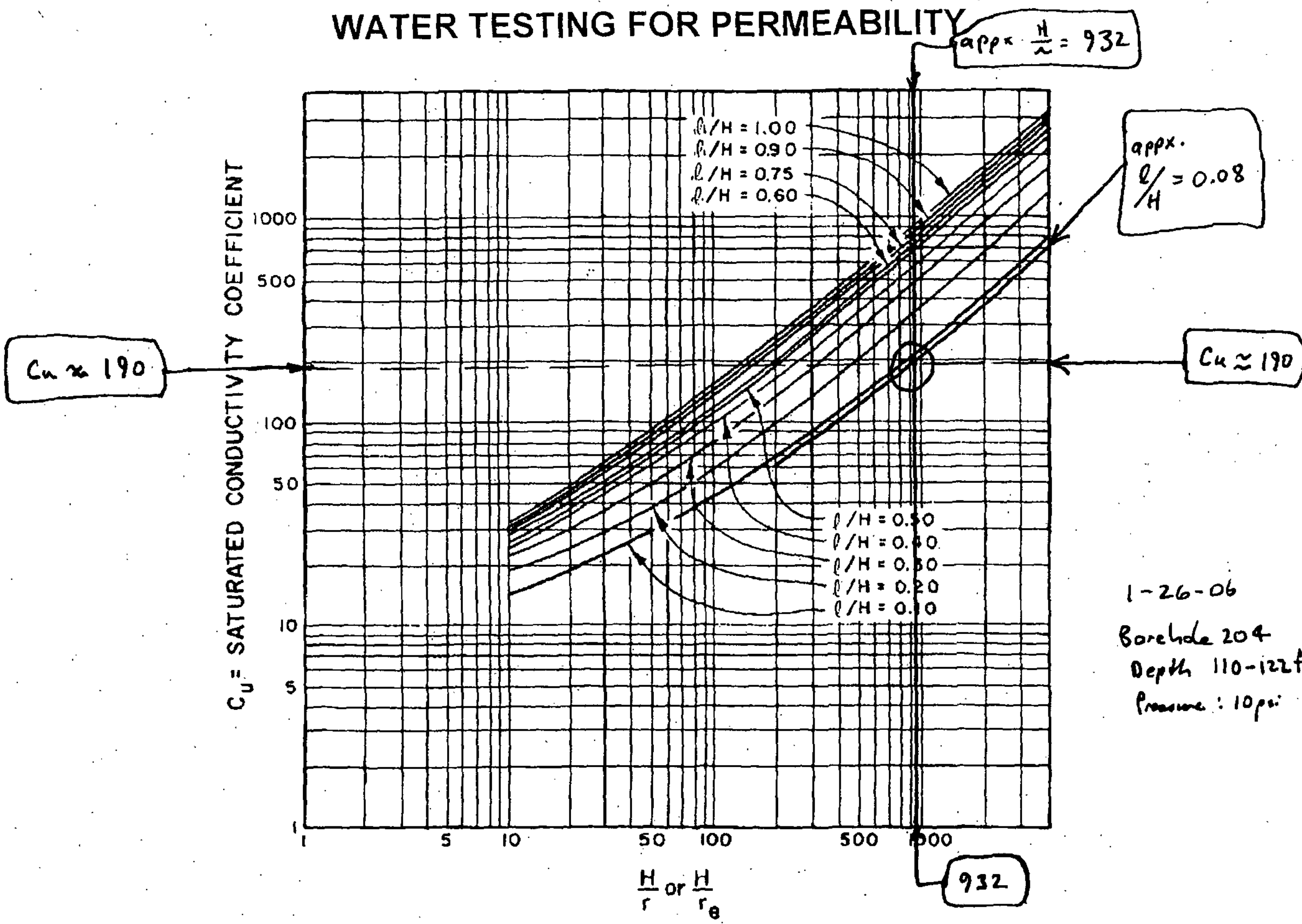


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 21$

$X = 59$

A-97



1-26-06
Borehole 204
Depth 110-122ft
Pressure: 10psi

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

JOB NO.: DATE: 1-26-06

JOB NAME: Crescent Junction site

Stoller

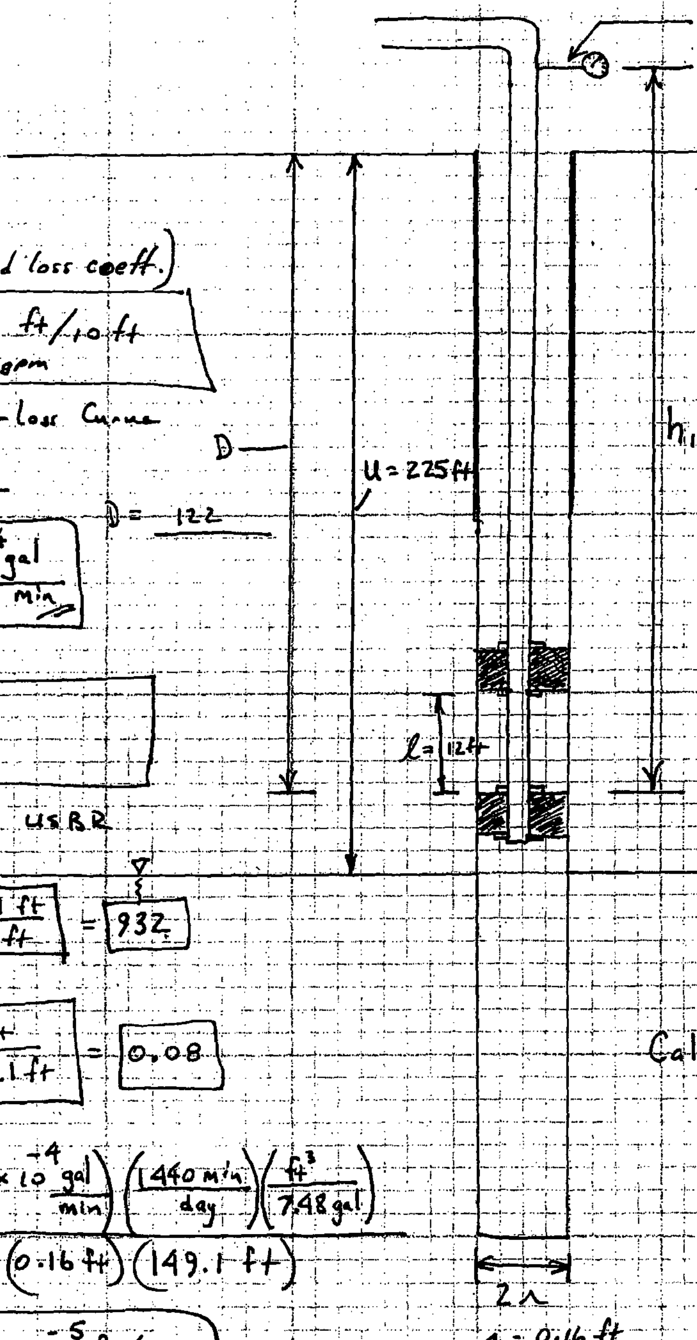
Packer Test Set-up Sheet

For straddle packer tests in Zone I
– Above water Table –

PREPARED: M. Kautsky REVIEWED:

SHEET NO.: OF

Borehole 204
Depth: 110–122 ft.
pressure: 10 psi



gage pressure (h_2) = 23.1 ft

h_1 = 126 ft

Obtain L (head loss coeff.)

$\boxed{L = \phi \text{ ft}/10 \text{ ft} \quad Q < 4 \text{ gpm}}$

from Pressure-loss Curve

$Q < \frac{0.01 \text{ gal}}{20 \text{ min}}$

$D = 122$

$\boxed{Q < 5.0 \times 10^{-4} \frac{\text{gal}}{\text{min}}}$

$H = h_1 + h_2 - L$
$= (126 + 23.1 - 0)$ ft

$\boxed{H = 149.1 \text{ ft}}$

[illegible]tain C_u

$\boxed{C_u = 190}$

from fig 17.7 USBR

$\frac{H}{r} = \boxed{\frac{149.1 \text{ ft}}{0.16 \text{ ft}}} = \boxed{932}$

$\frac{l}{H} = \boxed{\frac{12 \text{ ft}}{149.1 \text{ ft}}} = \boxed{0.08}$

Calculate K : Zone 1

$K = \frac{Q}{C_u\, r\, H}$

$K < \frac{\left(5.0 \times 10^{-4} \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{day}}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)}{(190)(0.16 \text{ ft})(149.1 \text{ ft})}$

$K < 2.1 \times 10^{-5}$ ft/day

$K < 7.5 \times 10^{-9} \frac{\text{cm}}{\text{sec}}$

PACKER TEST ANALYSES

BOREHOLE : 204
Depth : 110 - 122 ft
Pressure (h_2) : 20 psi (46.2 ft)

Unsaturated Zone Calculation:

Definitions: ℓ = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$\ell = 12$ ft

$T_u = U - D + H = (225 \text{ ft}) - (122 \text{ ft}) + (172.2 \text{ ft}) = 275.2 \text{ ft}$

$\frac{T_u}{\ell} = \frac{275.2 \text{ ft}}{12 \text{ ft}} = \boxed{23}$

$H = h_1 + h_2 - L = (126 \text{ ft}) + (46.2 \text{ ft}) - 0 = 172.2 \text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{172.2 \text{ ft}}{275.2 \text{ ft}}(100) = \boxed{63}$

$h_1 = 122 \text{ ft} + 4 \text{ ft} = 126 \text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

1-26-06

Borehole : 204
Depth : 110-122 ft
Pressure (h_2) : 46.2 ft (20 psi)

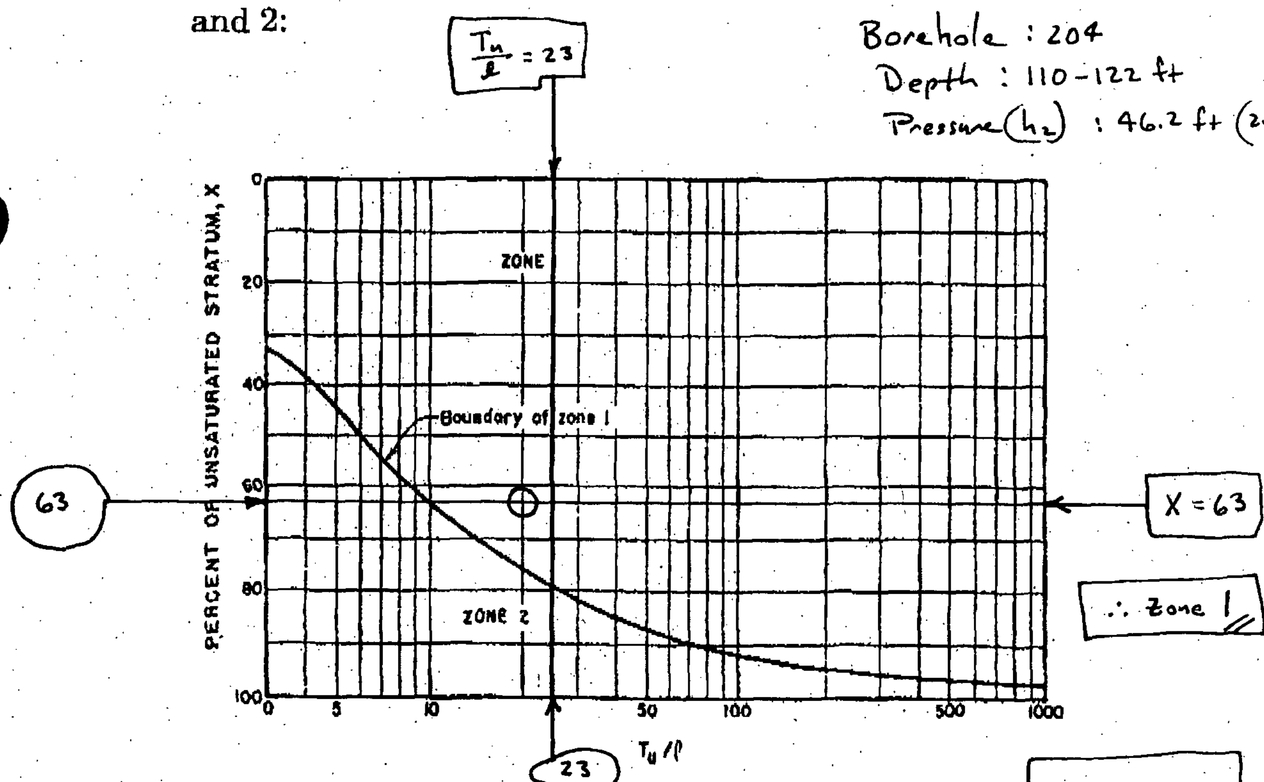


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 23$

$X = 63$

A-101

1-26-06
Borehole 204
Depth 110-122
pressure: 20 psi

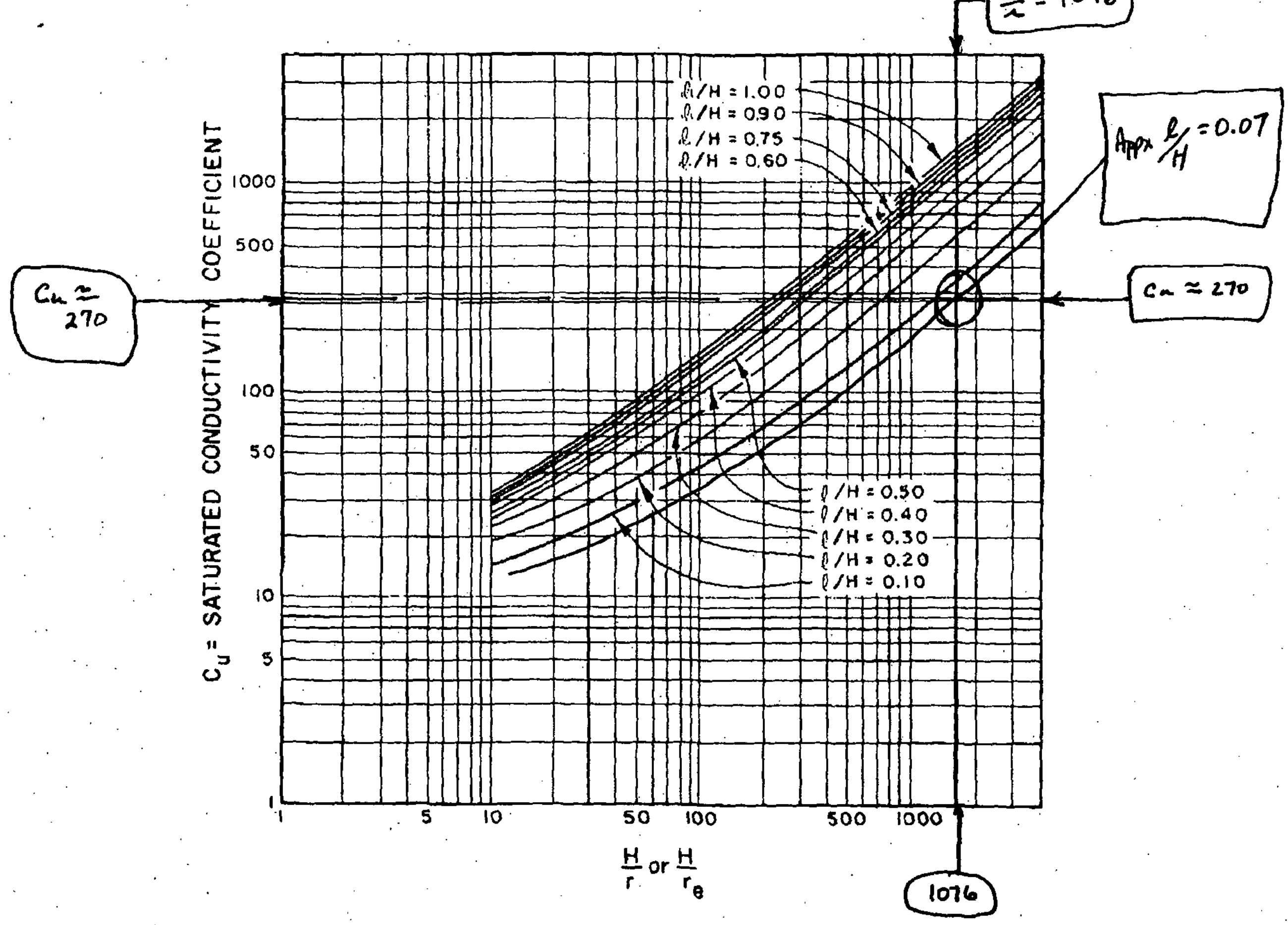


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

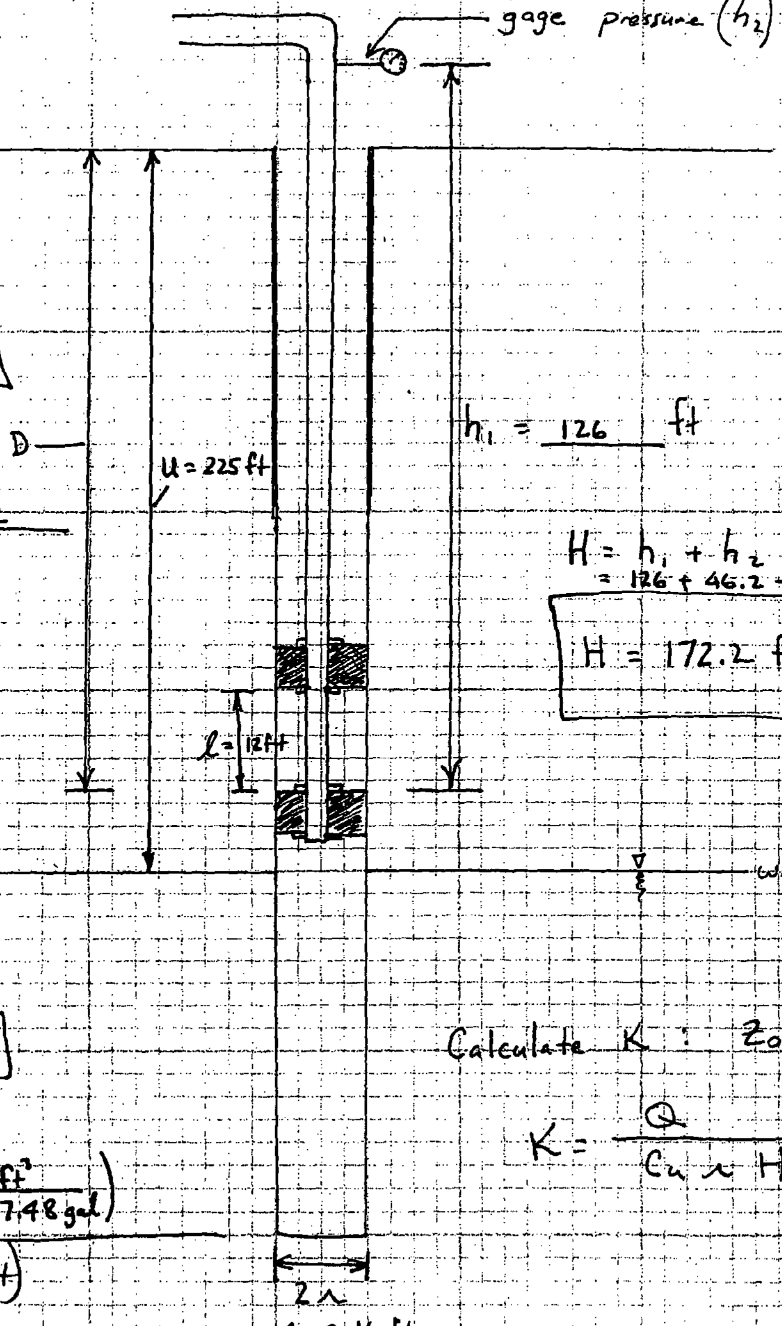
H = 72 + 57.8 - 4.7 = 125.1 feet

Stoller

Packer Test Set-up Sheet

For straddle packer tests in Zone I
- Above water Table -

JOB NO.:
DATE: 1-26-06
JOB NAME: Crescent Junction site
PREPARED: M. Kautsky
REVIEWED:
SHEET NO. ______ OF ______
Borehole: 204
Depth: 110 - 122 ft
pressure: 20psi



Injection Pipe

Obtain L (head loss coeff.)

$$\boxed{L = \frac{\emptyset}{Q < 4\,\text{gal/min}}\ \text{ft}/10\,\text{ft}}$$

from Pressure-loss Curve

$$\boxed{Q = 0.01\,\frac{\text{gal}}{\text{min}}}$$

per Packer-Test Record

D = 122

$$H = h_1 + h_2 - L$$
$$= 126 + 46.2 - 0$$
$$\boxed{H = 172.2\ \text{ft}}$$

Obtain C_u

$$\boxed{C_u = 270}$$

from fig 17.7 USBR

$$\frac{H}{r} = \boxed{\frac{172.2\ \text{ft}}{0.16\ \text{ft}}} = \boxed{1076}$$

$$\frac{\ell}{H} = \boxed{\frac{12\ \text{ft}}{172.2\ \text{ft}}} = \boxed{0.07}$$

Calculate K : Zone 1

$$K = \frac{Q}{C_u\, r\, H}$$

$$K = \frac{\left(\frac{0.01\ \text{gal}}{\text{min}}\right)\left(\frac{1440\ \text{min}}{\text{day}}\right)\left(\frac{\text{ft}^3}{7.48\ \text{gal}}\right)}{(270)(0.16\ \text{ft})(172.2\ \text{ft})}$$

$$K = 2.6 \times 10^{-4}\ \text{ft/d}$$

$$9.1 \times 10^{-8}\ \text{cm/sec}$$

PACKER TEST ANALYSES

BOREHOLE : 204
Depth : 110-122 ft
Pressure (h_2) : 30 psi $\boxed{69.3 \text{ ft}}$

Unsaturated Zone Calculation:

Definitions:
l = length of test section
$T_u = U - D + H$
U = Thickness of Unsaturated Material
D = distance from ground surface to bottom of test section
$H = h_1 + h_2 - L$
L = head loss ; ignore if $Q < 4$ gpm
$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S. Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 225 \text{ ft} - 122 \text{ ft} + 195.3 \text{ ft} = 298 \text{ ft}$

$\frac{T_u}{l} = \frac{298 \text{ ft}}{12 \text{ ft}} = \boxed{25}$

$H = h_1 + h_2 - L = 126 \text{ ft} + 69.3 \text{ ft} - 0 = 195.3 \text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{195.3 \text{ ft}}{298 \text{ ft}}(100) = \boxed{65}$

$h_1 = 122 \text{ ft} + 4 \text{ ft} = 126 \text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 204
Depth : 110-122
Pressure (h_2) : 30 psi (69.3 ft)

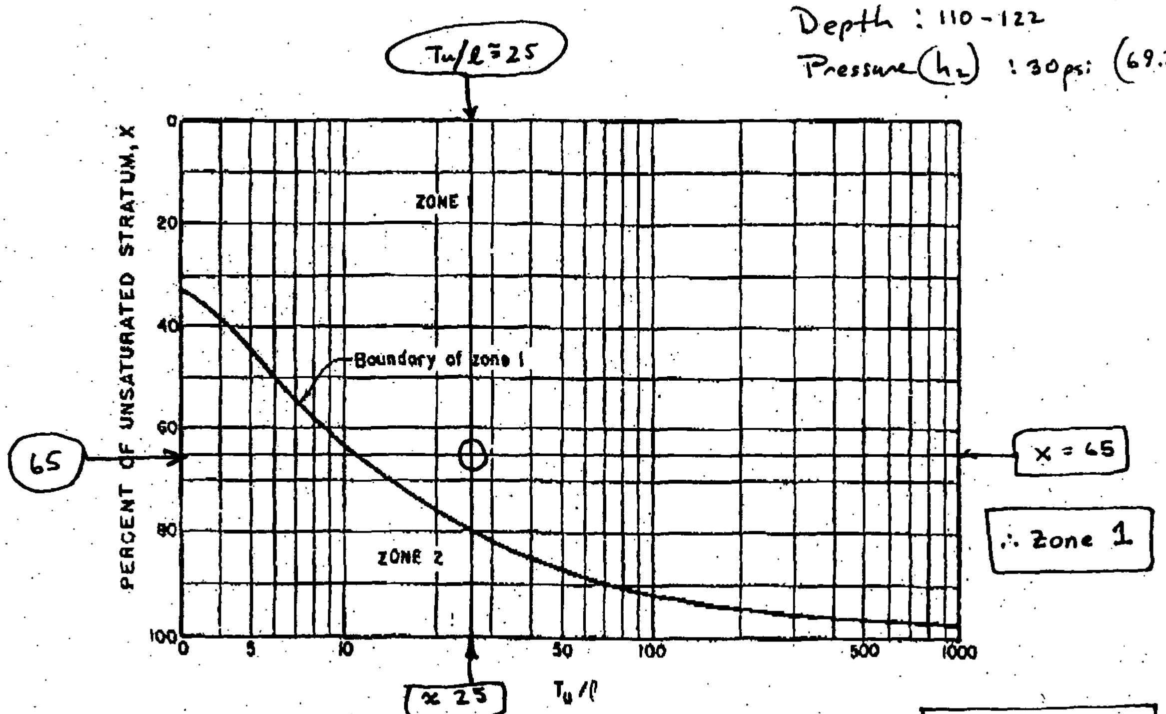


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 25$

$X = 65$

A-105

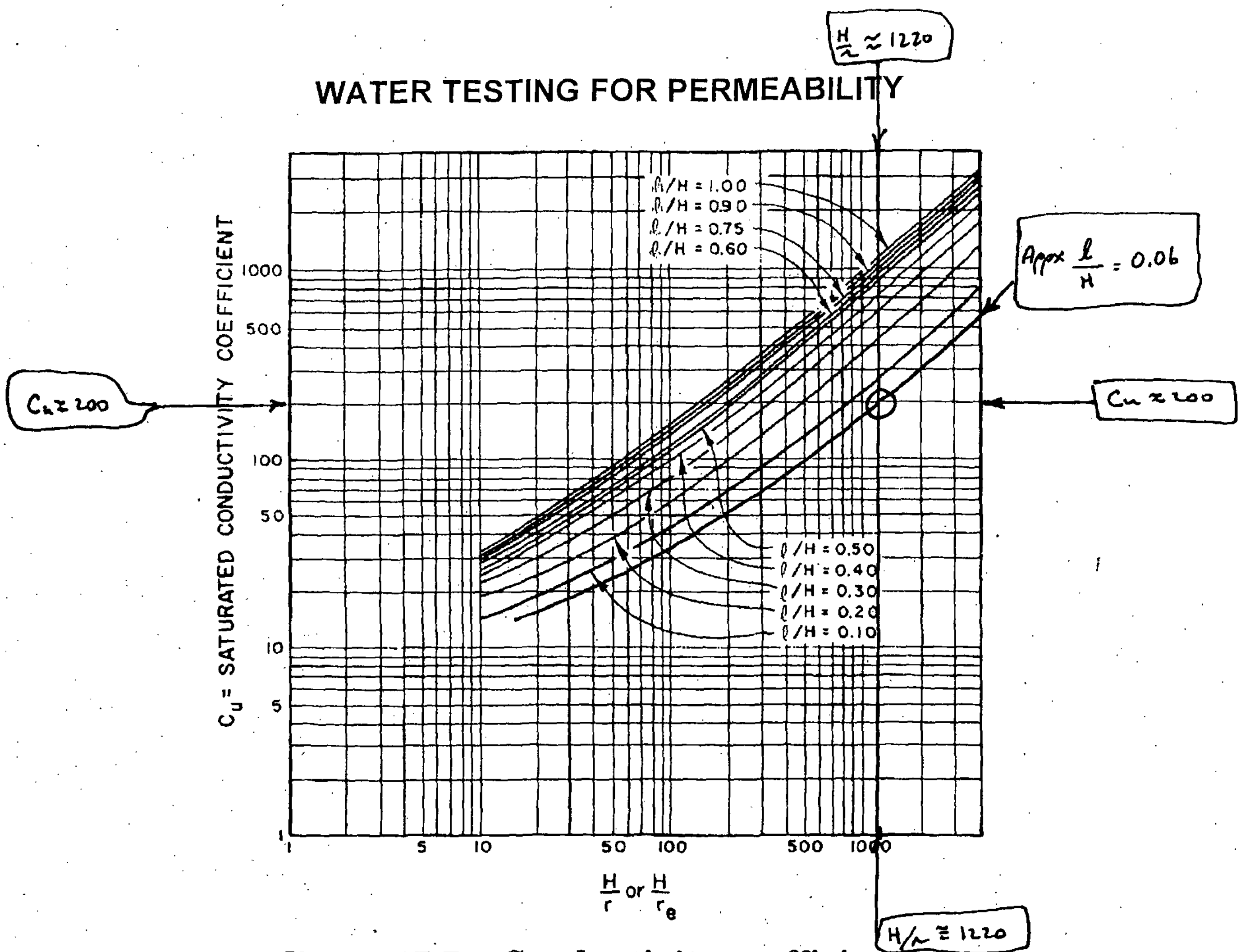


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

$H = 72 + 57.8 - 4.7 = 125.1$ feet

Stellar

JOB NO. ________ DATE: 1-26-06

JOB NAME: Crescent Junction Site

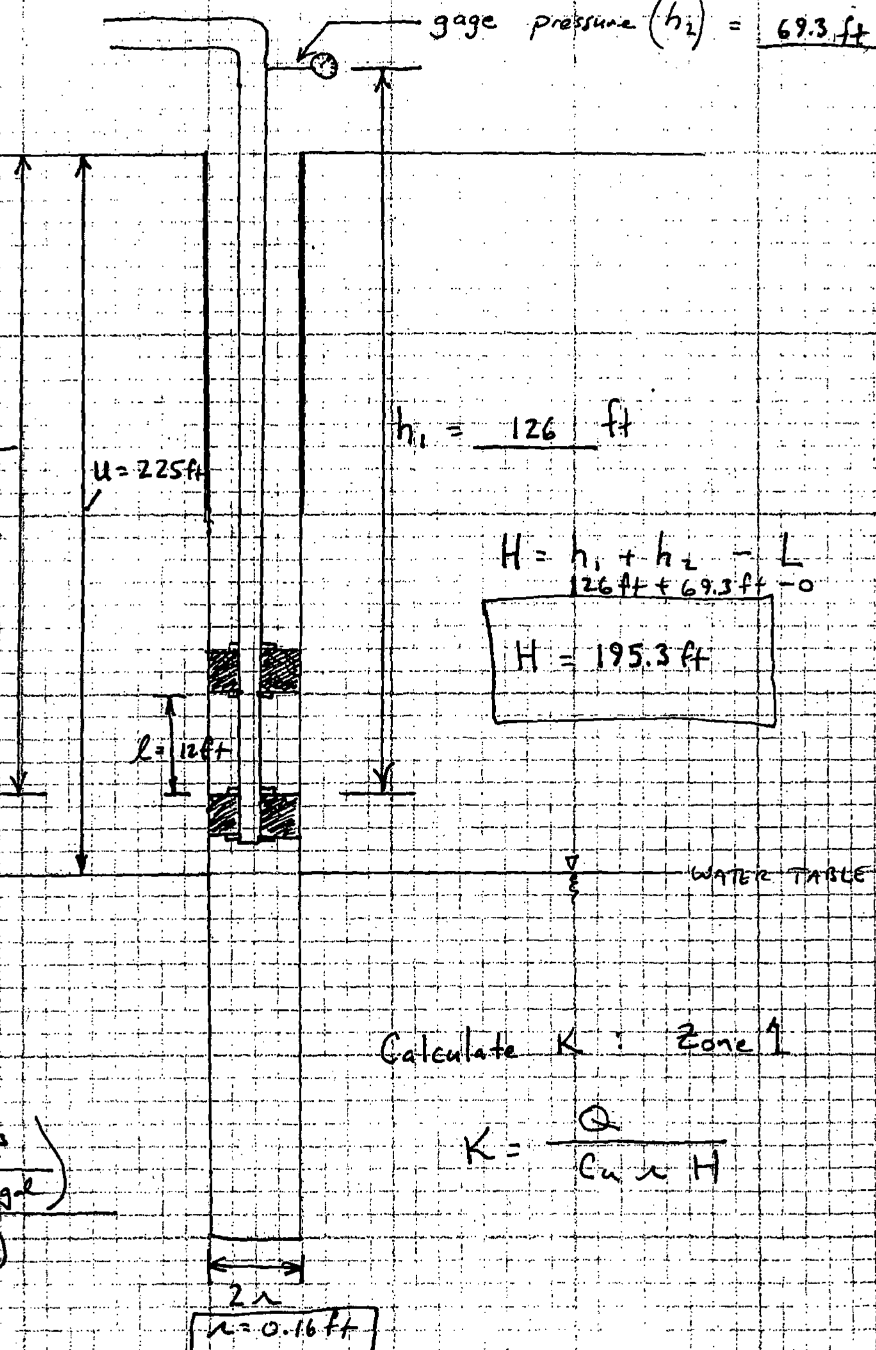
Packer Test Set-up Sheet

For straddle packer tests in Zone I
– Above water Table –

PREPARED: M. Koutsky REVIEWED:

Borehole 204
Depth: 110–122 ft
Pressure: 30 psi

SHEET NO. ______ OF ______



Injector Pipe

Obtain L (head loss coeff.)

$L = \varnothing$ ft/10 ft
(Q < 4 gal/min)

from pressure-loss curve

Q = 0.04 gal/min
from Packer-Test Record

D = 122 ft

$h_1 = 126$ ft

$$H = h_1 + h_2 - L$$
$$126\text{ ft} + 69.3\text{ ft} - 0$$

$$\boxed{H = 195.3\text{ ft}}$$

Obtain Cu

$C_u \approx 200$

from fig 17.7 USBR

$$\frac{H}{r} = \frac{195.3\text{ ft}}{0.16\text{ ft}} = 1220$$

$$\frac{l}{H} = \frac{12\text{ ft}}{195.3} = 0.06$$

Calculate K : Zone 1

$$K = \frac{Q}{C_u\, r\, H}$$

$$K = \frac{\left(\frac{0.04\text{ gal}}{\text{min}}\right)\left(\frac{1440\text{ min}}{d}\right)\left(\frac{ft^3}{7.48\text{ gal}}\right)}{(200)(0.16\text{ ft})(195.3\text{ ft})}$$

$K = 1.2 \times 10^{-3}$ ft/d

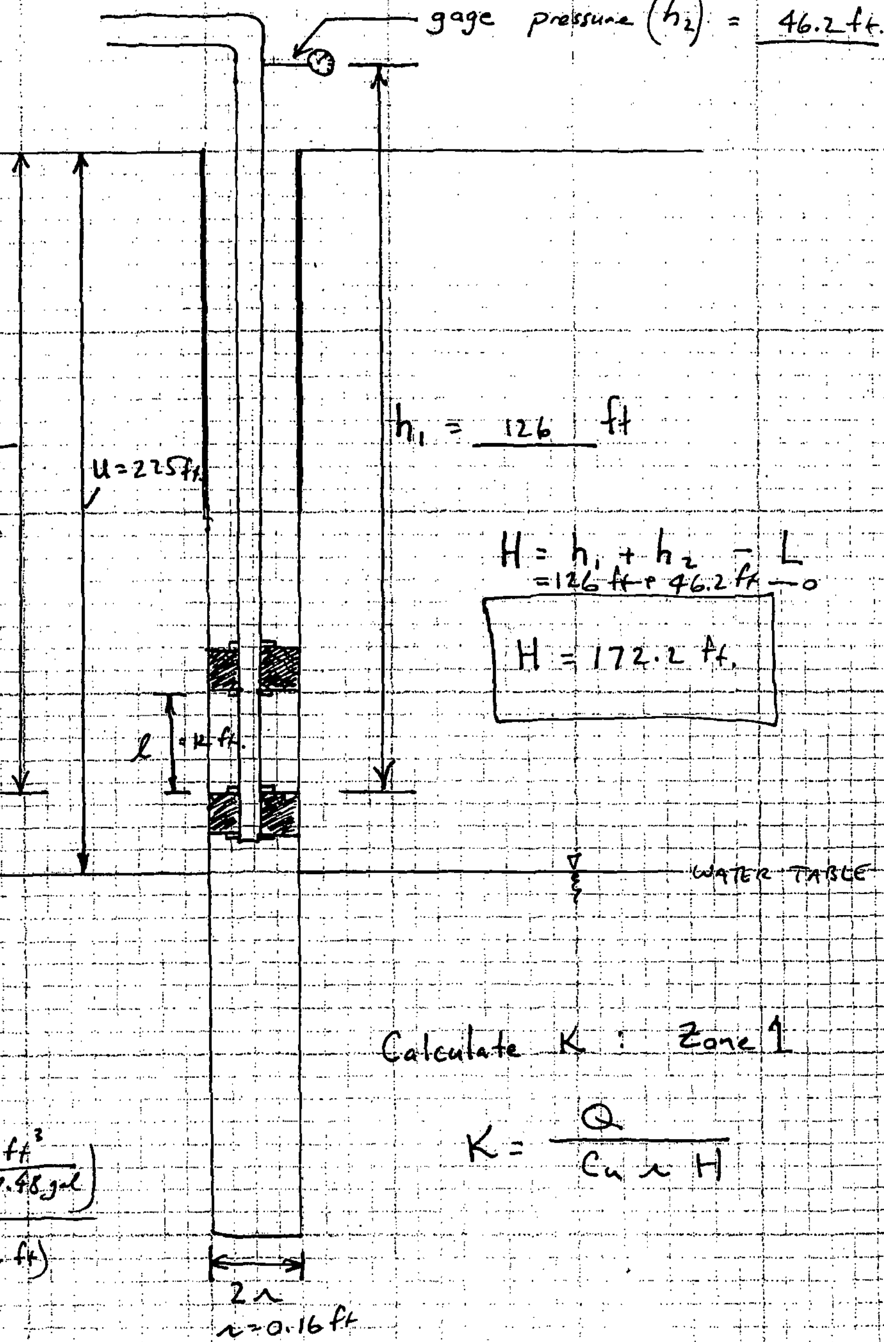
$K = 4.2 \times 10^{-7}$ cm/s

JOB NO. DATE: 1-26-06
JOB NAME: Crescent Junction Site
PREPARED: M. Kautsky REVIEWED:
SHEET NO. OF

Borehole : 204
Depth : 110 - 122
pressure : 20 psi (retest)

Packer Test Set-up Sheet

For straddle packer tests in Zone 1
– Above water Table –



Injector Pipe

Obtain L (head loss coeff.)

$L = \frac{\emptyset}{Q < 4\,gpm}$ ft/10 ft

from Pressure-loss Curve

Q < 0.1 gal/10 min

D —

per packer test Record

Q < .01 gal/min

D = 122

$H = h_1 + h_2 - L$
$= 126\ ft + 46.2\ ft - 0$

$\boxed{H = 172.2\ ft.}$

Obtain Cu

$\boxed{Cu = 270}$

from fig 17.7 USBR

$\frac{H}{r} = \boxed{\frac{172.2\ ft}{0.16\ ft}} = \boxed{1076}$

$\frac{\ell}{H} = \boxed{\frac{12\ ft}{172.2\ ft}} = \boxed{0.07}$

Calculate K : Zone 1

$$K = \frac{Q}{C_u\, r\, H}$$

$$K < \frac{\left(\frac{0.01\ gal}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{ft^3}{7.48\ gal}\right)}{270\ (0.16\ ft)\ (172.2\ ft)}$$

$K < 2.6 \times 10^{-4}$ ft/d

$K < 9.1 \times 10^{-8}$ cm/s

JOB NO. ______ DATE: 1-26-06

JOB NAME: Crescent Junction site

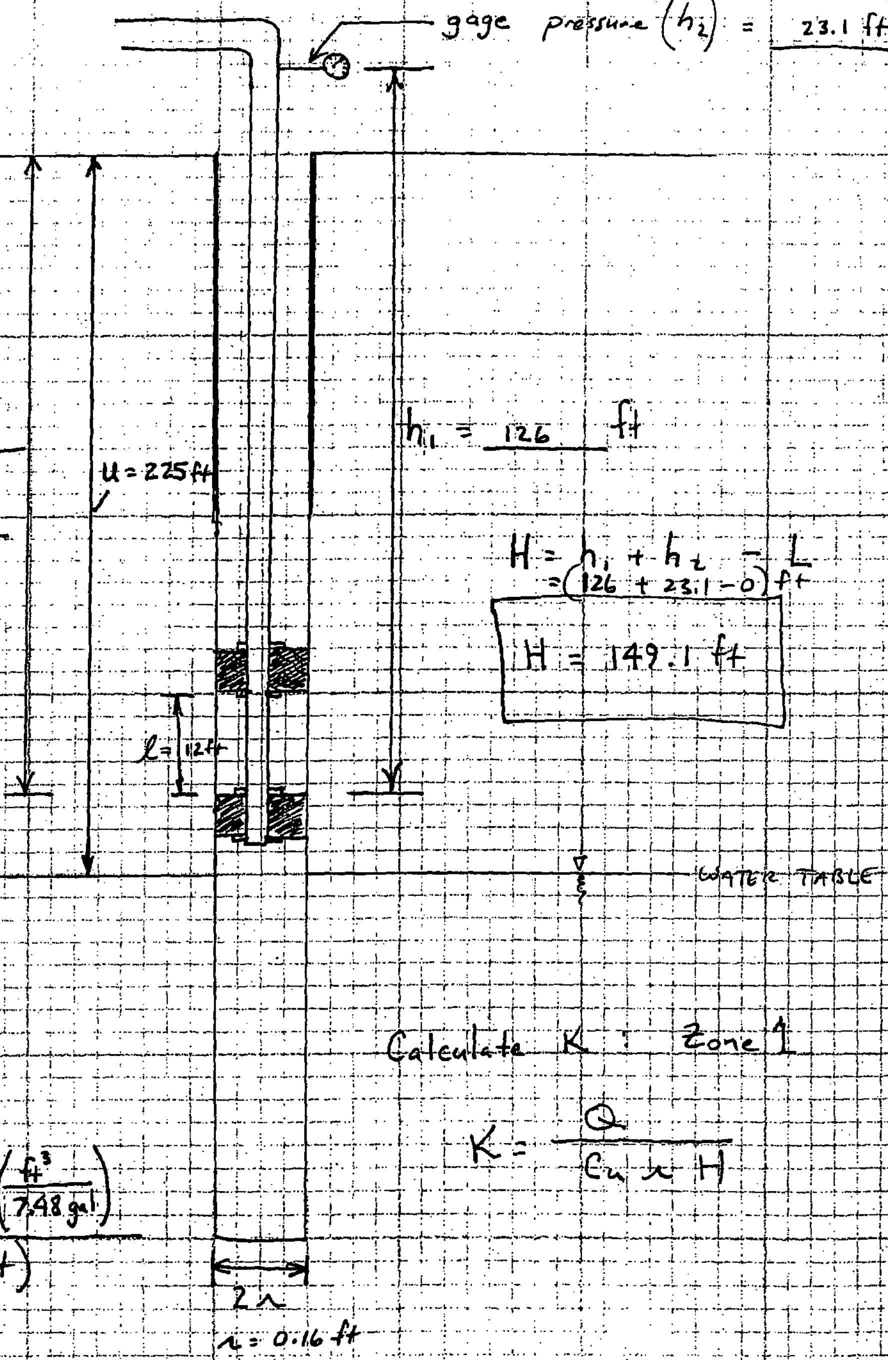
PREPARED: M. Kautsky REVIEWED:

SHEET NO. ______ OF ______

Borehole 204
Depth: 110-122 ft.
Pressure: 10 psi (retest)

Packer Test Set-up Sheet

For straddle packer tests in Zone I
- Above water Table -



Injector Pipe

Obtain L (head loss coeff.)

$$\boxed{L = \frac{\emptyset}{Q < 4\,gpm}\ ft/10\,ft}$$

from pressure - loss Curve

$Q < \dfrac{0.01\,gal}{20\,min}$

D = 122

$$\boxed{Q < 5.0 \times 10^{-4}\ \frac{gal}{min}}$$

Obtain Cu

$$\boxed{Cu = 190}$$

from fig 17.7 USBR

$$\frac{H}{r} = \boxed{\frac{149.1\,ft}{0.16\,ft}} = \boxed{932}$$

$$\frac{\ell}{H} = \boxed{\frac{12\,ft}{149.1\,ft}} = \boxed{0.08}$$

$$H = h_1 + h_2 - L$$
$$= (126 + 23.1 - 0)\,ft$$

$$\boxed{H = 149.1\ ft}$$

Calculate K : Zone 1

$$K = \frac{Q}{Cu\, r\, H}$$

$$K < \frac{\left(5.0 \times 10^{-4}\frac{gal}{min}\right)\left(\frac{1440\,min}{day}\right)\left(\frac{ft^3}{7.48\,gal}\right)}{(190)(0.16\,ft)(149.1\,ft)}$$

$$\boxed{\begin{array}{l} K < 2.1 \times 10^{-5}\ ft/day \\ K < 7.5 \times 10^{-9}\ \frac{cm}{sec} \end{array}}$$

Packer-Test Record

Project Name: Moab-Crescent Jct Characterization Date: 01/13/06

Field Representative: R. Ruiz Borehole No. 0204 Total Depth: 300 ft

Depth to Water (TOC): 225 ft Borehole Cleaned? Yes ✓ No____ Date: 01/12/06

Test Interval (BGL): from 283 to 295 ft. Swivel/Elbow Height (AGL) 2.0 ft.

Conductor Pipe, Type and Size: 1 inch ID thin wall steel tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
0953	5 psi	39344.4	
0958	5	39344.4	~~0~~
1003	5	39344.4	~~0~~
1008	5	39344.4	~~0~~
1013	5	39344.4	~~0~~
1015	10 psi	39345.2	
1020	10	39345.2	~~0~~
1025	10	39345.25	0.01 gpm
1030	10	39345.45	0.04
1035	10	39345.7	0.05
1040	10	39346.05	0.07
1045	10	39346.30	0.05
1050	10	39346.6	0.06
1055	10	39346.85	0.05
1100	10	39347.2	0.07
1105	10	39347.4	0.04
1110	10	39347.7	0.06
1115	10	39348.05	0.07
1120	10	39348.45	0.08
1125	10	39348.8	0.07
1130	10	39349.1	0.06

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct Characterization Date: 01/13/06

Field Representative: R. Rupp Borehole No. 0204 Total Depth: 300'

Depth to Water (TOC): 225' Borehole Cleaned? Yes ✓ No___ Date: 01/12/06

Test Interval (BGL): from 283 to 295 ft. Swivel/Elbow Height (AGL) 2.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin WALL STEEL Tubing

	Time	Gauge Pressure	Flow Meter Reading	Flow Rate
	1140	20 psi	39349.85	0.08 gpm
	1145	20	39349.85	-0
	1150	20	39349.85	-0
	1155	20	39349.85	-0
Adjust Valves	1200	20	39350.04	
Adjust VALVES	1205	20	39351.2	
	1210	20	39351.75	0.11 gpm
	1215	20	39352.35	0.12
	1220	20	39353.0	0.13
10 min →	1230	20	39354.4	0.14
	1235	20	39355.1	0.14
	1240	20	39355.95	0.17
	1245	20	39356.70	0.15
	1250	20	39357.60	0.18
	1255	20	39358.40	0.16
	1300	20	39359.1	0.14
	1305	20	39360.0	0.18
	1310	20	39360.8	0.16
	1315	20	39361.55	0.15
	1320	20	39362.4	0.17
	1325	20	39363.25	0.17

Stoller

established 1959

Packer-Test Record

Project Name: Moab-Crescent Jct characterization Date: 01/13/06

Field Representative: R. Rupp Borehole No. 0204 Total Depth: 300'

Depth to Water (TOC): 225' Borehole Cleaned? Yes ✓ No____ Date: 01/12/06

Test Interval (BGL): from 283 to 295 ft. Swivel/Elbow Height (AGL) 2.0'

Conductor Pipe, Type and Size: 1" ID - thin wall steel tubing

	Time	Gauge Pressure	Flow Meter Reading	Flow Rate
Adjust valves	1335	10 psi	39364.0	
	1340	10	39364.0	-0-
Adjust valves	1345	10	39364.1	0.02 gpm
	1350	10	39364.1	-0-
	1355	10	39364.1	-0-
	1400	10	39364.1	-0-
	1405	5	39364.0	-0-
	1410	5	39364.0	-0-
	1415	5	39364.0	-0-
	1420	5	39364.0	-0-

1-27-06
Crescent Junction Site.
Borehole 204
Depth 283 - 295
All pressures

$T_u = 75 - 65 + 125.1 = 135.1$ feet

$$X = \frac{125.1}{135.1}(100) = 92.6\% \quad also \quad \frac{T_u}{\ell} = \frac{135.1}{10} = 13.5$$

The test section is located in zone 2 (figure 17-6). To determine the saturated conductivity coefficient, C_s, from figure 17-8:

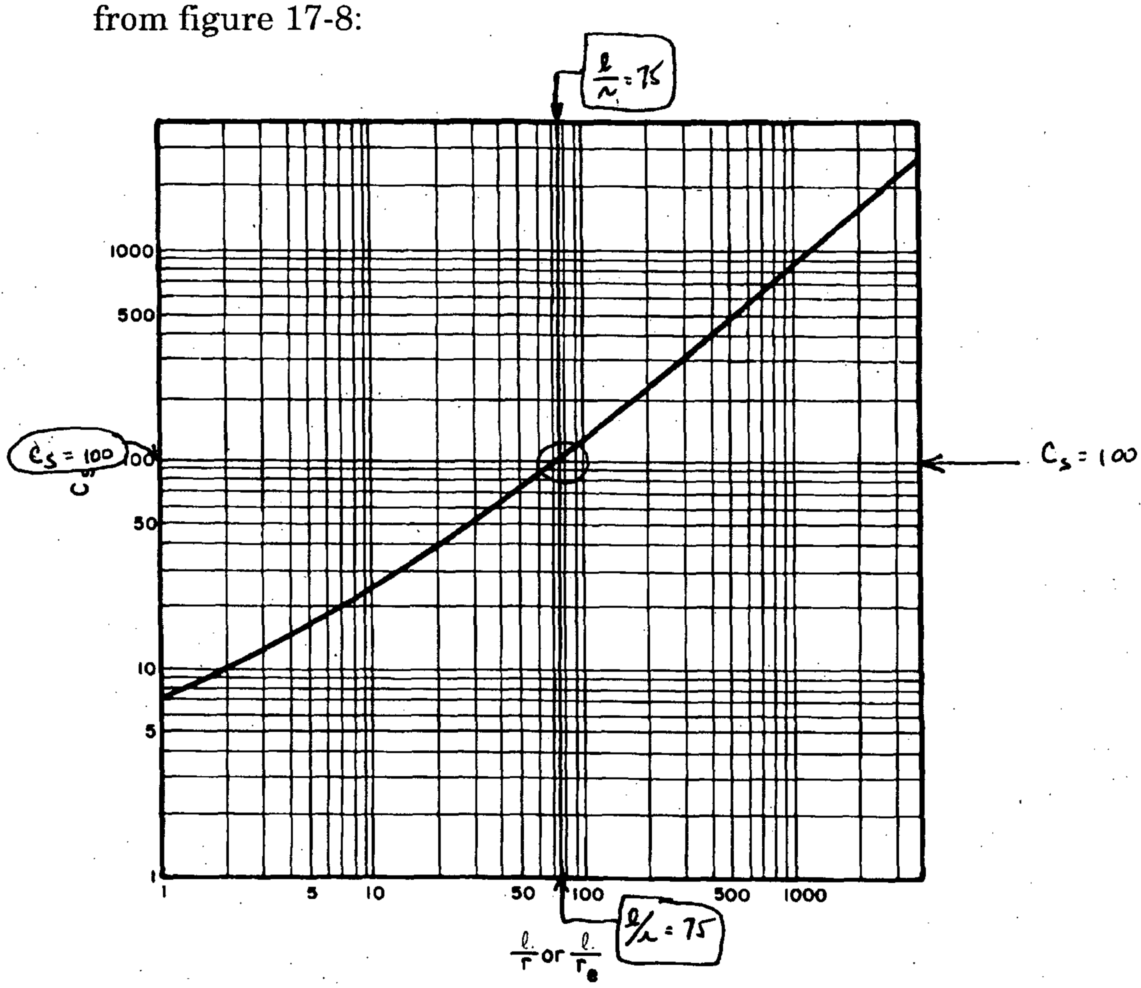


Figure 17-8.—Conductivity coefficients for semispherical flow in saturated materials through partially penetrating cylindrical test wells.

A-113

Stoller

For Straddle Packer tests below water table
Zone 3 ; Method 2 USBR

JOB NO.: DATE: 1-27-06

JOB NAME: Crescent Junction site

PREPARED: M. Koutsky REVIEWED:

Borehole 204
Depth 283-295
Pressure: 5 psi

SHEET NO.: OF

Obtain L from pressure-loss curve if $Q > 4$ gpm

$L = \boxed{\varnothing}$
$Q < 4$ gpm

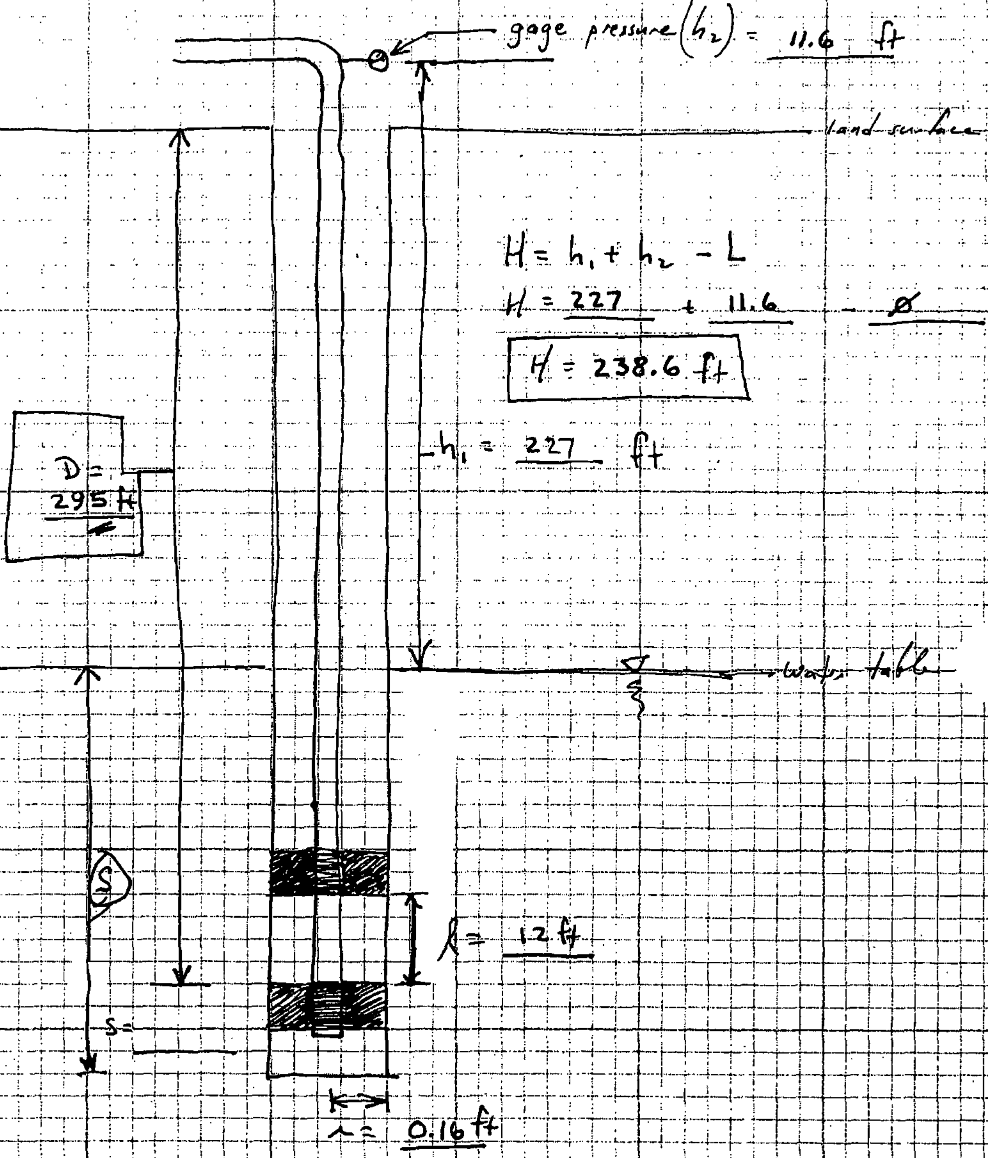
$Q < \frac{0.01 \text{ gal}}{20 \text{ min}}$

$\boxed{Q < 5 \times 10^{-4} \text{ gal/min}}$

$H = h_1 + h_2 - L$

$H = 227 + 11.6 - \varnothing$

$\boxed{H = 238.6 \text{ ft}}$



C_s from figure 17-8

$\frac{l}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K < \frac{Q}{C_s \, r \, H}$$

$$K < \frac{\left(5 \times 10^{-4} \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)}{(100)(0.16 \text{ ft})(238.6 \text{ ft})} ;$$

$\boxed{K < 2.5 \times 10^{-5} \text{ ft/d} \quad K < 8.9 \times 10^{-9} \text{ cm/s}}$

JOB NO.: DATE: 1-27-06

JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky REVIEWED:

Borehole 204

SHEET NO.: OF

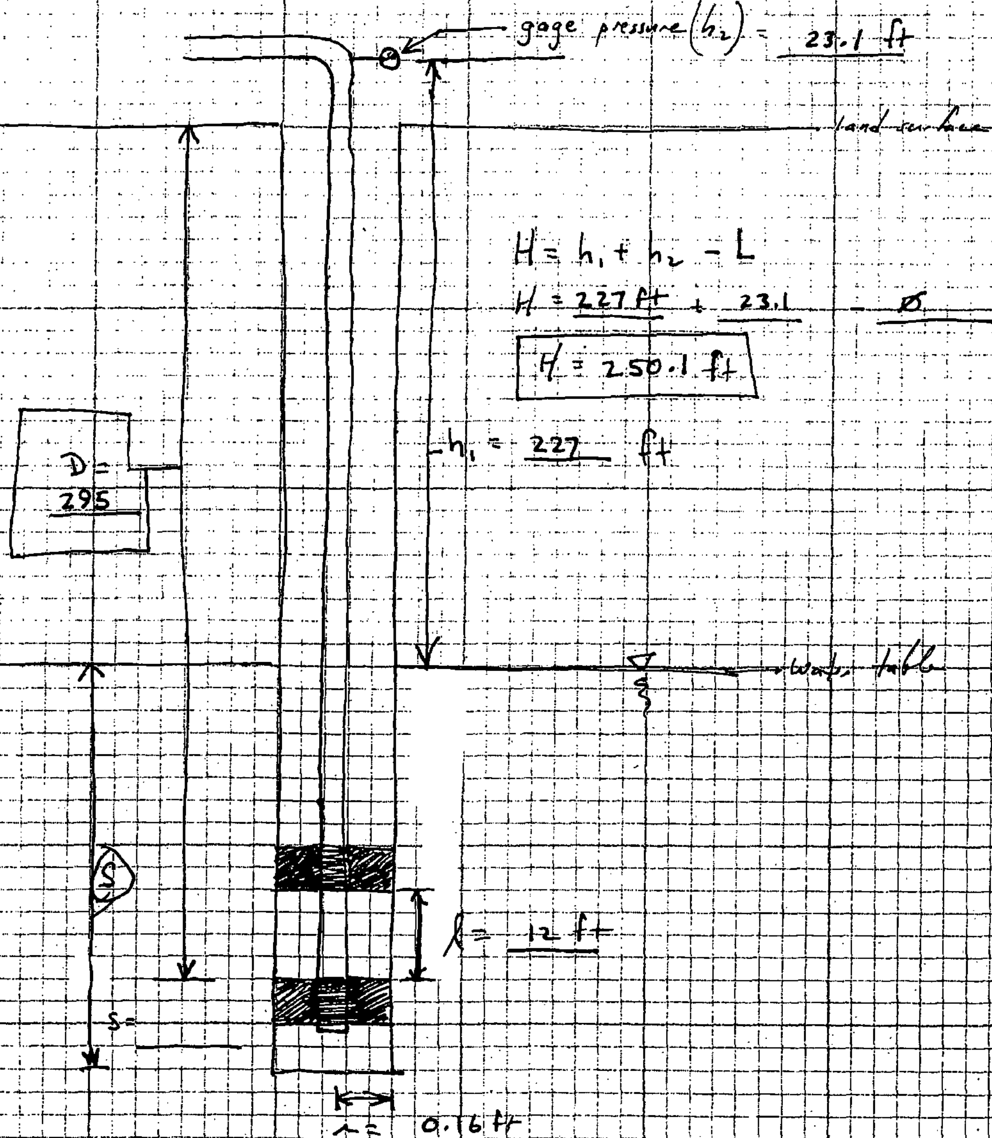
Depth: 283-295

Pressure: 10 psi

Stoller

For Straddle Packer Tests below water table

Zone 3; Method 2 USBR



Obtain L from pressure-loss curve if Q > 4 gpm

$\boxed{L = \varnothing}$ (Q < 4 gpm)

$\boxed{Q = 0.07\ \text{gal/min}}$

$H = h_1 + h_2 - L$

$H = 227\ \text{ft} + 23.1 - \varnothing$

$\boxed{H = 250.1\ \text{ft}}$

C_s from figure 17-8

$\frac{l}{r} = \frac{12\ \text{ft}}{0.16\ \text{ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s\, r\, H}$$

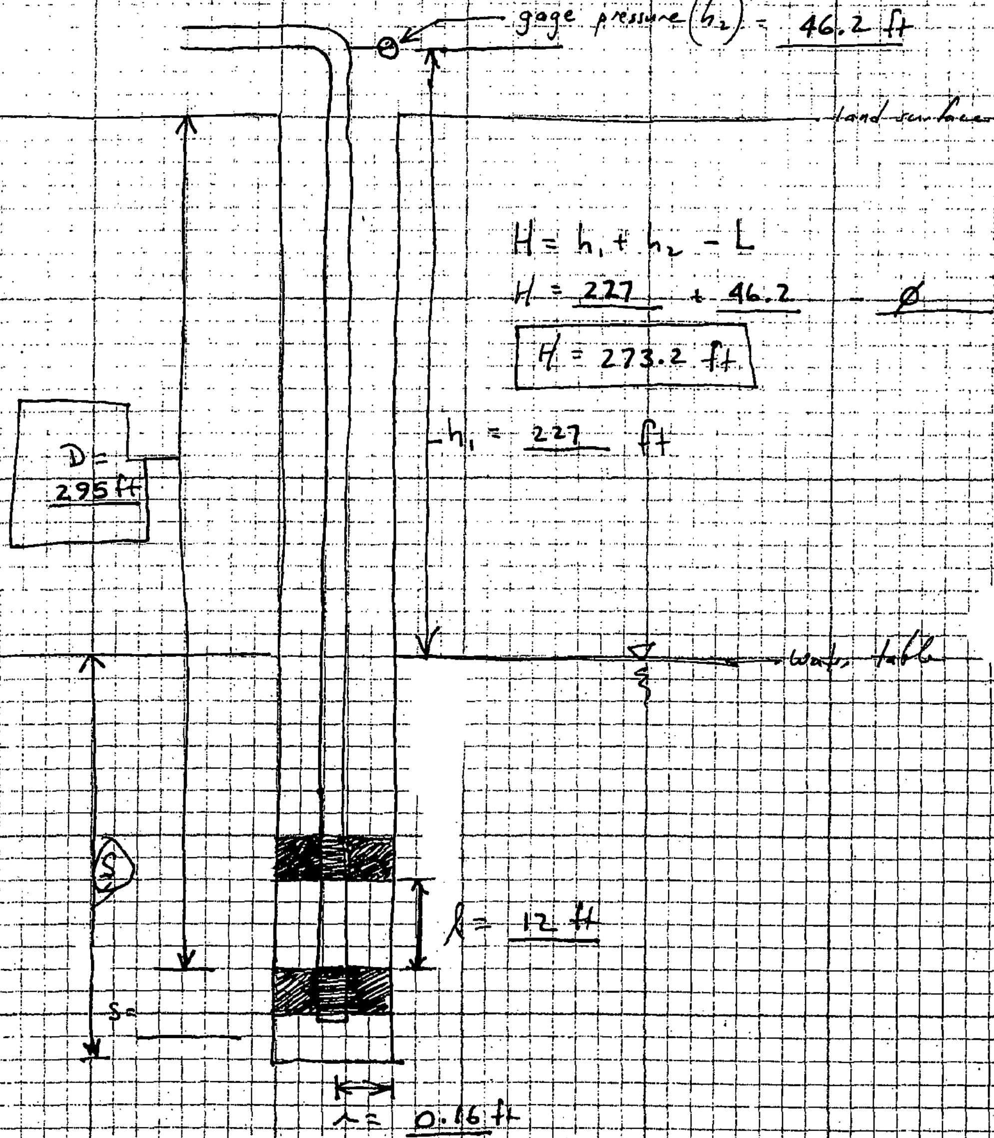
$$K = \frac{\left(0.07\,\frac{\text{gal}}{\text{min}}\right)\left(\frac{1440\ \text{min}}{\text{d}}\right)\left(\frac{1\ \text{ft}^3}{7.48\ \text{gal}}\right)}{(100)\,(0.16\ \text{ft})\,(250.1\ \text{ft})} = 3.4 \times 10^{-3}\ \text{ft/d}$$

$$\boxed{K = 3.4 \times 10^{-3}\ \text{ft/d}\ ;\ K = 1.2 \times 10^{-6}\ \text{cm/s}}$$

Stoller

For Straddle Packer Tests below water table
Zone 3 ; Method 2 USBR

JOB NO.: ____ DATE: 1-27-06
JOB NAME: Crescent Junction site
PREPARED: M. Kautsky REVIEWED: ____
Borehole 204
SHEET NO.: ____ OF ____ Depth : 283 - 295 ft
pressure : 20 psi



Obtain L from pressure-loss curve if Q > 4 gpm

$$\boxed{L = \emptyset}$$

(Q < 4 gal/min)

$$\boxed{Q = 0.17\ \text{gal/min}}$$

$$H = h_1 + h_2 - L$$

$$H = 227 + 46.2 - \emptyset$$

$$\boxed{H = 273.2\ \text{ft}}$$

C_s from figure 17-8

$$\frac{\ell}{r} = \frac{12\ \text{ft}}{0.16\ \text{ft}} = 75$$

$$C_s = \boxed{100}$$

$$K = \frac{Q}{C_s\, r\, H}$$

$$K = \frac{\left(\frac{0.17\ \text{gal}}{\text{min}}\right)\left(\frac{1440\ \text{min}}{d}\right)\left(\frac{1\ \text{ft}^3}{7.48\ \text{gal}}\right)}{(100)(0.16\ \text{ft})(273.2\ \text{ft})}$$

$$\boxed{\begin{array}{l} K = 7.5 \times 10^{-3}\ \text{ft/d} \\ K = 2.6 \times 10^{-6}\ \text{cm/s} \end{array}}$$

Stoller

For Straddle Packer Tests below water table
Zone 3 ; Method 2 USBR

JOB NO.:

DATE: 1-27-06

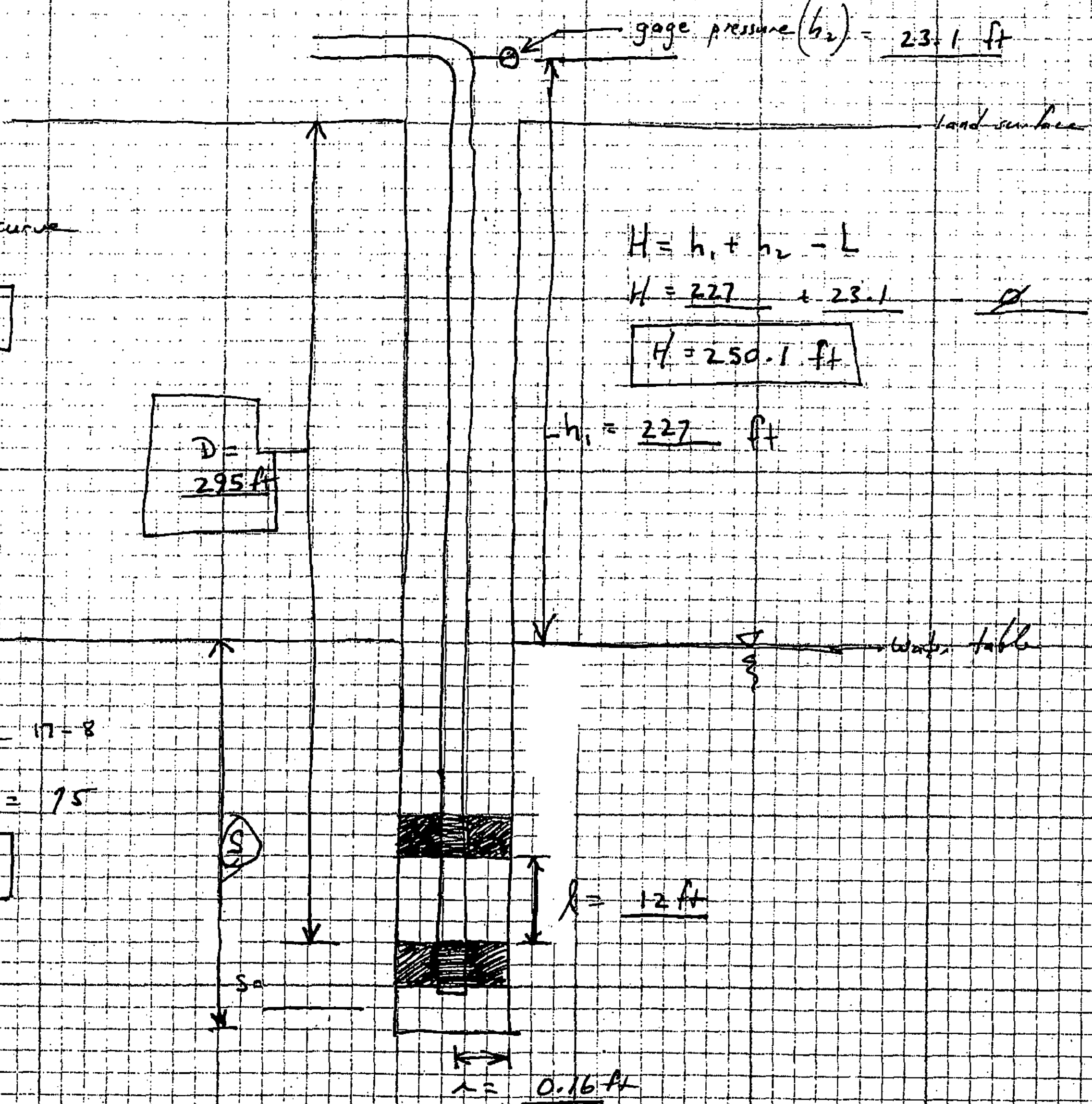
JOB NAME: Crescent Junction Site

PREPARED: Mark Kautsky

REVIEWED:

SHEET NO.: ___ OF ___

Borehole : 204
Depth : 283-295 ft.
pressure : 10 psi (retest)



Obtain L from pressure-loss curve if Q > 4 gpm

$L = \boxed{\emptyset}$ (Q < 4 gpm)

$H = h_1 + h_2 - L$

$H = 227 + 23.1 - \emptyset$

$\boxed{H = 250.1 \text{ ft}}$

$Q < \dfrac{0.01 \text{ gal}}{15 \text{ min}}$

$\boxed{Q < 6.7 \times 10^{-4} \text{ gpm}}$

C_s from figure 17-8

$\dfrac{l}{r} = \dfrac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s \, r \, H}$$

$$K < \frac{\left(6.7 \times 10^{-4} \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{d}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)}{(100)\,(0.16 \text{ ft})\,(250.1 \text{ ft})} ; \quad \boxed{\begin{array}{l} K < 3.2 \times 10^{-5} \text{ ft/d} \\ K < 1.1 \times 10^{-8} \text{ cm/s} \end{array}}$$

Stoller

For Straddle Packer Tests below water table
Zone 3 ; Method 2 USBR

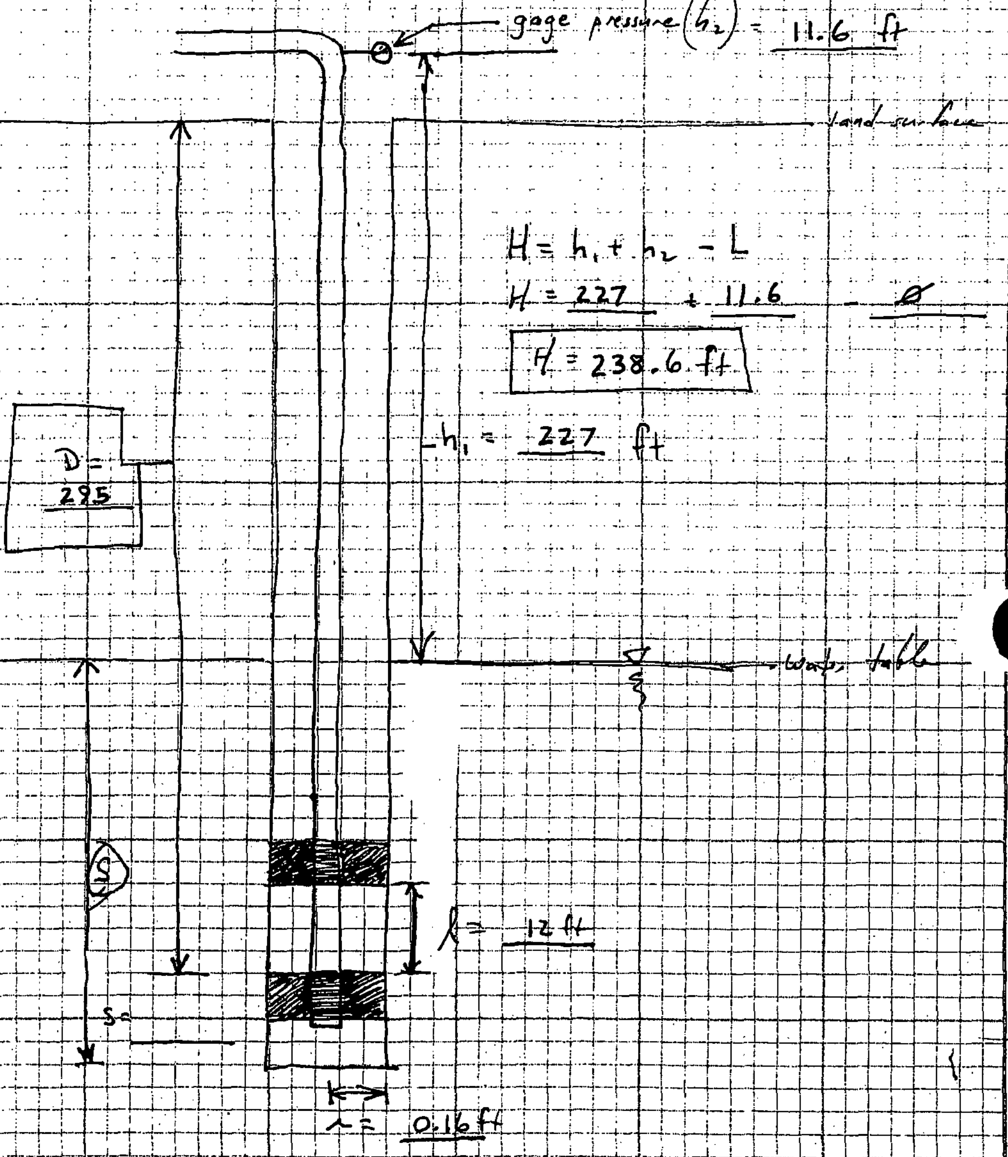
JOB NO.: DATE: 1-27-06

JOB NAME: Crescent Junction site

PREPARED: Mark Kautsky REVIEWED:

SHEET NO.: OF

Borehole 204
Depth : 283–295 ft
pressure : 5 psi (retest)



Obtain L from pressure-loss curve if Q > 4 gpm

$L = \boxed{\emptyset}$
(Q < 4 gal/min)

$H = h_1 + h_2 - L$

$H = 227 + 11.6 - \emptyset$

$\boxed{H = 238.6 \text{ ft}}$

$Q < \dfrac{0.01 \text{ gal}}{15 \text{ min}}$

$\boxed{Q < 6.7 \times 10^{-4} \dfrac{\text{gal}}{\text{min}}}$

C_s from figure 17-8

$\dfrac{l}{r} = \dfrac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s \, r \, H}$$

$$K < \frac{\left(6.7 \times 10^{-4} \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(100)\,(0.16 \text{ ft})\,(238.6 \text{ ft})} ;$$

$\boxed{\begin{array}{l} K < 3.4 \times 10^{-5} \text{ ft/d} \\ K < 1.2 \times 10^{-8} \text{ cm/s} \end{array}}$

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct Characterization Date: 01/16/06

Field Representative: R. RUPP Borehole No. 0208 Total Depth: 300 ft

Depth to Water (TOC): 187.5 ft Borehole Cleaned? Yes ✓ No ___ Date: 01/15/06

Test Interval (BGL): from 90 to 102 ft. Swivel/Elbow Height (AGL) 4.5 ft.

Conductor Pipe, Type and Size: 1-inch ID thin wall steel tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
0800	10 psi	39421.70	
0805	10	39421.70	0
0810	10	39421.70	0
0815	10	39421.70	0
0820	10	39421.70	0
0825	10	39421.70	0
0830	10	39421.70	0 gpm
0835	20 psi	39422.40	0.14
0840	20	39422.40	0
0845	20	39422.35	-0.01
0850	20	39422.35	0
0855	20	39422.35	0
0900	20	39422.35	0
0905	20	39422.35	0 gpm
0910	30 psi	39422.75	0.08
0915	30	39422.75	0
0920	30	39422.75	0
0925	30	39422.75	0

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct characterization Date: 01/16/06

Field Representative: R. Rupp Borehole No. 0208 Total Depth: 300 ft.

Depth to Water (TOC): 187.5 ft Borehole Cleaned? Yes ✓ No ___ Date: 01/15/06

Test Interval (BGL): from 90 to 102 ft. Swivel/Elbow Height (AGL) 4.5 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin Wall steel Tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
0930	30 psi	39422.75	0
0935	30	39422.75	0
0940	30	39422.75	0 gpm
0945	20 psi	39422.70	-0.01
0950	20	39422.70	0
0955	20	39422.70	0
1000	20	39422.70	0
1005	20	39422.70	0
1010	20	39422.70	0
1015	20	39422.70	0
1020	10 psi	39422.70	0
1025	10	39422.70	0
1030	10	39422.70	0
1035	10	39422.70	0
1040	10	39422.70	0
1045	10	39422.70	0
1050	10	39422.70	0

1-23-06

Crescent Junction

N. Kautsky

PACKER TEST ANALYSES

BOREHOLE : 208
Depth : 90 – 102 ft
Pressure (h_2) : 10 psi ($h_2 = 23.1$ ft)

Unsaturated Zone Calculation:

Definitions:

l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 187.5\text{ ft} - 102\text{ ft} + 129.6\text{ ft} = 215.1\text{ ft}$

$\frac{T_u}{l} = \frac{215\text{ ft}}{12\text{ ft}} = \boxed{17.9}$

Q < 4gpm

$H = h_1 + h_2 - \underset{0}{L} = 106.5\text{ ft} + 23.1\text{ ft} - 0 = 129.6\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{129.6\text{ ft}}{215.1\text{ ft}}(100) = \boxed{60.2}$

$h_1 = (102 + 4.5)\text{ ft} = 106.5\text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole: 208
Depth: 90-102 ft
Pressure: 10 psi

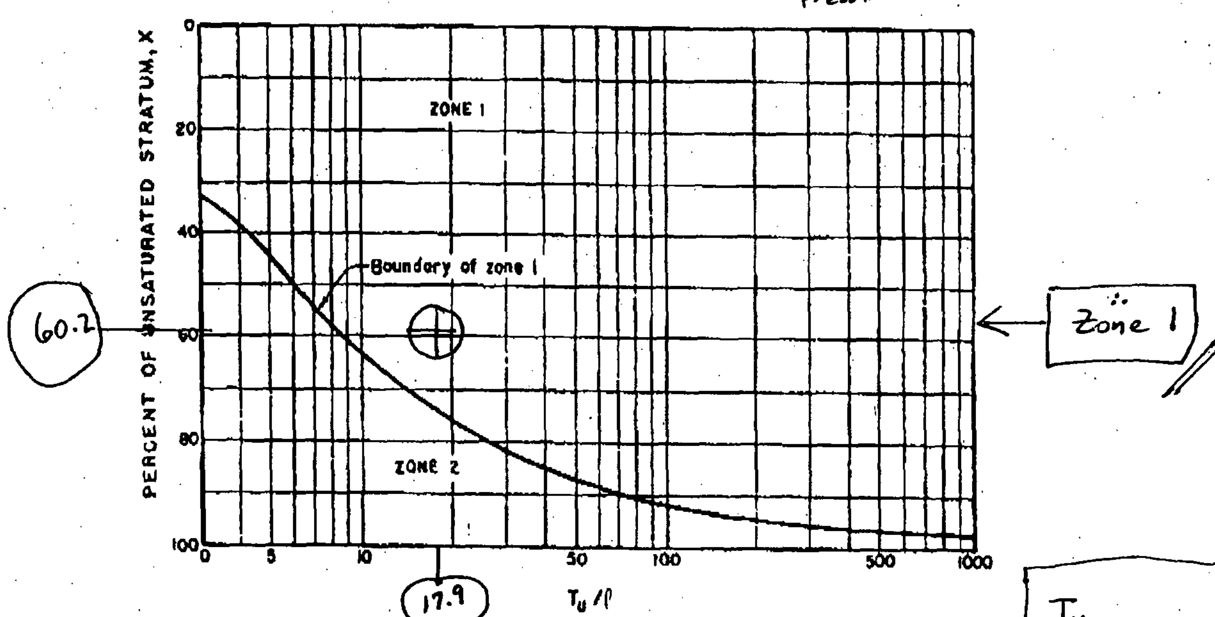


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{l} = 17.9$

$X = 60.2$

A-122

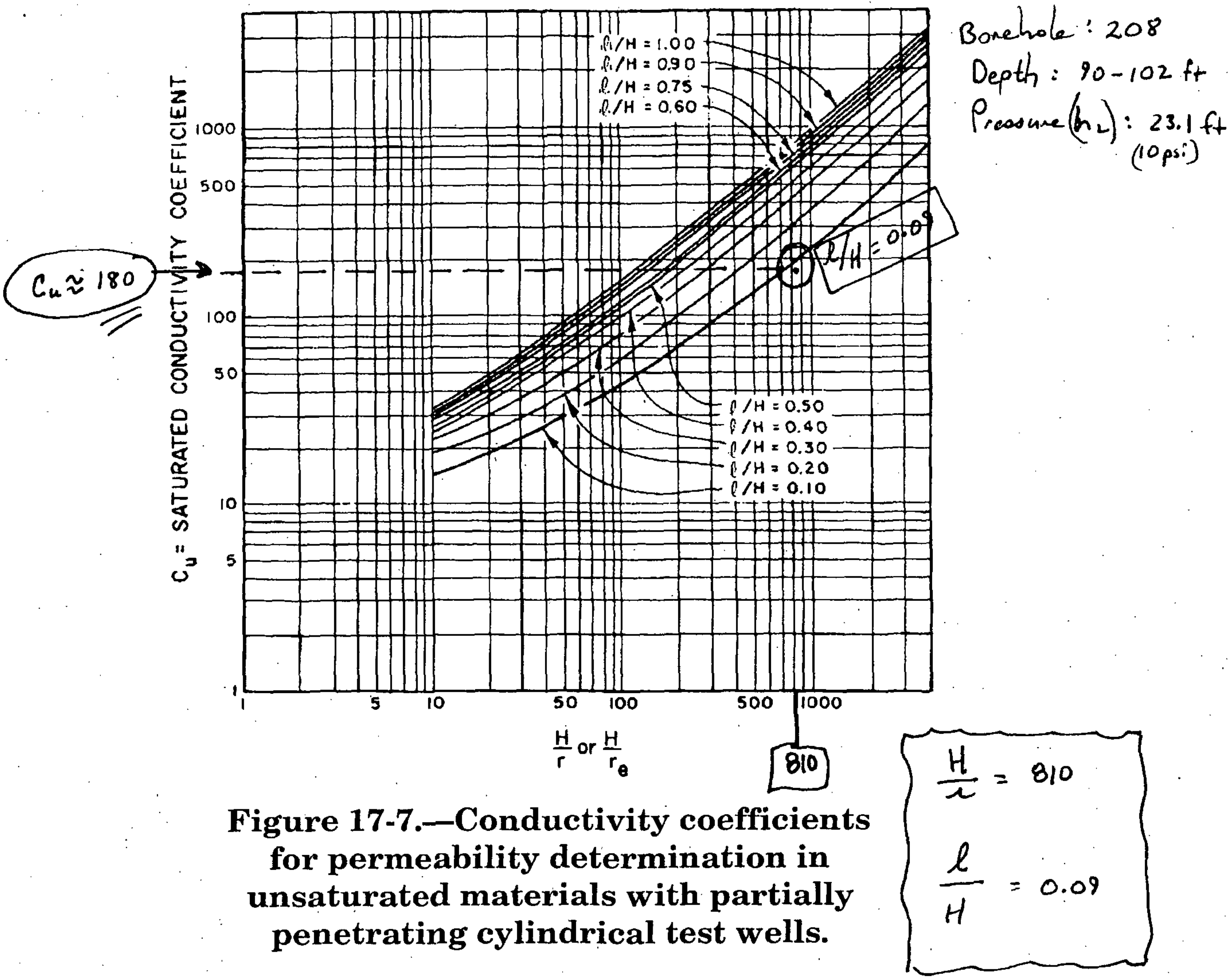


Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Borehole: 208

Depth: 90–102 ft

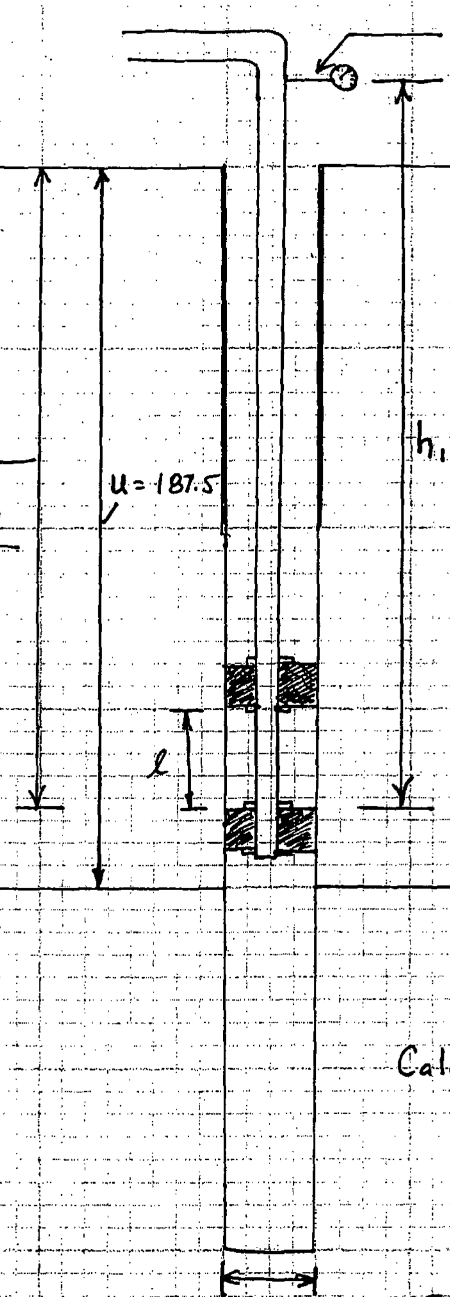
Pressure (h_2) : 23.1 ft

Crescent Junction Site

Packer Test Set-up Sheet

For straddle packer tests in Zone I

– Above water Table –



gage pressure (h_2) = (10 psi) 23.1 ft

Injection Pipe

Obtain L (head loss coeff.)

$\boxed{L = 0.0 \text{ ft}/10 \text{ ft}}$

from pressure-loss Curve

$Q < 4$ gpm; $L \approx 0$

D = 102 ft

h_1 = 106.5 ft

$H = h_1 + h_2 - L$ → 0

$H = 106.5 + 23.1 =$

$\boxed{H = 129.6 \text{ ft}}$

Obtain Cu

$\boxed{C_u \cong 180}$

from fig 17.7 USBR (Attached)

$\frac{H}{r} = \boxed{\frac{129.6 \text{ ft}}{0.16 \text{ ft}}} = \boxed{810}$

$\frac{l}{H} = \boxed{\frac{12 \text{ ft}}{129.6 \text{ ft}}} = \boxed{0.09}$

Calculate K : Zone 1

$$K = \frac{Q}{C_u \, r \, H}$$

$Q < \frac{0.01 \text{ gal}}{30 \text{ min}}$

$\boxed{Q < 3.33 \times 10^{-4} \text{ gpm}}$

$2r = 3.785$ in (0.32 ft)

$r = 0.16$ ft

$K <$ ~~$\frac{3.33 \times 10^{-4} \text{ gal/min} \quad 7.48 (\text{ft}^3)}{(180)(0.16 \text{ ft})(129.6 \text{ ft})(7.48 \text{ gal})}$~~

$$K < \frac{3.33 \times 10^{-4} \text{ gal/min}}{(180)(0.16 \text{ ft})(129.6 \text{ ft})} \left(\frac{1440 \text{ min}}{d}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right);$$

$$\boxed{\begin{array}{l} K < 1.7 \times 10^{-5} \text{ ft/d} \\ K < 6 \times 10^{-9} \text{ cm/s} \end{array}}$$

1-23-06

Crescent Junction

M. Kautsky

PACKER TEST ANALYSES

BOREHOLE : 208
Depth : 90-102
Pressure (h_2) : 20 psi ($h_2 = 46.2$ ft)

Unsaturated Zone Calculation:

Definitions:
l = length of test section
$T_u = U - D + H$
U = Thickness of Unsaturated Material
D = distance from ground surface to bottom of test section
$H = h_1 + h_2 - L$
L = head loss ; ignore if $Q < 4$ gpm
$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 187.5 \text{ ft} - 102 \text{ ft} + 152.7 \text{ ft} = 238.2 \text{ ft}$

$\frac{T_u}{l} = \frac{238.2 \text{ ft}}{12. \text{ ft}} = \boxed{19.8}$

$H = h_1 + h_2 - L = 106.5 + 46.2 = 152.7$ ft

$L = 0$ ($Q < 4$ gpm)

$X = \frac{H}{T_u}(100) = \frac{152.7 \text{ ft}}{238.2 \text{ ft}} = 0.64(100) = \boxed{64}$

$h_1 = (102 + 4.5)$ ft $= 106.5$ ft.

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 208
Depth : 90-102
Pressure (h_2) : 20 psi

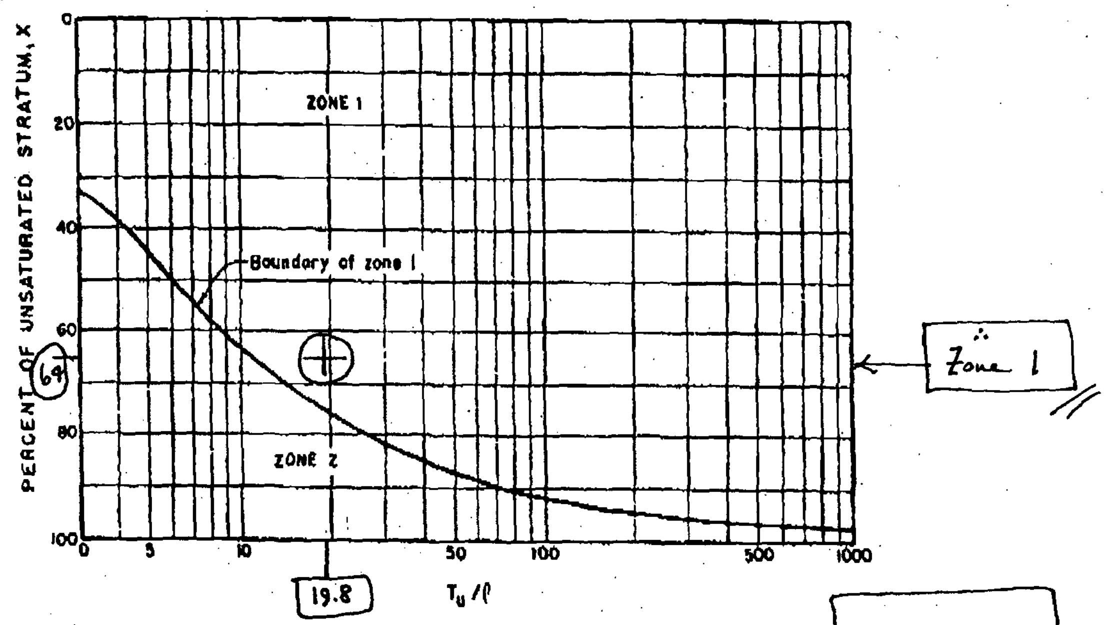
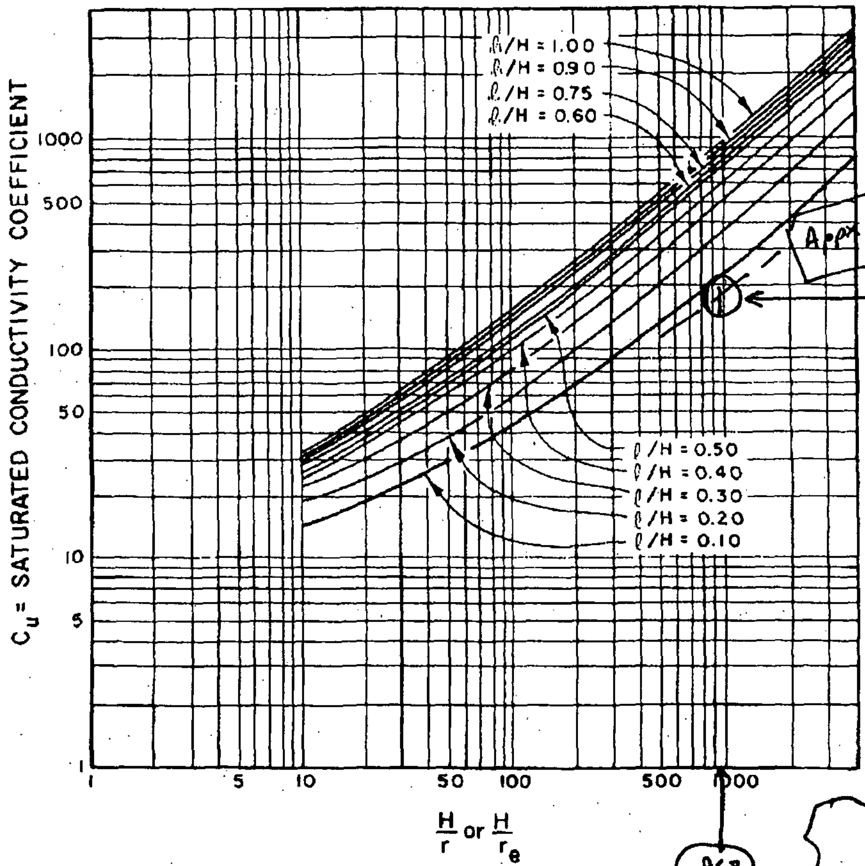


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$$\frac{T_u}{\ell} = 19.8$$

$$X = 64$$



Borehole: 208
Depth: 90-102
Pressure (h_2): 46.2 ft. (20 psi)

$\ell/H = 0.08$

$C_u \approx 180$

$\frac{H}{r} = 968.2$

$\frac{\ell}{H} = 0.08$

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

JOB NO. Borehole 208 DATE:

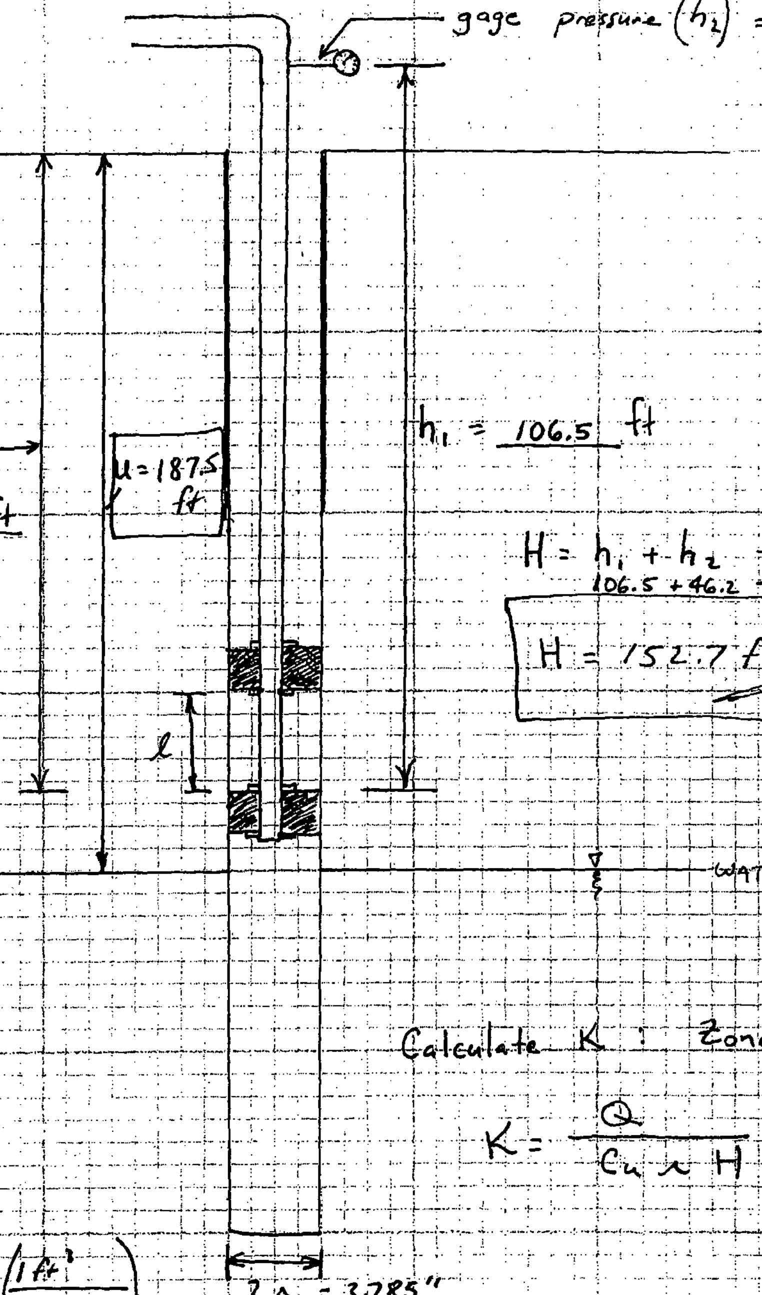
JOB NAME: Depth 90–102 ft.

PREPARED: Pressure $(h_2) = 46.2$ ft (20 psi) REVIEWED:

SHEET NO.: OF

Packer Test Set-up Sheet

For straddle packer tests in zone I
– Above water Table –



Injector Pipe

Obtain L (head loss coeff.)

$\boxed{L = \varnothing \text{ ft}/10 \text{ ft} \quad (Q < 4 \text{ gpm})}$

from Pressure-loss Curve

D = 102 ft

$h_1 = 106.5$ ft

$H = h_1 + h_2 - L$

$106.5 + 46.2 - 0$

$\boxed{H = 152.7 \text{ ft}}$

Obtain Cu

$\boxed{Cu \cong 180}$

from fig 17.7 USBR (Attached)

$$\frac{H}{r} = \boxed{\frac{152.7 \text{ ft}}{0.16 \text{ ft}}} = \boxed{968.2}$$

$$\frac{l}{H} = \boxed{\frac{12 \text{ ft}}{152.7 \text{ ft}}} = \boxed{0.08}$$

Calculate K : Zone 1

$$K = \frac{Q}{Cu\, r\, H}$$

$Q < 0.01$ gal/20 min

$Q < 5.0 \times 10^{-4}$ gal/min

$$K < \frac{(5.0 \times 10^{-4} \text{ gal/min})}{(180)(0.16 \text{ ft})(152.7 \text{ ft})}\left(\frac{1440 \text{ min}}{d}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)$$

$$\boxed{\begin{array}{l} K < 2.2 \times 10^{-5} \text{ ft/d} \\ K < 7.7 \times 10^{-9} \text{ cm/s} \end{array}}$$

Crescent Junction

M. Kautsky

Packer Test Analyses

Borehole : 208
Depth : 90-102 ft
Pressure (h_2) : 30psi $\boxed{h_2 = 69.3 ft}$

Unsaturated Zone Calculation:

Definitions: l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 187.5 ft - 102 ft + 175.8 ft = 261.3 ft$

$\frac{T_u}{l} = \frac{261.3 ft}{12 ft} = \boxed{21.8}$

$H = h_1 + h_2 - \underbrace{\cancel{L}}_{0}$ ($Q < 4$gpm) $= h_1 + h_2 = 106.5 ft + 69.3 ft = 175.8 ft$

$X = \frac{H}{T_u}(100) = \frac{175.8 ft}{261.3 ft}(100) = \boxed{67.3}$

$h_1 = (102 + 4.5) ft = 106.5 ft$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 208
Depth : 90-102 ft
Pressure (h_2) : 30 psi (69.3 ft) (= h_2)

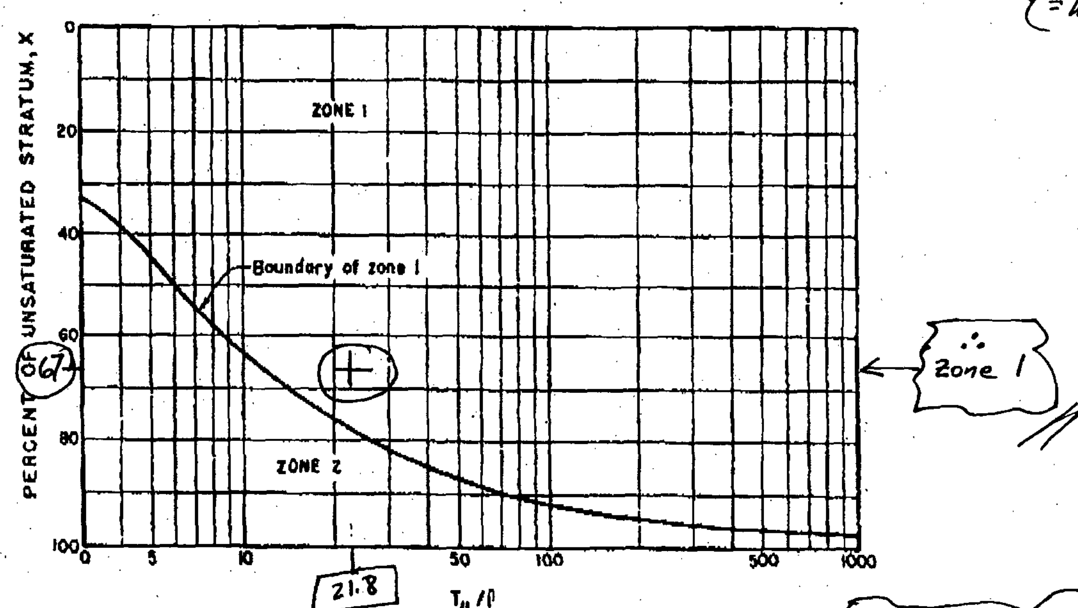
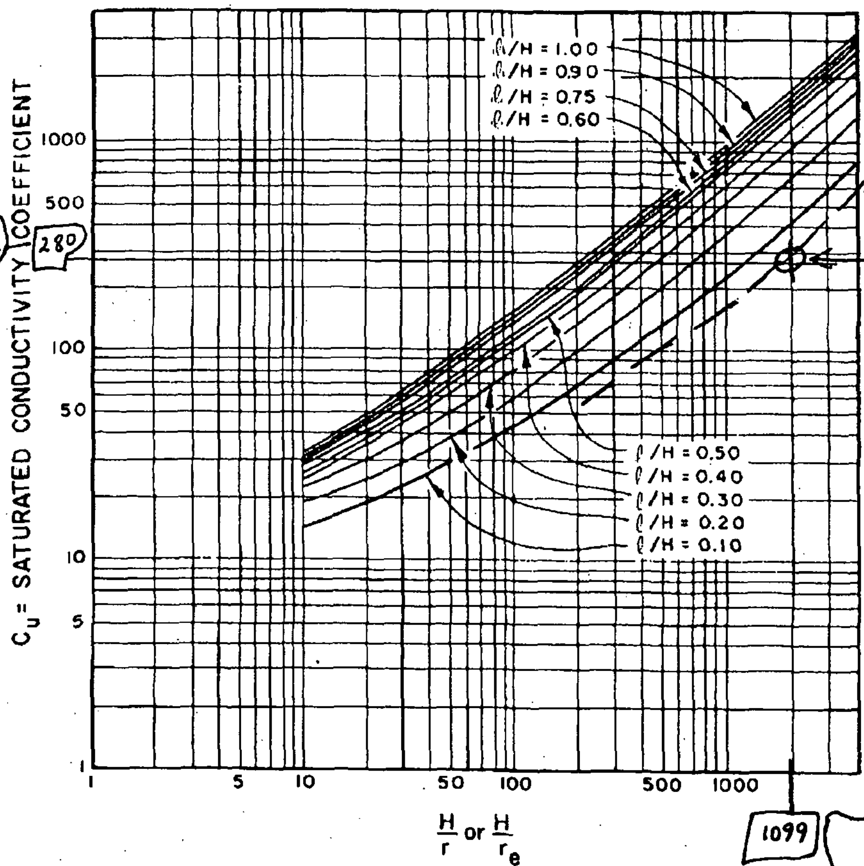


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 21.8$

$X = 67.3$



Borehole : 208
Depth : 90 - 102
Pressure (h_2) : 30psi

Appx $\frac{\ell}{H}$ = 0.07

$C_u \approx$ 280

$C_u \approx$ 280

1099

$\frac{H}{r}$ = 1099

$\frac{\ell}{H}$ = 0.07

Figure 17-7.—Conductivity coefficients for permeability determination in unsaturated materials with partially penetrating cylindrical test wells.

Zone 2

Given: U, ℓ, r, h_2, Q, and L are as given in example 1, D = 65 feet, and h_1 = 72 feet

If the distance from the gauge to the bottom of the intake pipe is 62 feet, the total L is (6.2) (0.76) = 4.7 feet.

H = 72 + 57.8 - 4.7 = 125.1 feet

Borehole 208

Depth 90 - 102 ft.

Pressure (h_2) = 30 psi (69.3 ft)

Packer Test Set-up Sheet

For straddle packer tests in Zone I

- Above water Table -

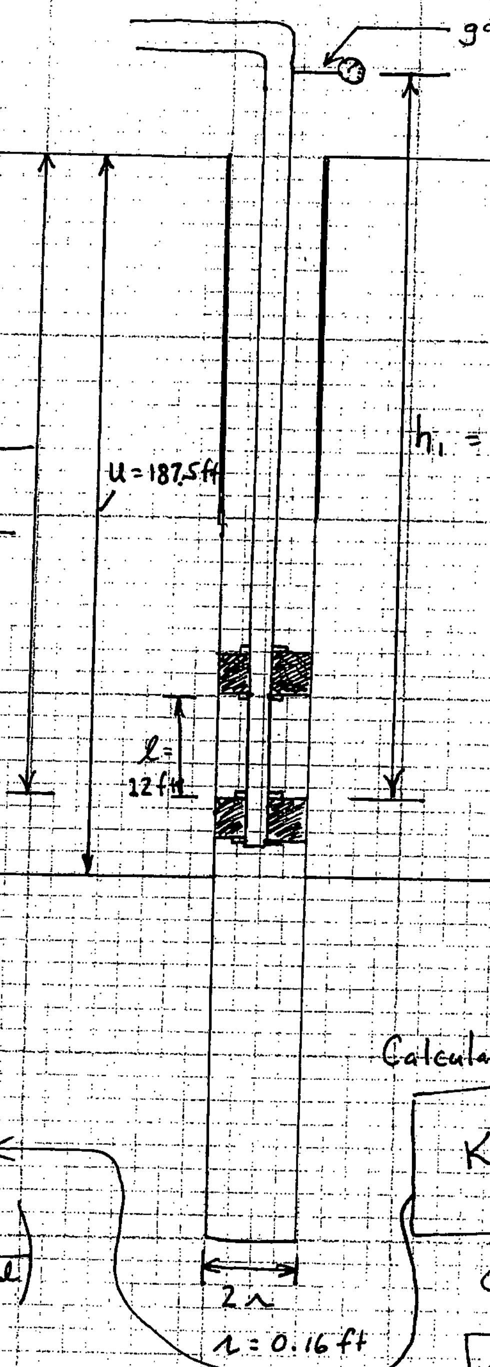
Injector Pipe

Obtain L (head loss coeff.)

$L =$ 0.0 ft/10 ft
(Q < 4 gpm)

from Pressure-loss Curve

D = 102 ft



$H = h_1 + h_2 - L$
$= 106.5 + 69.3 - 0$

$\boxed{H = 175.8 \text{ ft.}}$

Obtain Cu

$\boxed{Cu \cong 280}$

from fig 17.7 USBR

$$\frac{H}{r} = \boxed{\frac{175.8 \text{ ft}}{0.16 \text{ ft}}} = \boxed{1099}$$

$$\frac{\ell}{H} = \boxed{\frac{12 \text{ ft}}{175.8 \text{ ft}}} = \boxed{0.07}$$

Calculate K : Zone 1

$$\boxed{K = \frac{Q}{Cu\, r\, H}}$$

$$Q < \frac{0.01 \text{ gal}}{30 \text{ min}}$$

$$\boxed{Q < 3.3 \times 10^{-4} \text{ gal/min}}$$

$$K = \frac{Q}{Cu\, r\, H}$$

$$K < \frac{(3.3 \times 10^{-4} \text{ gal/min})}{(280)(0.16 \text{ ft})(175.8 \text{ ft})} \left(\frac{1440 \text{ min}}{d}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)$$

$$\boxed{\begin{array}{l} K < 8.2 \times 10^{-6} \text{ ft/d} \\ K < 2.9 \times 10^{-9} \text{ cm/s} \end{array}}$$

Stoller

JOB NO. Borehole 208 DATE:

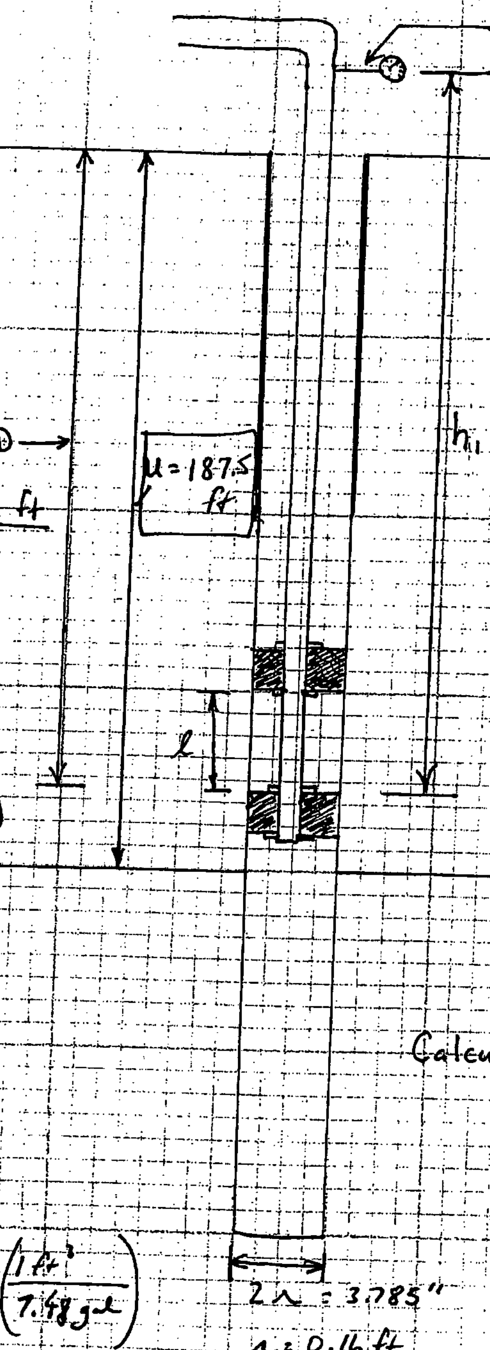
JOB NAME: Depth 90-102 ft.

PREPARED: Pressure $(h_2) = 46.2$ ft (20 psi) (retest) REVIEWED:

SHEET NO. OF

Packer Test Set-up Sheet

For straddle packer tests in Zone I
- Above water Table -



Injector Pipe

Obtain L (head loss coeff.)

$L = \varnothing$ ft/10 ft
($Q < 4$ gpm)

from Pressure-loss Curve

D = 102 ft

$H = h_1 + h_2 - L$
$106.5 + 46.2 - 0$

$\boxed{H = 152.7\ ft}$

Obtain C_u

$\boxed{C_u \cong 180}$

from fig 17.7 USBR (Attached)

$$\frac{H}{r} = \boxed{\frac{152.7\ ft}{0.16\ ft}} = \boxed{968.2}$$

$$\frac{\ell}{H} = \boxed{\frac{12\ ft}{152.7\ ft}} = \boxed{0.08}$$

Calculate K Zone 1

$$K = \frac{Q}{C_u\, r\, H}$$

$Q < 0.01$ gal/20 min

$Q < 5.0 \times 10^{-4}$ gal/min

$$K < \frac{(5.0 \times 10^{-4}\ gal/min)}{(180)(0.16\ ft)(152.7\ ft)}\left(\frac{1440\ min}{d}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)$$

$K < 2.2 \times 10^{-5}$ ft/d
7.7×10^{-9} cm/s

JOB NO.: Borehole: 208 DATE:

JOB NAME: Depth: 90–102 ft

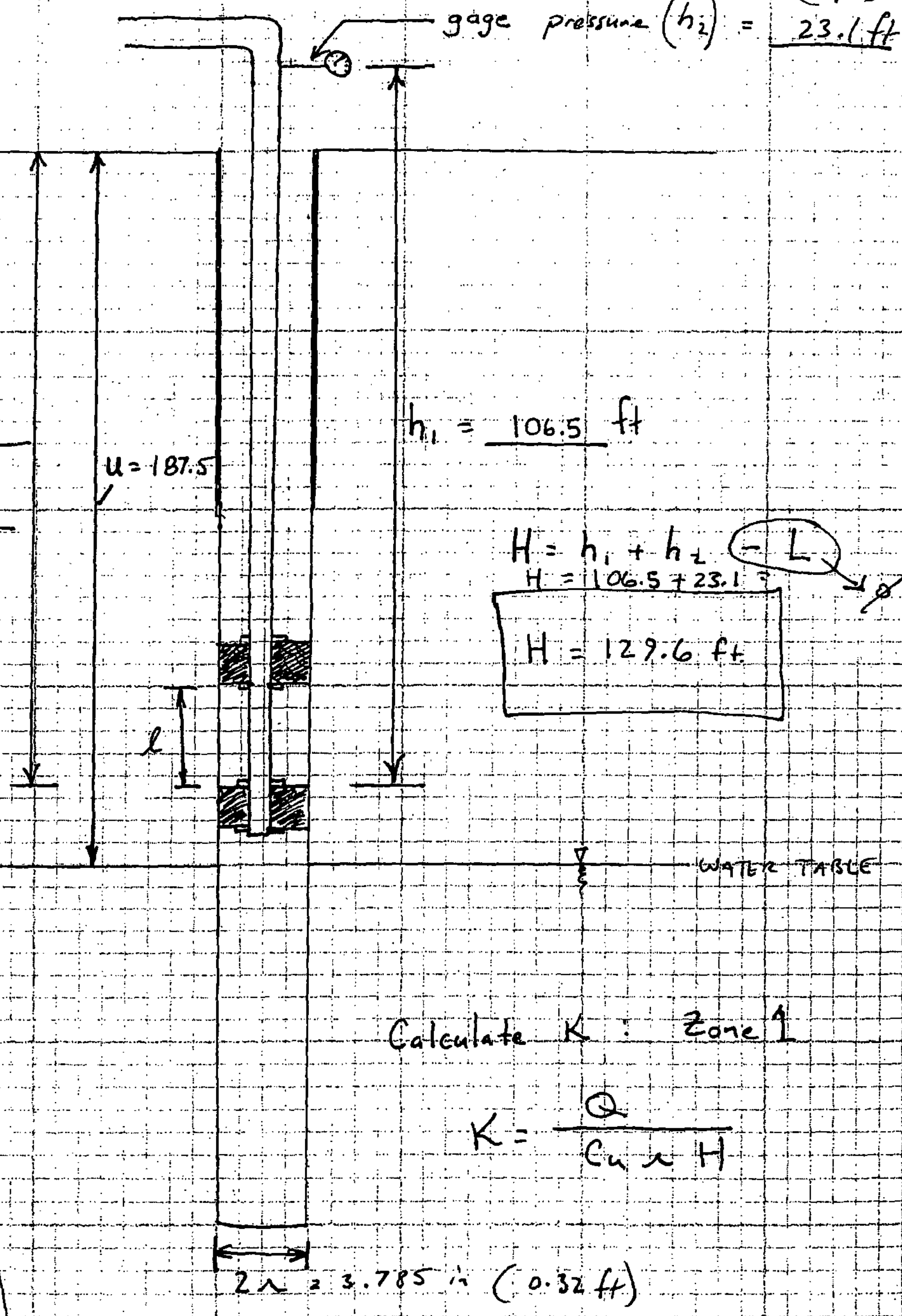
PREPARED: Pressure (h_2) : 23.1 ft REVIEWED:

SHEET NO.: Crescent Junction Site

Packer Test Set-up Sheet

For straddle packer tests in Zone 1

– Above water Table –



Injection Pipe

Obtain L (head loss coeff.)

$\boxed{L = 0.0 \text{ ft}/10 \text{ ft}}$

from pressure-loss Curve

$Q < 4 \text{ gpm};\ L \approx 0$

D = 102 ft

$H = h_1 + h_2 - L$

$H = 106.5 + 23.1 =$

$\boxed{H = 129.6 \text{ ft}}$

Obtain Cu

$\boxed{Cu \cong 180}$

from fig 17.7 USBR (Attached)

$\frac{H}{r} = \boxed{\frac{129.6 \text{ ft}}{0.16 \text{ ft}}} = \boxed{810}$

$\frac{\ell}{H} = \boxed{\frac{12 \text{ ft}}{129.6 \text{ ft}}} = \boxed{0.09}$

Calculate K : Zone 1

$$K = \frac{Q}{Cu\, r\, H}$$

$Q < \frac{0.01 \text{ gal}}{30 \text{ min}}$

$\boxed{Q < 3.33 \times 10^{-4} \text{ gpm}}$

$K < \cancel{\frac{3.33 \times 10^{-4} \text{ gal/min}}{(180)(0.16 \text{ ft})(129.6 \text{ ft})} \left(\frac{7.48}{\text{ft}^3}\right)}$

$$K < \frac{3.33 \times 10^{-4} \text{ gal/min}}{(180)(0.16 \text{ ft})(129.6 \text{ ft})} \left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right);\quad \boxed{\begin{array}{l} K < 1.7 \times 10^{-5} \text{ ft/d} \\ K < 6 \times 10^{-9} \text{ cm/s} \end{array}}$$

Stoller

established 1959

Packer-Test Record

Project Name: Moab-Crescent Jet Characterization Date: 01/15/06

Field Representative: R. Rupp Borehole No. 0208 Total Depth: 300 ft.

Depth to Water (TOC): 187.5 ft. Borehole Cleaned? Yes ✓ No___ Date: 1/15/06

Test Interval (BGL): from 121' to 133' ft. Swivel/Elbow Height (AGL) 4.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin Wall Steel Tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
1335	10 psi	39418.85	
1340	10	39418.80	-0.01 gpm
1345	10	39418.80	0
1350	10	39418.80	0
1355	10	39418.80	0
1400	10	39418.80	0
1405	10	39418.80	0
1410	10	39418.80	0
1415	20 psi	39420.05	0.25 gpm
1420	20	39420.10	0.01
1425	20	39420.10	0
1430	20	39420.15	0.01
1435	20	39420.15	0
1440	20	39420.15	0
1445	20	39420.20	0.01 gpm
1450	20	39420.25	0.01
1455	20	39420.25	0
1500	20	39420.25	0
1505	20	39420.25	0 gpm

Stoller

established 1959

Packer-Test Record

Project Name: Moab-Crescent Jct. characterization Date: 01/15/06

Field Representative: R. Rupp Borehole No. 0208 Total Depth: 300'

Depth to Water (TOC): 187.5 ft. Borehole Cleaned? Yes ✓ No___ Date: 01/15/06

Test Interval (BGL): from 121' to 133' ft. Swivel/Elbow Height (AGL) 4.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin WALL STEEL Tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
1510	30 psi	39421.20	0.19 gpm
1515	30	39421.40	0.04
1520	30	39421.60	0.04
1525	30	39421.80	0.04
1530	30	39422.00	0.04
1535	30	39422.20	0.04
1540	20 psi	39422.15	-0.01 gpm
1545	20	39422.15	0
1550	20	39422.15	0
1555	20	39422.15	0
1600	20	39422.15	0
1605	20	39422.15	0 gpm
1610	10 psi	39422.00	-0.03 gpm
1615	10	39422.00	0
1620	10	39422.00	0
1625	10	39422.00	0
1630	10	39422.00	0
1635	10	39422.00	0

PACKER TEST ANALYSES

BOREHOLE : 208

Depth : 121 - 133 ft.

Pressure (h_2) : 10 psi (23.1 ft)

Unsaturated Zone Calculation:

Definitions:

l = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if $Q < 4$ gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 187.5\text{ ft} - 133\text{ ft} + 160.1\text{ ft} = 205.6\text{ ft}$

$\frac{T_u}{l} = \frac{205.6\text{ ft}}{12\text{ ft}} = \boxed{17.1}$

$H = h_1 + h_2 - L = 137\text{ ft} + 23.1\text{ ft} - 0 = 160.1\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{160.1\text{ ft}}{205.6\text{ ft}}(100) = \boxed{78}$

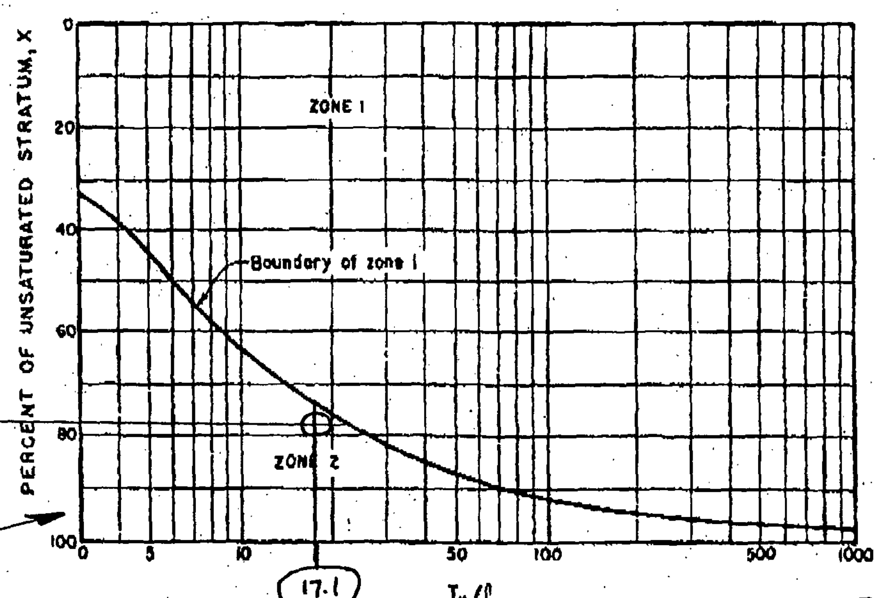
$h_1 = 133\text{ ft} + 4\text{ ft} = 137\text{ ft.}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 208
Depth : 121-133 ft.
Pressure (h_2) : 10 psi: $\boxed{23.1 \text{ ft}}$



X = 78

∴ Zone 2

17.1

Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$$\frac{T_u}{l} = 17.1$$

$$X = 78$$

$T_u = 75 - 65 + 125.1 = 135.1$ feet

$$X = \frac{125.1}{135.1}(100) = 92.6\% \quad also \quad \frac{T_u}{\ell} = \frac{135.1}{10} = 13.5$$

The test section is located in zone 2 (figure 17-6). To determine the saturated conductivity coefficient, C_s, from figure 17-8:

Borehole: 208
Depth: 121 - 133 ft
h_2 = 10psi

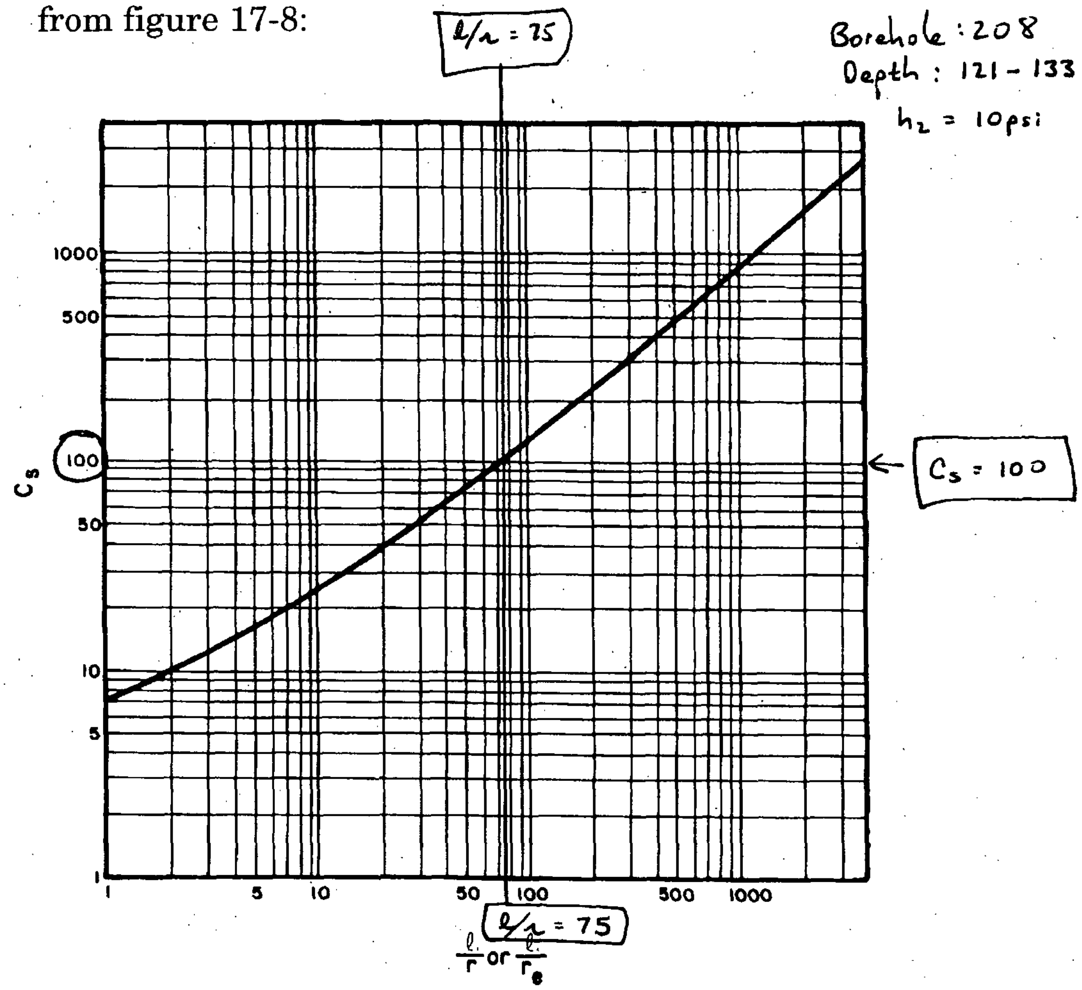


Figure 17-8.—Conductivity coefficients for semispherical flow in saturated materials through partially penetrating cylindrical test wells.

Stoller

PACKER TEST SET-UP SHEET

ZONE 2 / METHOD 2

JOB NO.: ______ DATE: 1-24-06

JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky REVIEWED: ______

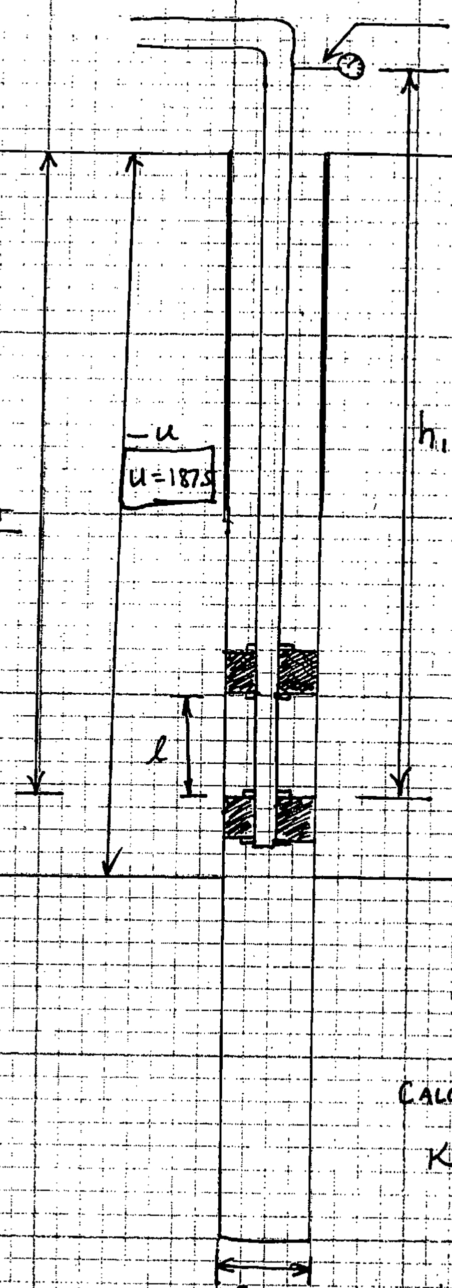
SHEET NO.: ______ OF ______

Borehole 208

Depth 121-133 ft

Pressure (h_2): 10 psi (23.1 ft)

gage pressure (h_2) = 23.1 ft



C_s from figure 17-8

$\frac{l}{r} = \frac{12\,ft}{0.16\,ft} = \boxed{75}$

$\boxed{C_s = 100}$

D = 133 ft

Injector Pipe

Obtain L (head-loss coeff)

$\boxed{L = \frac{\emptyset}{(Q < 4\,gpm)}\ ft/10\,ft.}$

from pressure-loss Curve.

$h_1 = 137$ ft

$H = h_1 + h_2 - L$

$H = 137 + 23.1 - 0$

$\boxed{H = 160.1}$

WATER TABLE

Obtain Tu:

$T_u = U - D + H$

$T_u = 187.5 - 133.0 + 160.1$

$\boxed{T_u = 205.6\,ft}$

CALCULATE K : ZONE 2

$K = \frac{2Q}{(C_s r)(T_u + H - l)}$

$Q < \frac{0.01\,gal}{30\,min}$

$\boxed{Q < 3.3 \times 10^{-4}\,gal/min}$

$K < \frac{2(3.3 \times 10^{-4}\,gal/min)}{100(0.16)(205.6 + 160.1 - 12)}$

$K < 1.2 \times 10^{-7}\,gal/min/ft^2$

$K < \left(1.2 \times 10^{-7} \frac{gal}{min \cdot ft^2}\right)\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,min}{d}\right) = \boxed{2.27 \times 10^{-5}\,ft/d}$

$\boxed{K < 8.0 \times 10^{-9}\,cm/s}$

DATE 1-23-06

JOB NAME: Crescent Junction

PREPARED: M. Kautsky REVIEWED:

SHEET NO. ______ OF ______

PACKER TEST ANALYSES

BOREHOLE : 208

Depth : 121 - 133

Pressure (h_2) : 20 psi (46.2 ft)

Unsaturated Zone Calculation:

Definitions: ℓ = length of test section

$T_u = U - D + H$

U = Thickness of Unsaturated Material

D = distance from ground surface to bottom of test section

$H = h_1 + h_2 - L$

L = head loss ; ignore if Q < 4 gpm

$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

ℓ = 12 ft

$T_u = U - D + H = 187.5\text{ ft} - 133\text{ ft} + 183.2\text{ ft} = 237.7\text{ ft}$

$\frac{T_u}{\ell} = \frac{237.7\text{ ft}}{12\text{ ft}} = \boxed{19.8}$

$H = h_1 + h_2 - L = 137\text{ ft} + 46.2\text{ ft} - 0 = 183.2\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{183.2\text{ ft}}{237.7\text{ ft}} = 0.77(100) = \boxed{77}$

$h_1 = 133\text{ ft} + 4\text{ ft} = 137\text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 208
Depth : 121 – 133
Pressure (h_2) : 46.2 ft
(20 psi)

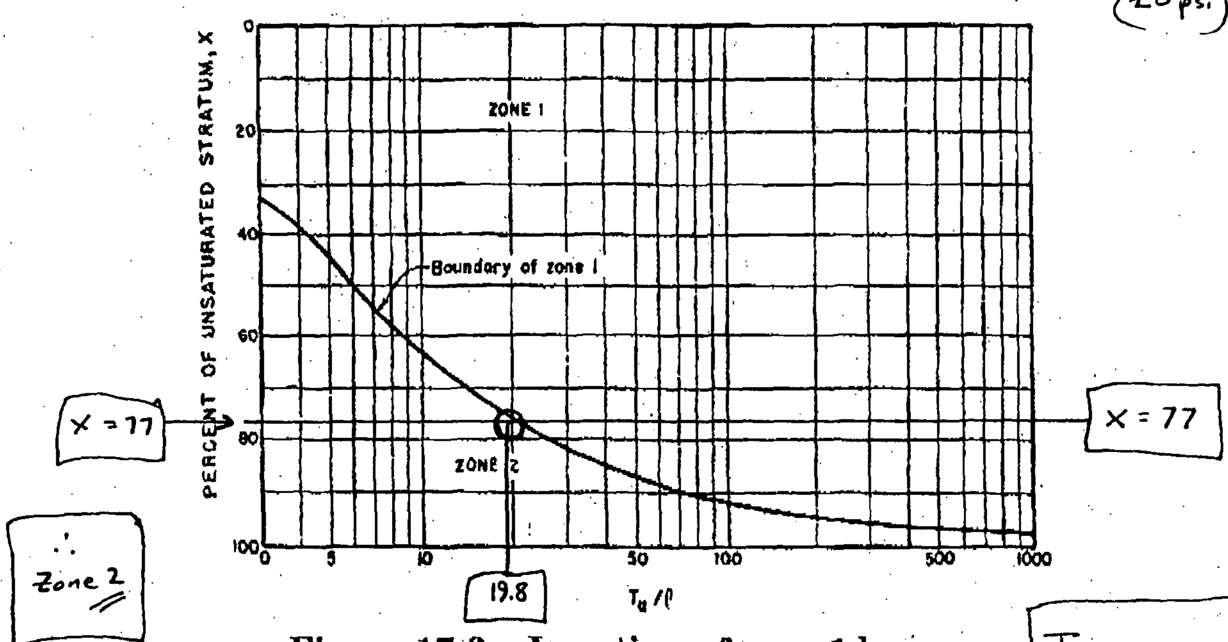


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 19.8$

$X = 77$

Stoller

PACKER TEST SET-UP SHEET

ZONE 2 / METHOD 2

JOB NO.: DATE: 1-24-06

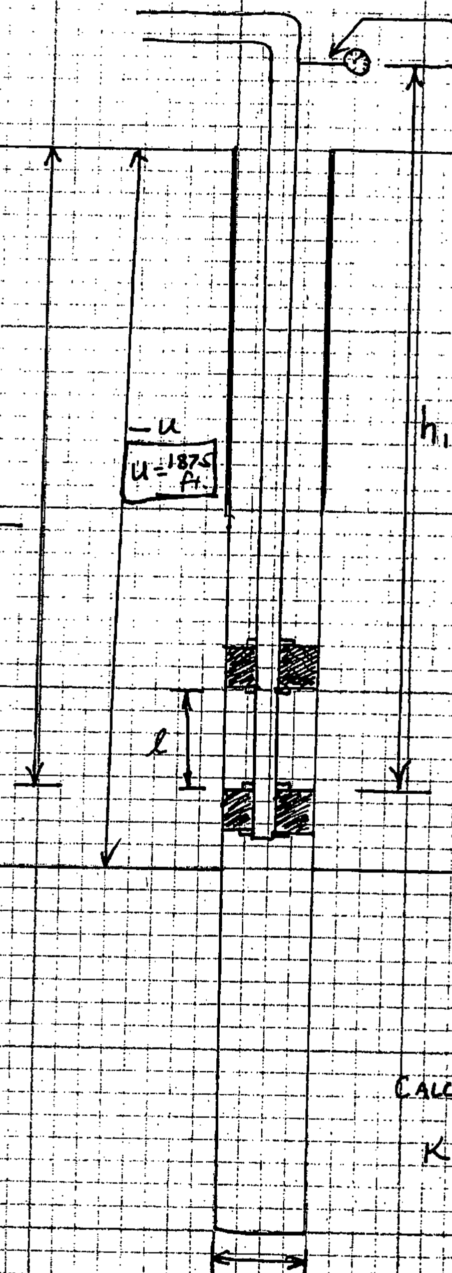
JOB NAME: Crescent Junction site

PREPARED: M. Kautsky REVIEWED:

SHEET NO.: OF

Borehole 208
Depth 121-133
pressure: 20 psi

gage pressure (h_2) = 46.2 ft



C_s from figure 17-8

$\frac{l}{r} = \frac{12\text{ ft}}{0.16\text{ ft}} = 75$

$\boxed{C_s = 100}$

D = 133 ft

$\boxed{u = 187.5\text{ ft}}$

$h_1 = 137$ ft

$H = h_1 + h_2 - L$

$H = 137 + 46.2 - 0$

$\boxed{H = 183.2\text{ ft}}$

Injection Pipe
Obtain L (head-loss coeff)

$L = \frac{0.0\text{ ft}/10\text{ ft}}{(Q < 4\text{ gpm})}$

from Pressure-Loss Curve.

Obtain Tu:

$Tu = u - D + H$

$Tu = 187.5 - 133 + 183.2$

$\boxed{Tu = 237.7}$

CALCULATE K : ZONE 2

$K = \frac{2Q}{(C_s\, r)(Tu + H - l)}$

$Q < \frac{0.01\text{ gal}}{15\text{ min}}$

$\boxed{Q < 6.7 \times 10^{-4}\text{ gal/min}}$

2r

$$K < \frac{2(6.7 \times 10^{-4}\text{ gal/min})}{(100)(0.16\text{ ft})(237.7\text{ ft} + 183.2\text{ ft} - 12\text{ ft})}\left(\frac{1\text{ ft}^3}{7.48\text{ gal}}\right)\left(\frac{1440\text{ min}}{\text{d}}\right)$$

$$\boxed{\begin{array}{l} K < 3.9 \times 10^{-5}\text{ ft/d} \\ K < 1.4 \times 10^{-8}\text{ cm/s} \end{array}}$$

PACKER TEST ANALYSES

BOREHOLE : 208
Depth : 121 - 133 ft
Pressure (h_2) : 30 psi (69.3 ft)

Unsaturated Zone Calculation:

Definitions:
l = length of test section
$T_u = U - D + H$
U = Thickness of Unsaturated Material
D = distance from ground surface to bottom of test section
$H = h_1 + h_2 - L$
L = head loss ; ignore if $Q < 4$ gpm
$X = \frac{H}{T_u}(100)$; percent unsaturated material

Reference Figure 17-6 U.S Bureau of Rec. Earth Manual

$l = 12$ ft

$T_u = U - D + H = 187.5\text{ ft} - 133\text{ ft} + 206.3\text{ ft} = 260.8\text{ ft}$

$\frac{T_u}{l} = \frac{260.8\text{ ft}}{12\text{ ft}} = \boxed{21.7}$

$H = h_1 + h_2 - L = 137\text{ ft} + 69.3\text{ ft} - 0\text{ ft} = 206.3\text{ ft}$

$X = \frac{H}{T_u}(100) = \frac{206.3\text{ ft}}{260.8\text{ ft}}(100) = \boxed{79}$

$h_1 = 133\text{ ft} + 4\text{ ft} = 137\text{ ft}$

- Effective head, the difference in feet (m) between the elevation of the free water surface in the pipe and the elevation of the gauge plus the applied pressure. If a pressure transducer is used, the effective head in the test section is the difference in pressure before water is pumped into the test section and the pressure readings made during the test.

The following examples show some typical calculations using Methods 1 and 2 in the different zones shown in figure 17-5. Figure 17-6 shows the location of the zone 1 lower boundary for use in unsaturated materials.

Pressure permeability tests examples using Methods 1 and 2:

Borehole : 208
Depth : 121-133 ft
Pressure (h_2) : 30 psi (69.3 ft)

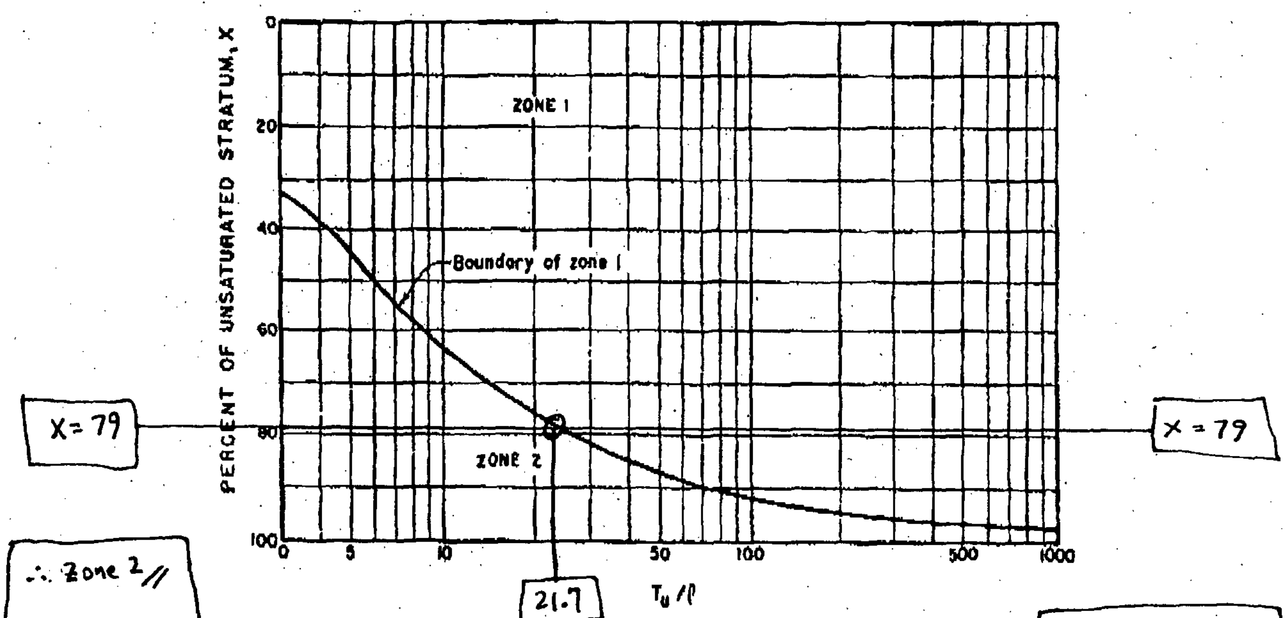


Figure 17-6.—Location of zone 1 lower boundary for use in unsaturated materials.

$\frac{T_u}{\ell} = 21.7$

$X = 79$

Stoller

PACKER TEST SET-UP SHEET

ZONE 2 / METHOD 2

JOB NO.: ______ DATE: 1-24-06

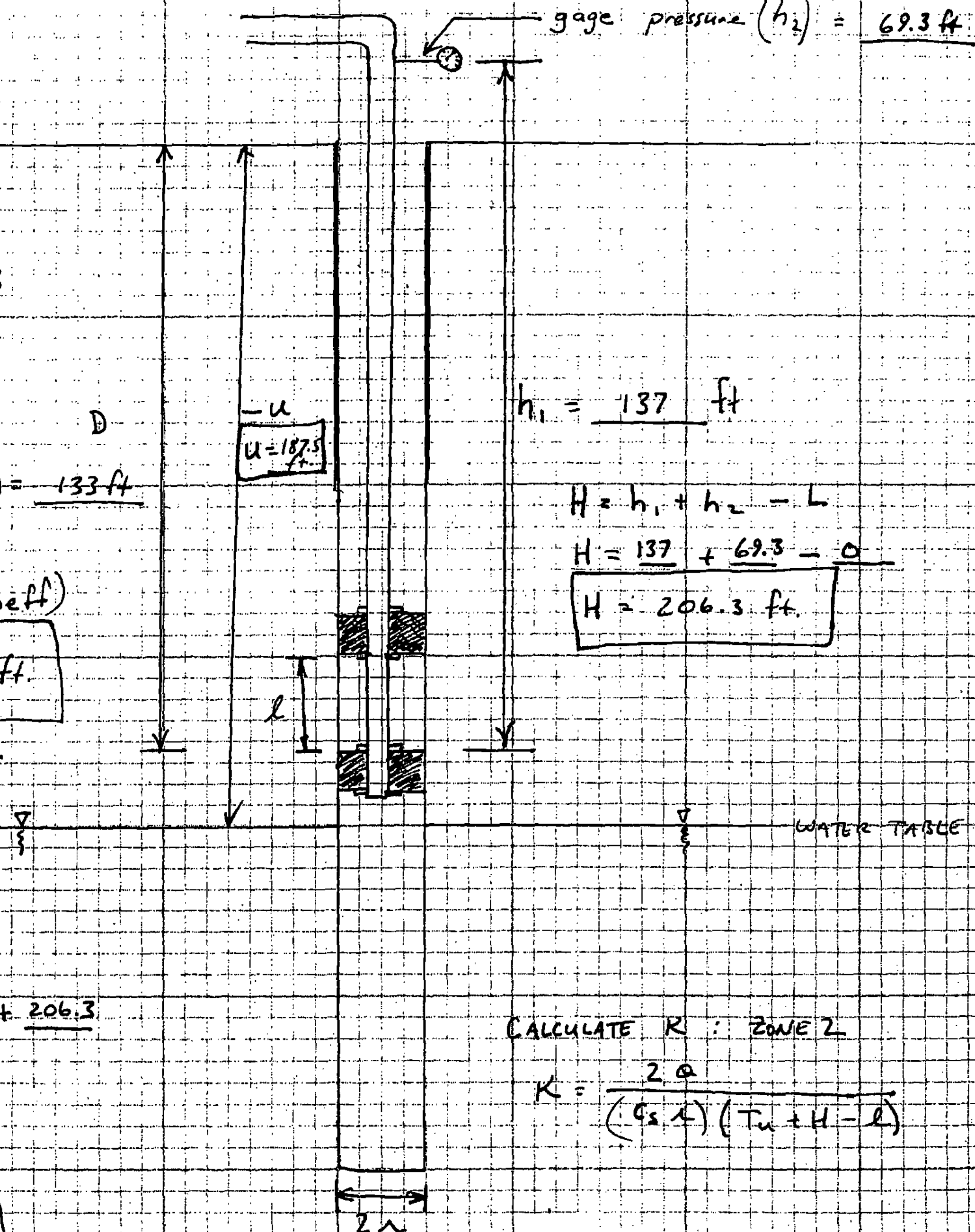
JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky REVIEWED: ______

Borehole: 208

SHEET NO.: ______ OF ______ Depth: 121 - 133

pressure: 30 psi



C_s from figure 17-8

$\frac{\ell}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$\boxed{C_s = 100}$

Injection Pipe
Obtain L (head-loss coeff)

$\boxed{L = \frac{0}{(Q < 4 \text{ gpm})} \text{ ft}/10 \text{ ft}}$

from Pressure-loss Curve.

$H = h_1 + h_2 - L$

$H = 137 + 69.3 - 0$

$\boxed{H = 206.3 \text{ ft}}$

Obtain Tu:

$Tu = U - D + H$

$Tu = 187.5 - 133 + 206.3$

$\boxed{Tu = 260.8 \text{ ft}}$

$\boxed{Q = 0.04 \text{ gpm} \text{ (from data sheet)}}$

CALCULATE K : ZONE 2

$$K = \frac{2Q}{(C_s r)(Tu + H - \ell)}$$

$$K = \frac{2(0.04 \text{ gal/min})}{(100)(0.16 \text{ ft})(260.8 \text{ ft} + 206.3 \text{ ft} - 12 \text{ ft})}\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)$$

$$\boxed{\begin{array}{l} K = 2.1 \times 10^{-3} \text{ ft/d} \\ K = 7.5 \times 10^{-7} \text{ cm/s} \end{array}}$$

Stoller

PACKER TEST SET-UP SHEET

ZONE 2 / METHOD 2

JOB NO.:

DATE: 1-24-06

JOB NAME: Crescent Junction site

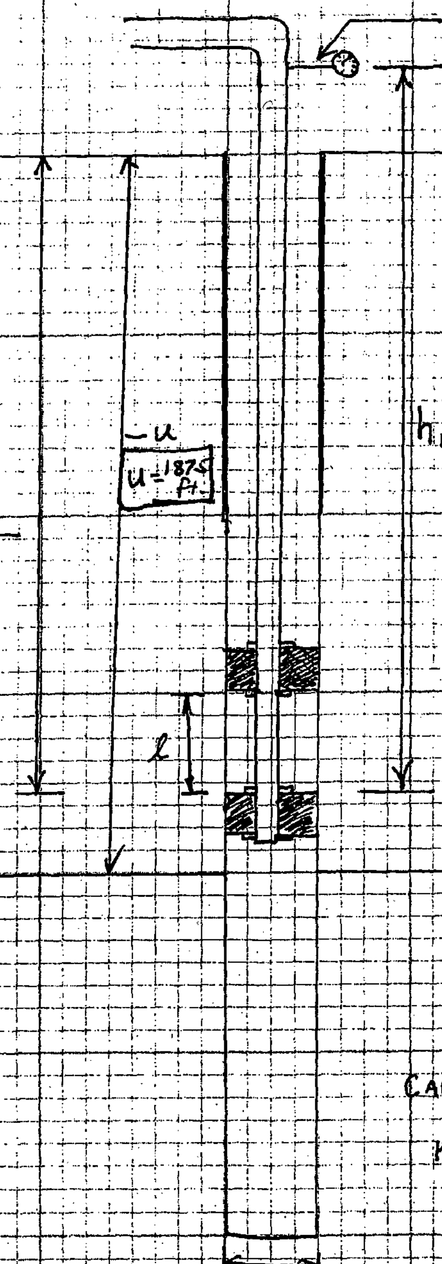
PREPARED: M. Kautsky

REVIEWED:

SHEET NO.: ______ OF ______

Borehole 208
Depth 121-133
pressure: 20 psi
(Retest)

gage pressure (h_2) = 46.2 ft



WATER TABLE

C_s from figure 17-8

$\frac{l}{r} = \frac{12\ ft}{0.16\ ft} = 75$

$\boxed{C_s = 100}$

D = 133 ft

h_1 = 137 ft

$H = h_1 + h_2 - L$

$H = 137 + 46.2 - 0$

$\boxed{H = 183.2\ ft}$

Injection Pipe
obtain L (head-loss coeff)

L = 0.0 ft / 10 ft.
(Q < 4 gpm)

from pressure-loss Curve.

Obtain Tu:

$T_u = U - D + H$

$T_u = 187.5 - 133 + 183.2$

$\boxed{T_u = 237.7}$

CALCULATE K : ZONE 2

$K = \frac{2Q}{(C_s\, r)(T_u + H - l)}$

$Q < \frac{0.01\ gal}{15\ min}$

$\boxed{Q < 6.7 \times 10^{-4}\ gal/min}$

$K < \frac{2\,(6.7 \times 10^{-4}\ gal/min)}{(100)(0.16\ ft)(237.7\ ft + 183.2\ ft - 12\ ft)} \left(\frac{1\ ft^3}{7.48\ gal}\right)\left(\frac{1440\ min}{d}\right)$

$K < 3.9 \times 10^{-5}\ ft/d$

$K < 1.4 \times 10^{-8}\ cm/s$

Stoller

PACKER TEST SET-UP SHEET

ZONE 2 / METHOD 2

JOB NO.: ________ DATE: 1-24-06

JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky REVIEWED: ________

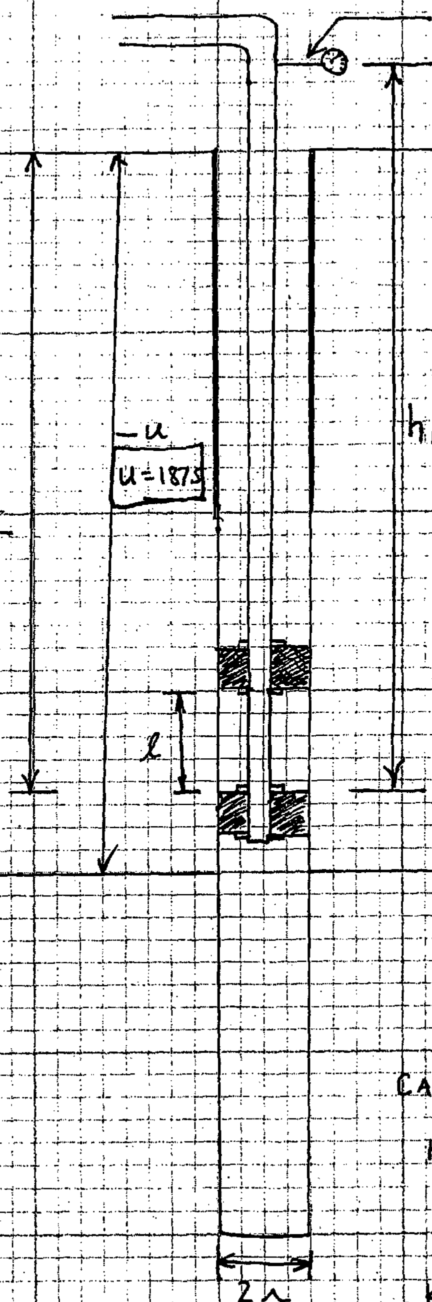
SHEET NO.: ______ OF ______

Borehole 208

Depth 121-133 ft

Pressure (h_2): 10 psi (23.1 ft) (Retest)

gage pressure (h_2) = 23.1 ft



h_1 = 137 ft

C_s from figure 17-8

$\frac{\ell}{r} = \frac{12\ ft}{0.16\ ft} = \boxed{75}$

$\boxed{C_s = 100}$

$H = h_1 + h_2 - L$

$H = \underline{137} + \underline{23.1} - \underline{0}$

$\boxed{H = 160.1}$

Injection Pipe
Obtain L (head-loss coeff)

$\boxed{L = \frac{\emptyset}{(Q < 4\ gpm)}\ ft/10\ ft}$

from pressure-loss curve.

Obtain Tu:

$T_u = U - D + H$

$T_u = \underline{187.5} - \underline{133.0} + \underline{160.1}$

$\boxed{T_u = 205.6\ ft}$

CALCULATE K : ZONE 2

$K = \frac{2Q}{(C_s\, r)(T_u + H - \ell)}$

$Q < \frac{0.01\ gal}{30\ min}$

$\boxed{Q < 3.3 \times 10^{-4}\ gal/min}$

$K < \frac{2\,(3.3 \times 10^{-4}\ gal/min)}{100\,(0.16)\,(205.6 + 160.1 - 12)}$

$K < 1.2 \times 10^{-7}\ gal/min/ft^2$

$K < \left(\frac{1.2 \times 10^{-7}\ gal}{min \cdot ft^2}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)\left(\frac{1440\ min}{d}\right) = \boxed{2.27 \times 10^{-5}\ ft/d}$

$\boxed{K < 8.0 \times 10^{-9}\ cm/s}$

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct characterization Date: 01/15/06

Field Representative: R. Rupp Borehole No. #0208 Total Depth: 300'

Depth to Water (TOC): 187.5 ft Borehole Cleaned? Yes ✓ No____ Date: 1/15/06

Test Interval (BGL): from 282' to 294 ft. Swivel/Elbow Height (AGL) 3.0 ft.

Conductor Pipe, Type and Size: 1-inch ID Thin WALL STEEL Tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
0935	5 psi	39405.45	
0940	5 psi	39405.60	0.03 gpm
0945	5	39405.75	0.03
0950	5	39405.95	0.04
0955	5	39406.20	0.05
1000	5	39406.40	0.04
1005	5	39406.60	0.04
1010	5	39406.75	0.03
1015	5	39406.90	0.03
1020	5	39407.05	0.03 gpm
1025	10 psi	39407.35	0.06
1030	10	39407.55	0.04
1035	10	39407.75	0.04
1040	10	39407.90	0.03
1045	10	39408.10	0.04
1050	10	39408.25	0.03
1055	10	39408.40	0.03
1100	10	39408.55	0.03 gpm

Stoller

established 1959

Packer-Test Record

Project Name: Moab - Crescent Jct Characterization Date: 01/15/06

Field Representative: R. Rupp Borehole No. #0208 Total Depth: 300 ft.

Depth to Water (TOC): 187.5 ft Borehole Cleaned? Yes ✓ No____ Date: 01/15/06

Test Interval (BGL): from 282' to 294 ft. Swivel/Elbow Height (AGL) 3.0 ft.

Conductor Pipe, Type and Size: 1-inch ID thin wall steel tubing

Time	Gauge Pressure	Flow Meter Reading	Flow Rate
1105	20 psi	39408.80	0.05 gpm
1110	20	39408.80	0
1115	20	39408.80	0
1120	20	39408.80	0
1125	20	39408.80	0
1130	20	39408.80	0
1135	20	39408.80	0 gpm
1140	10 psi	39408.80	0
1145	10	39408.80	0
1150	10	39408.80	0
1155	10	39408.80	0
1200	10	39408.80	0
1205	10	39408.80	0
1210	10	39408.80	0
1215	10	39408.80	0 gpm
1220	5 psi	39408.85	0.01 gpm
1225	5	39408.95	0.02
1230	5	39409.05	0.02
1235	5	39409.15	0.02
1240	5	39409.25	0.02
1245	5	39409.30	0.01
1250	5	39409.35	0.01

1-25-06
Borehole 208
Depth 282-294
All pressures (5, 10, 20 ps

$T_u = 75 - 65 + 125.1 = 135.1$ feet

$$X = \frac{125.1}{135.1}(100) = 92.6\% \quad \textit{also} \quad \frac{T_u}{\ell} = \frac{135.1}{10} = 13.5$$

The test section is located in zone 2 (figure 17-6). To determine the saturated conductivity coefficient, C_s, from figure 17-8:

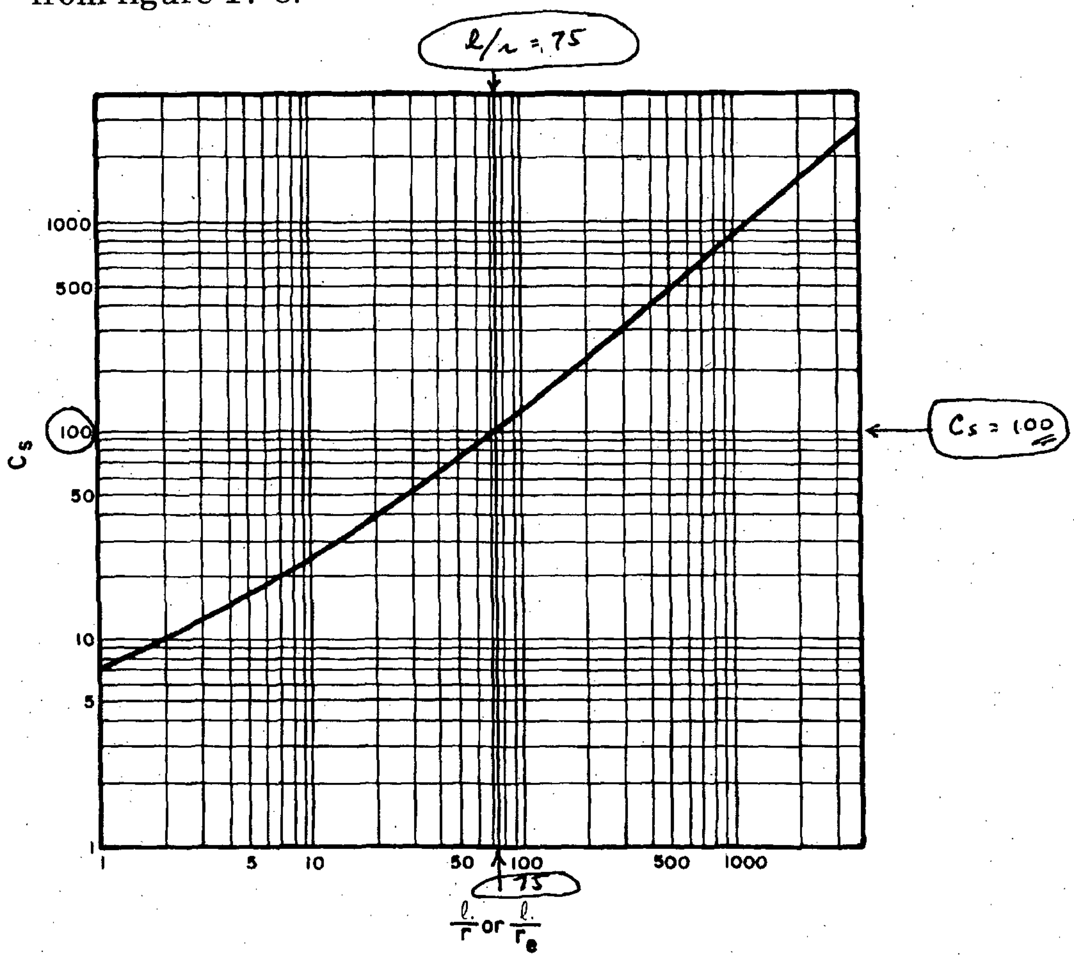


Figure 17-8.—Conductivity coefficients for semispherical flow in saturated materials through partially penetrating cylindrical test wells.

$T_u = 75 - 65 + 125.1 = 135.1$ feet

$$X = \frac{125.1}{135.1}(100) = 92.6\% \quad \textit{also} \quad \frac{T_u}{\ell} = \frac{135.1}{10} = 13.5$$

The test section is located in zone 2 (figure 17-6). To determine the saturated conductivity coefficient, C_s, from figure 17-8:

Borehole 208
Depth: 282-294 ft
Pressure: 5 psi
1-25-06

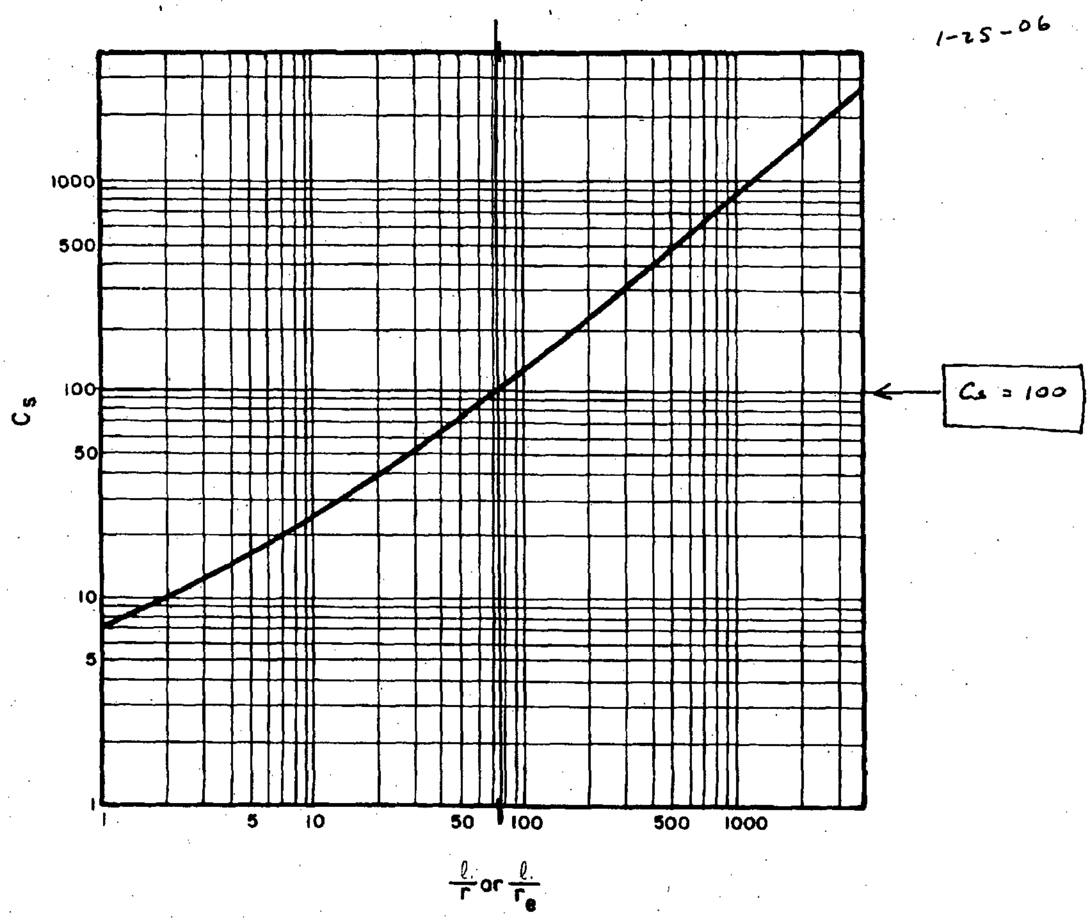
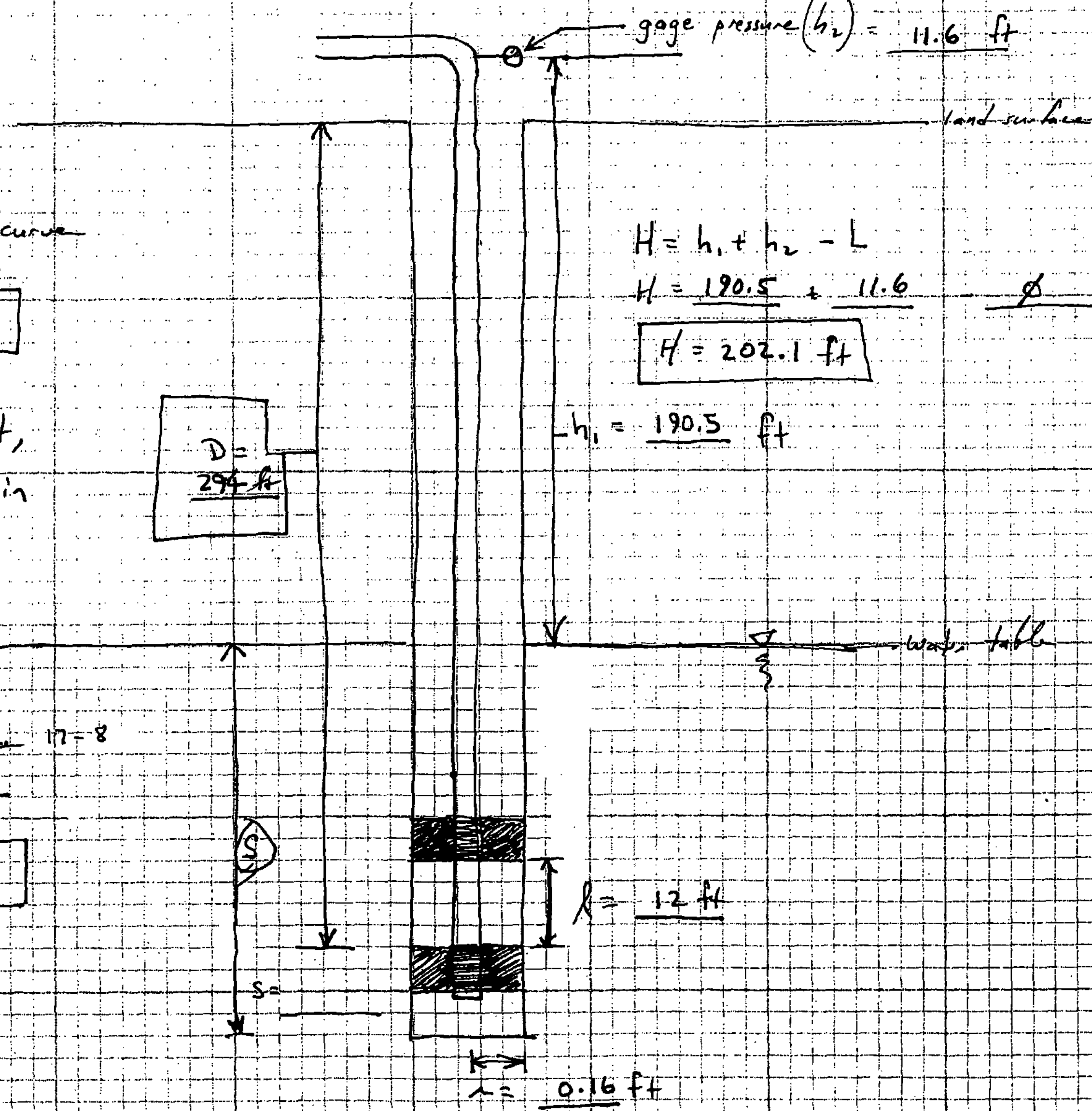


Figure 17-8.—Conductivity coefficients for semispherical flow in saturated materials through partially penetrating cylindrical test wells.

Stoller

For Straddle Packer tests below water table
Zone 3 ; Method 2 USBR

JOB NO.:
DATE: 1-25-06
JOB NAME: Crescent Junction Site
PREPARED: M. Kautsky
REVIEWED:
SHEET NO.: OF
Borehole 208
Depth 282-294
Pressure : 5 psi



Obtain L from pressure-loss curve if Q > 4 gpm

$L = \boxed{\emptyset}$

$\therefore Q < 4$ gpm

$\bar{Q}$ from data sheet,

$\bar{Q}$ = 0.03 gal/min

$H = h_1 + h_2 - L$

$H = 190.5 + 11.6 - \emptyset$

$\boxed{H = 202.1 \text{ ft}}$

C_s from figure 17-8

$\frac{l}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s \, r \, H} \; ;$$

$$K = \frac{\left(0.03 \frac{\text{gal}}{\text{min}}\right)\left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{100 \, (0.16 \text{ ft}) \, (202.1 \text{ ft})}$$

$\boxed{K = 1.8 \times 10^{-3} \text{ ft/d} \qquad K = 6.3 \times 10^{-7} \text{ cm/s}}$

Stoller

For Straddle Packer tests below water table
Zone 3 ; Method 2 USBR

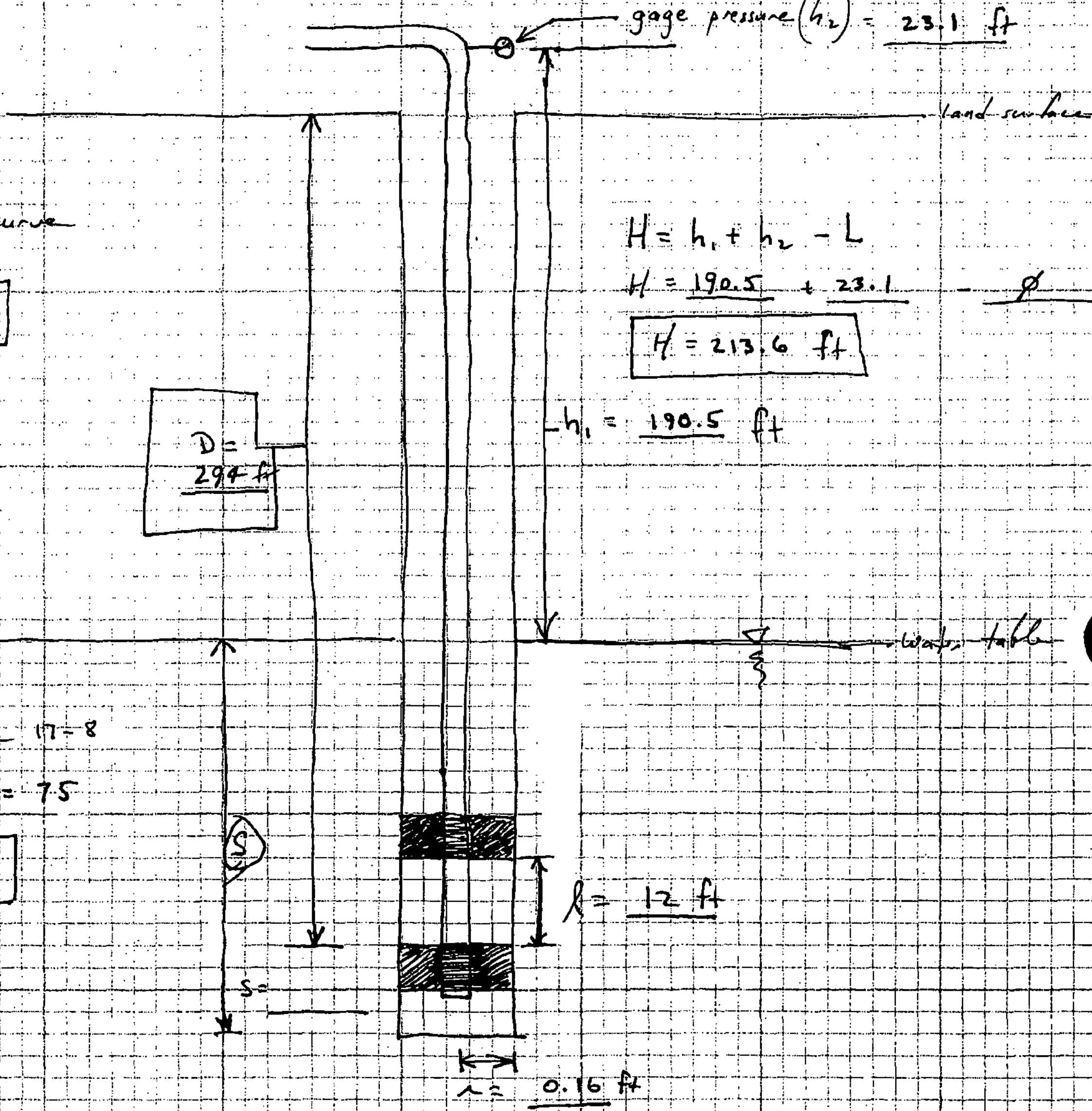
JOB NO.: ______ DATE: 1-25-06

JOB NAME: Crescent Junction site

PREPARED: M. Kautsky REVIEWED: ______

SHEET NO.: ______ OF ______

Borehole 208
Depth 282 - 294 ft
Pressure : 10 psi



Obtain L from pressure-loss curve if Q > 4 gpm

$L = \boxed{\phi}$ (Q < 4 gpm)

$\bar{Q}$ = 0.03 gal/min per data sheet

$H = h_1 + h_2 - L$

$H = 190.5 + 23.1 - \phi$

$\boxed{H = 213.6 \text{ ft}}$

C_s from figure 17-8

$\frac{\ell}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s \, r \, H}$$

$$K = \frac{0.03 \frac{\text{gal}}{\text{min}} \left(\frac{1440 \text{ min}}{\text{d}}\right)\left(\frac{\text{ft}^3}{7.48 \text{ gal}}\right)}{(100)\,(0.16 \text{ ft})\,(213.6 \text{ ft})} = \boxed{\begin{array}{c} 1.7 \times 10^{-3} \text{ ft/d} \\ 6.0 \times 10^{-7} \text{ cm/s} \end{array}}$$

Stoller

For Straddle Packer Tests below water table
Zone 3 ; Method 2 USBR

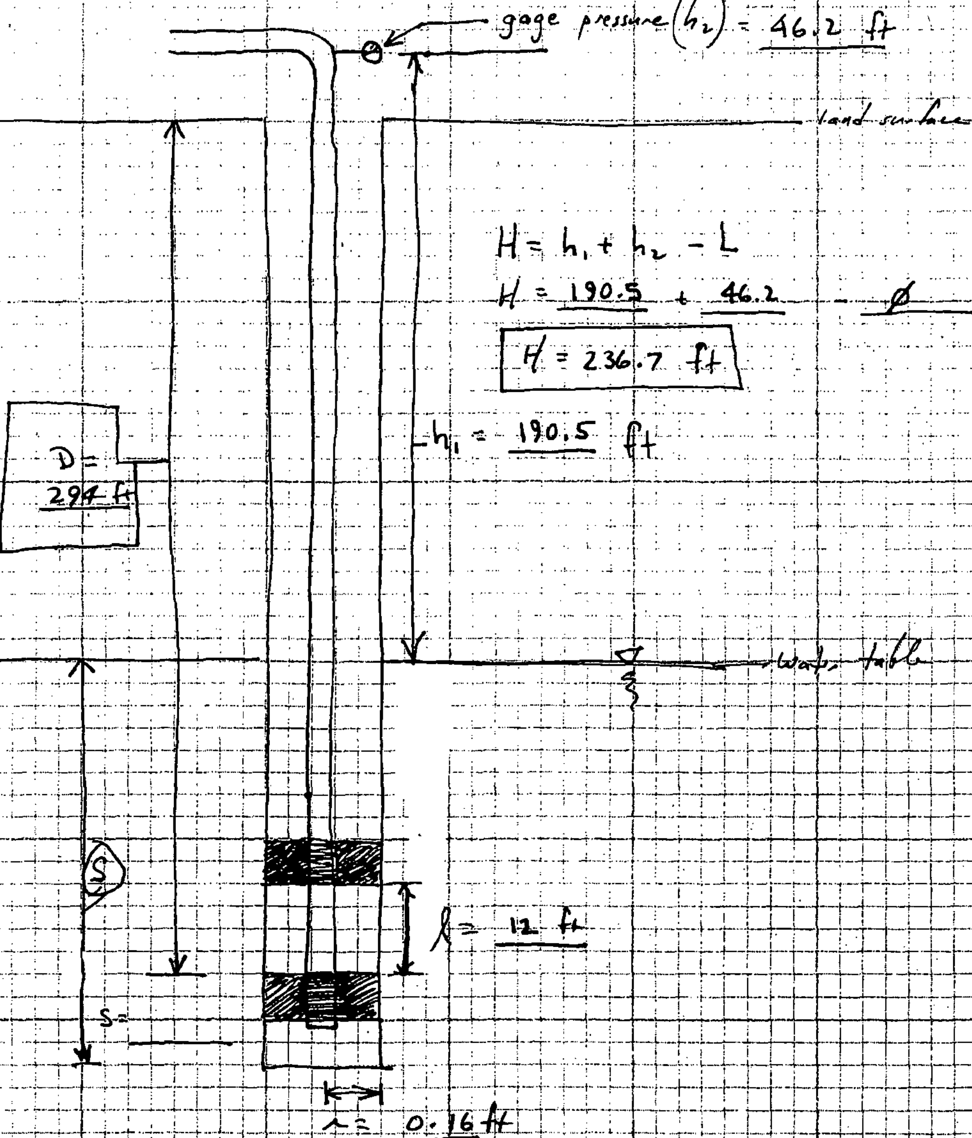
JOB NO.: ______ DATE: 1-25-06

JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky REVIEWED: ______

Borehole : 208
Depth : 282-294
Pressure : 20 psi

SHEET NO.: ______ OF ______



Obtain L from pressure-loss curve if Q > 4 gpm

$L = \boxed{\emptyset}$

(Q < 4 gpm)

$H = h_1 + h_2 - L$

$H = 190.5 + 46.2 - \emptyset$

$\boxed{H = 236.7 \text{ ft}}$

Q < 0.01 gal/30 min

$Q < 3.33 \times 10^{-4}$ gal/min
per data sheet

C_s from figure 17-8

$\frac{l}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s \, r \, H}$$

$$K < \frac{(3.33 \times 10^{-4} \text{ gal/min}) \left(\frac{1440 \text{ min}}{d}\right) \left(\frac{ft^3}{7.48 \text{ gal}}\right)}{(100)\,(0.16 \text{ ft})\,(236.7 \text{ ft})} = 1.7 \times 10^{-5} \text{ ft/d}$$

$$\boxed{K < 1.7 \times 10^{-5} \text{ ft/d} \; ; \; K < 6.0 \times 10^{-9} \text{ cm/s}}$$

Stoller

JOB NO.:

DATE: 1-25-06

JOB NAME: Crescent Junction Site

PREPARED: M. Kautsky

REVIEWED:

SHEET NO.: ______ OF ______

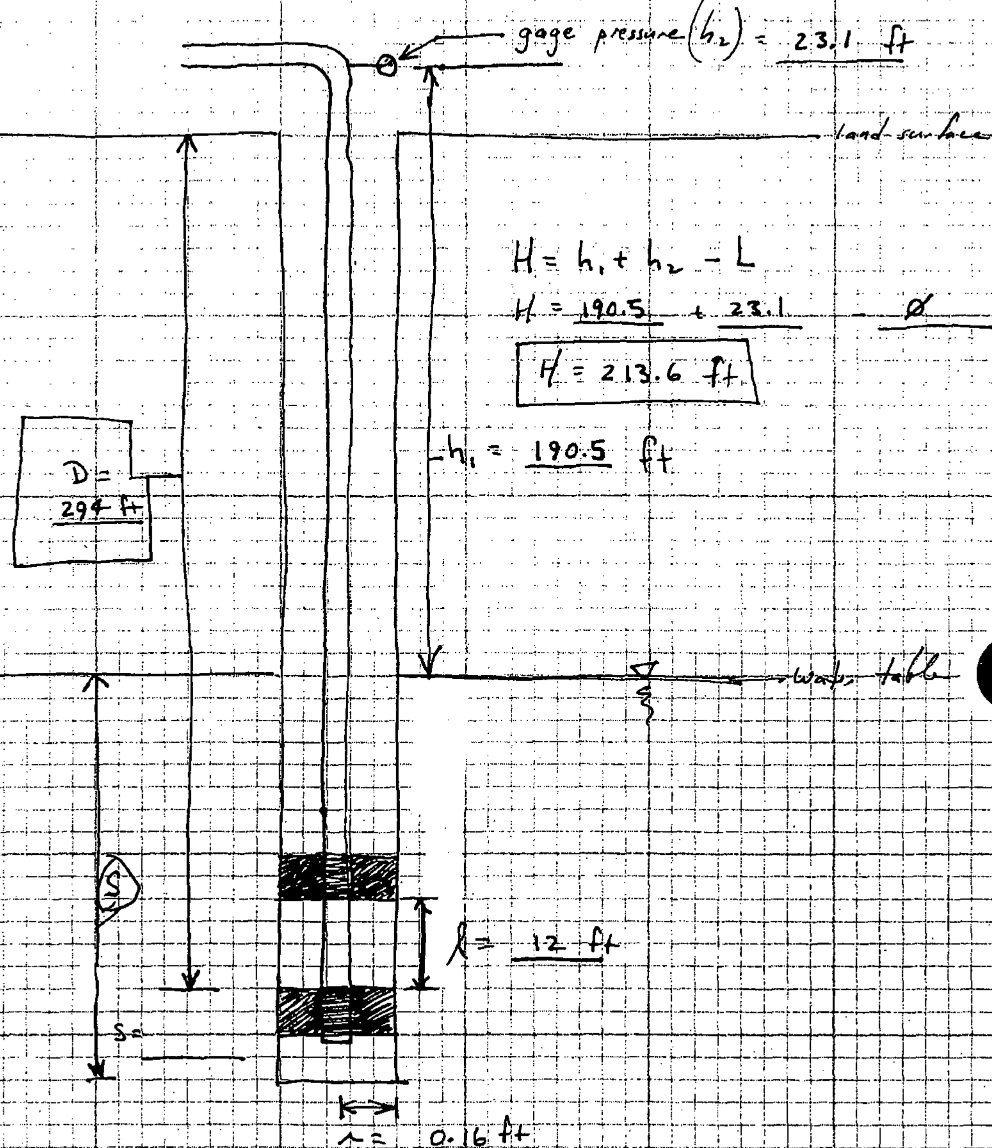
For Straddle Packer Tests below water table

Zone 3 ; Method 2 USBR

Borehole 208

Depth: 282-294

pressure: 10 psi retest



Obtain L from pressure-loss curve if Q > 4 gpm

$L = \boxed{\emptyset}$

Q < 4 gpm

$H = h_1 + h_2 - L$

$H = 190.5 + 23.1 - \emptyset$

$\boxed{H = 213.6 \text{ ft}}$

$Q < \frac{0.01 \text{ gal}}{35 \text{ min}}$

$Q < 2.86 \times 10^{-4}$ gal/min

(per data sheet)

C_s from figure 17-8

$\frac{l}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}} = 75$

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s\, r\, H}$$

$$K < \frac{(2.86 \times 10^{-4} \text{ gal/min}) \left(\frac{1440 \text{ min}}{d}\right) \left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right)}{(100)\,(0.16 \text{ ft})\,(213.6 \text{ ft})}$$

$$\boxed{K < 1.6 \times 10^{-5} \text{ ft/d} \;;\; K < 5.7 \times 10^{-9} \text{ cm/s}}$$

Stoller

For Straddle Packer Tests below water table
zone 3 ; Method 2 USBR

JOB NO.: ______ DATE: 1-25-06

JOB NAME: Crescent Junction site

PREPARED: M. Koutsky REVIEWED: ______

SHEET NO.: ______ OF ______

Borehole 208
Depth: 282-294
pressure: 5 psi refeet

Obtain L from pressure-loss curve if Q > 4 gpm

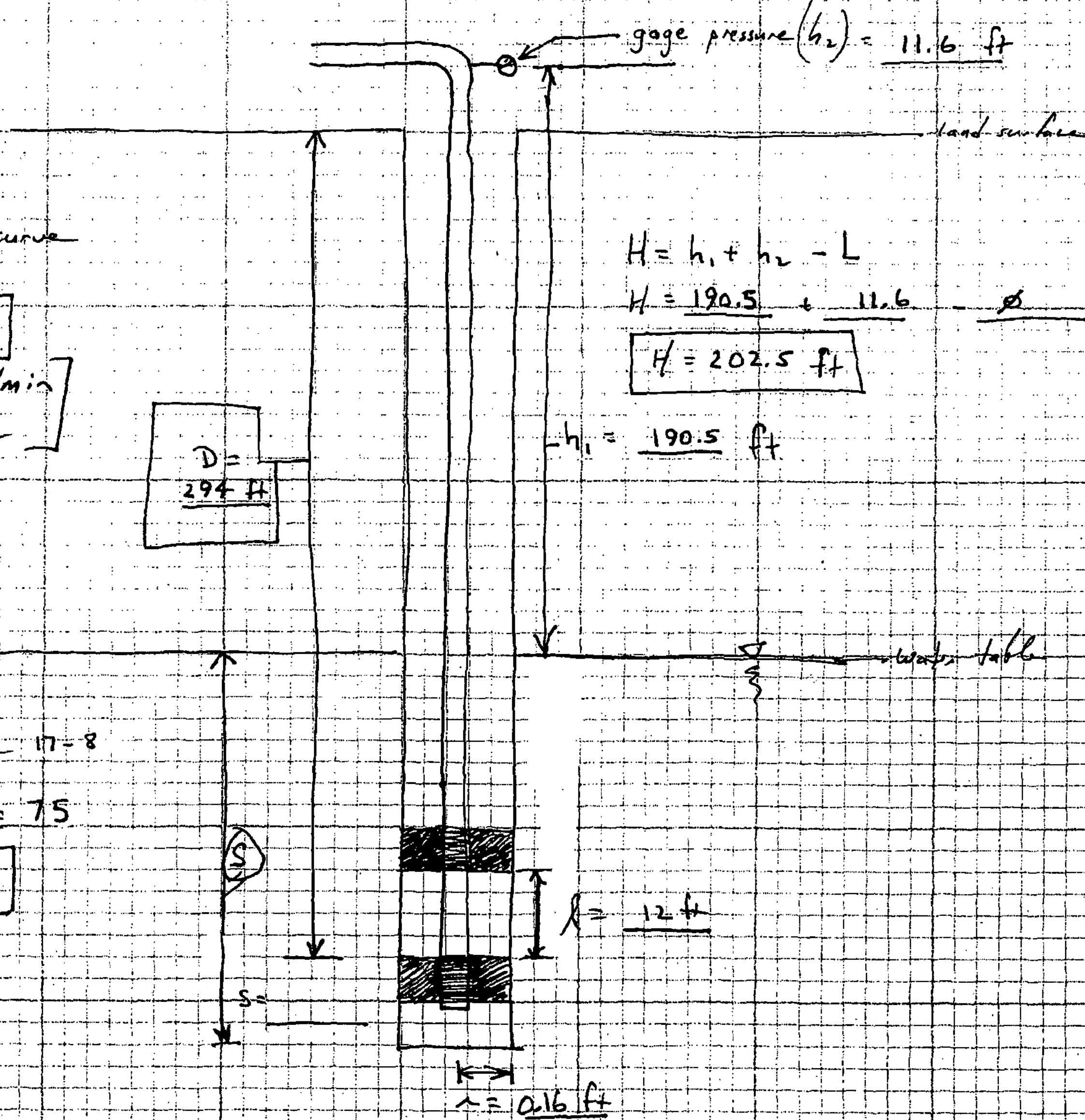
L = $\boxed{0}$

[$\bar{Q}$ = 0.01 gal/min from data sheet]

$H = h_1 + h_2 - L$

$H = \underline{190.5} + \underline{11.6} - \underline{\varnothing}$

$\boxed{H = 202.5 \text{ ft}}$



C_s from figure 17-8

$\frac{\ell}{r} = \frac{12 \text{ ft}}{0.16 \text{ ft}}$ 75

$C_s = \boxed{100}$

$$K = \frac{Q}{C_s \, r \, H}$$

$$K = \frac{\left(0.01 \frac{gal}{min}\right)\left(\frac{1440 \text{ min}}{d}\right)\left(\frac{ft^3}{7.48 \text{ gal}}\right)}{(100)(0.16 \text{ ft})(202.5 \text{ ft})}$$

$\boxed{K = 6.0 \times 10^{-4} \text{ ft/d} \; ; \; K = 2.1 \times 10^{-7} \text{ cm/s}}$

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-04-2006-2-03-00 **Discipline:** Hydrologic Properties **No. of Sheets:** 8
Doc. No.: X0149600

Location: Attachment 3, Appendix D

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site, Utah

Feature: Hydrologic Characterization – Ground Water Pumping Records

Sources of Data:

Field records of ground water pumping (copies furnished in Appendix A)

Sources of Formulae and References:

DOE (U.S. Department of Energy) 2005. *Work Plan for Characterization of the Crescent Junction, Utah, Disposal Site*, DOE-EM/GJ912-2005.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: 5-31-07
Name Date

Checked by: Dave Peterson 5/31/07
Name Date
31 May 07
Name Date

Approved by: 5/31/07
Name Date

Craig Goodknight 31 May 07
Name Date
5/31/07
Name Date

No text for this page

Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified a 2,300-acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for a final disposal cell for the Moab uranium mill tailings. The proposed disposal cell would cover approximately 250 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction disposal site is being evaluated from several technical aspects, including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation is to impart the volume of ground water pumped from the Mancos Shale during the investigation of subsurface conditions at the Crescent Junction Disposal Site.

This calculation will be incorporated into Attachment 3 (Hydrology) of the Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site, and summarized in the appropriate sections of the Remedial Action Selection report for the Moab Site.

DOE (2005; p. 3–1) stated, "There are likely discontinuous saturated units within the Mancos Shale, but they are not anticipated to have significant lateral extent or interconnection, or contain usable ground water." During site characterization, a total of ten coreholes were drilled to a depth of 300 feet at the locations shown in Figure 1, and ground water was encountered in seven of them. In five of the coreholes (0201, 0202, 0203, 0204, 0208) the ground water was found to be highly saline, possibly exceeding the salinity levels found in seawater (total dissolved solids [TDS] approximately 34,500 milligrams per liter [mg/L]). Based on its occurrence and composition, the water intersected by these coreholes appears to be *connate water,* or in other words, water that has been trapped in the pores of the rock since the rock (Mancos Shale) was formed.

In the two other coreholes containing ground water at the site (0205 and 0210), water-level recovery rates are very slow; consequently, ground water has not been pumped systematically from either location. One water sample collected from corehole 0210 was found to be very saline (TDS = 37,000 mg/L). Ground water from corehole 0205 has not been sampled but is also expected to be saline.

Pumping began in October 2005 at corehole 0208 and was followed shortly thereafter with pumping from the remaining coreholes. This calculation documents the volume of ground water extracted between October 31, 2005 and March 15, 2006.

Method of Solution:

Submersible pumps, which were powered with a portable generator, were installed in coreholes 0201, 0202, 0203, 0204, and 0208 shortly after the coreholes were drilled. Locations of the coreholes are shown in Figure 1. Discharge from each corehole was piped through a flow meter prior to being released at the land surface. Flow-meter readings were taken each time a corehole was evacuated. The incremental flow-meter readings were entered into an Excel spreadsheet, and the cumulative flows were determined by summation.

Assumptions:

- Per the assumption stated in the work plan (DOE 2005; p. 3–1), ground water at the site was anticipated to occur in discontinuous water-bearing conduits within the Mancos Shale.
- If the submersible pump is set at a fixed elevation in a formation with discontinuous water-bearing conduits, systematic pumping through time will gradually yield lesser volumes of ground water.

Figure 1. Map of Corehole Locations at the Crescent Junction Site

Calculation:

The objective of ground water pumping at the Crescent Junction Site has been to test the hypothesis that the ground water occurs in discontinuous water-bearing conduits within the Mancos Shale. It was reasoned that systematic pumping of the ground water would gradually deplete the source of connate water entering the coreholes if the ground water occurs in discontinuous water-bearing conduits.

Figures 2 through 6 present the incremental and cumulative pumping results to date for each corehole. As of March 17, 2006, a total of approximately 8,270 gallons had been removed from the five coreholes that contain connate water. The extracted amounts range from approximately 569 gallons from corehole 0204 to approximately 3,395 gallons from corehole 0203.

Analysis of the pumping curves in Figures 2 through 6 and the pumping data in Appendix A show that pumping first began in corehole 0208 and was followed with pumping from corehole 0203. A hiatus occurred from December 2, 2005, to mid-January 2006, during which time no pumping occurred. During the second week of January 2006, pumps were installed in coreholes 0201, 0202, and 0204, and regular systematic pumping began at all five coreholes.

A qualitative analysis presented in Figures 2 through 6 shows that the incremental pumping volumes remained steady and the slope of the cumulative pumping curves remained unchanged at coreholes 0201, 0203, 0204, and 0208. This observation contrasts with an apparent decrease in incremental pumping volumes at corehole 0202 and a reduction in the slope of the cumulative pumping curve, which began at the end of January 2006. The qualitative results may indicate that the source of connate water to corehole 0202 is being depleted; however, the same cannot be said for coreholes 0201, 0203, 0204, and 0208.

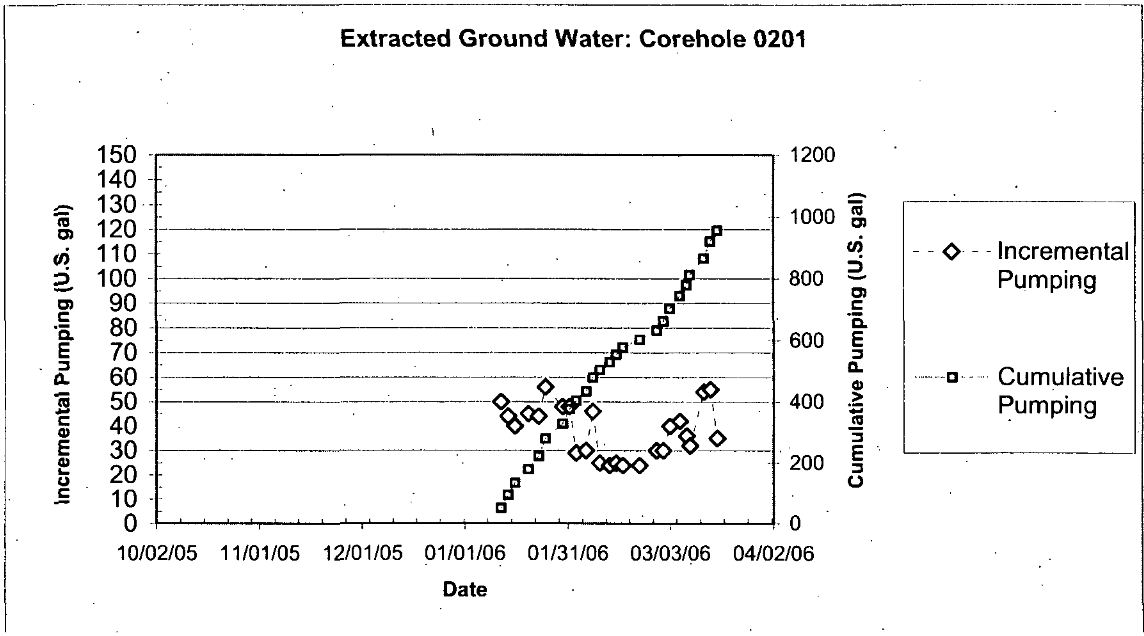


Figure 2. Ground Water Withdrawal from Corehole 0201, Crescent Junction, Utah, Disposal Site

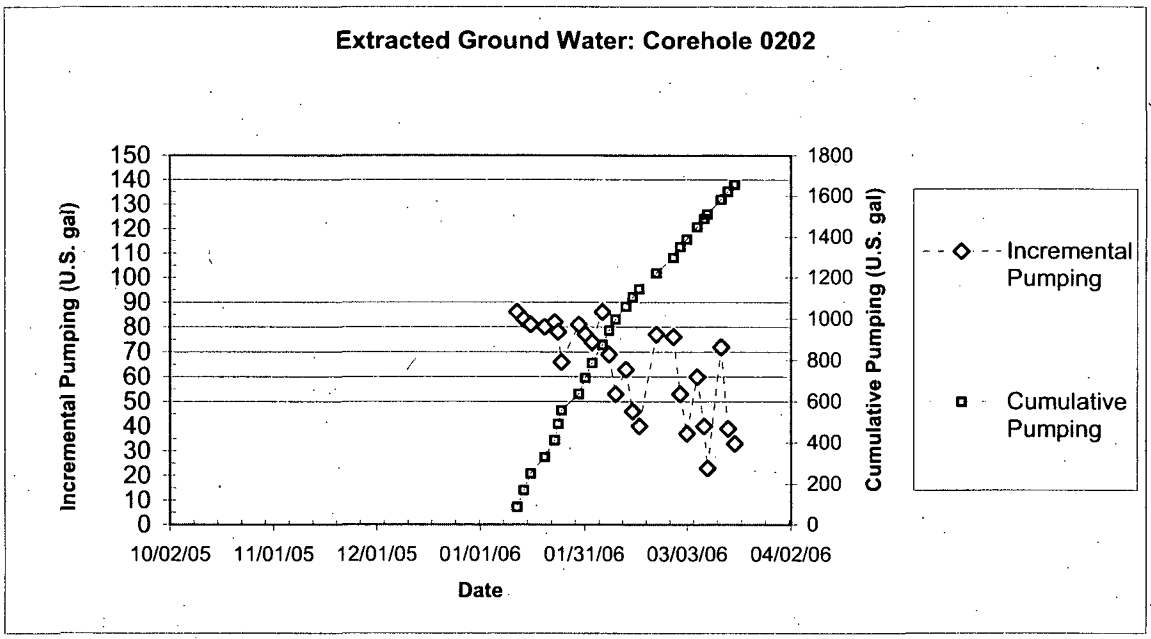


Figure 3. Ground Water Withdrawal from Corehole 0202, Crescent Junction, Utah, Disposal Site

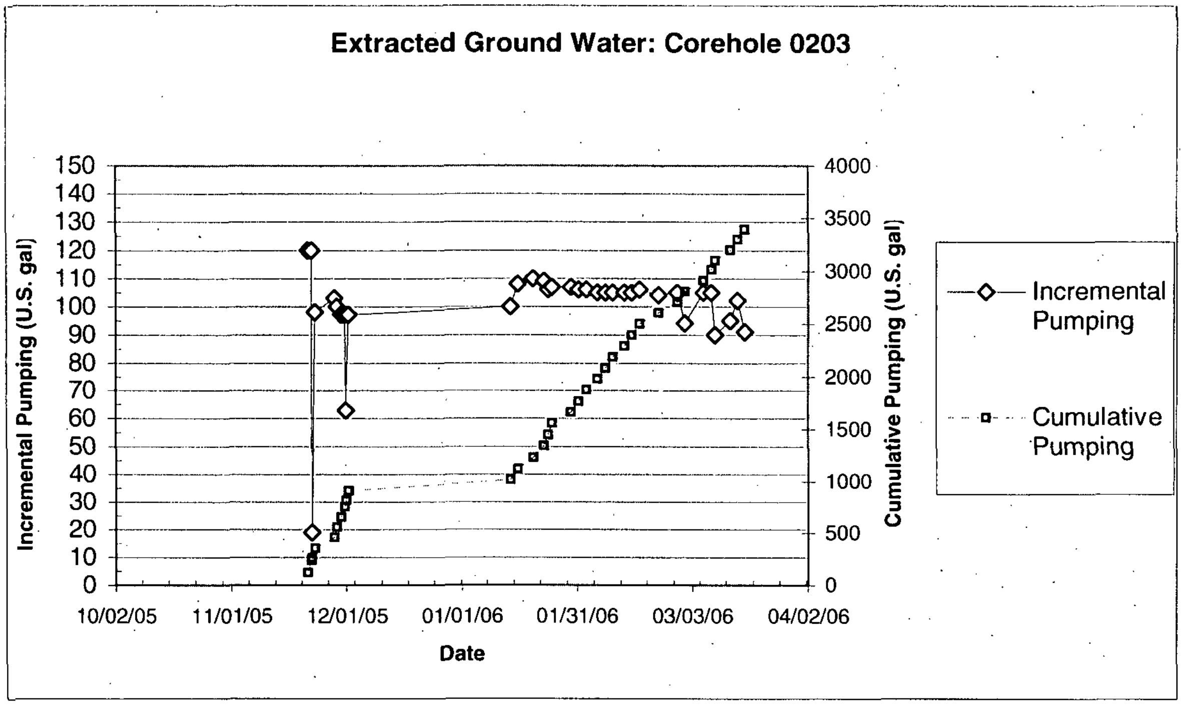


Figure 4. Ground Water Withdrawal from Corehole 0203, Crescent Junction, Utah, Disposal Site

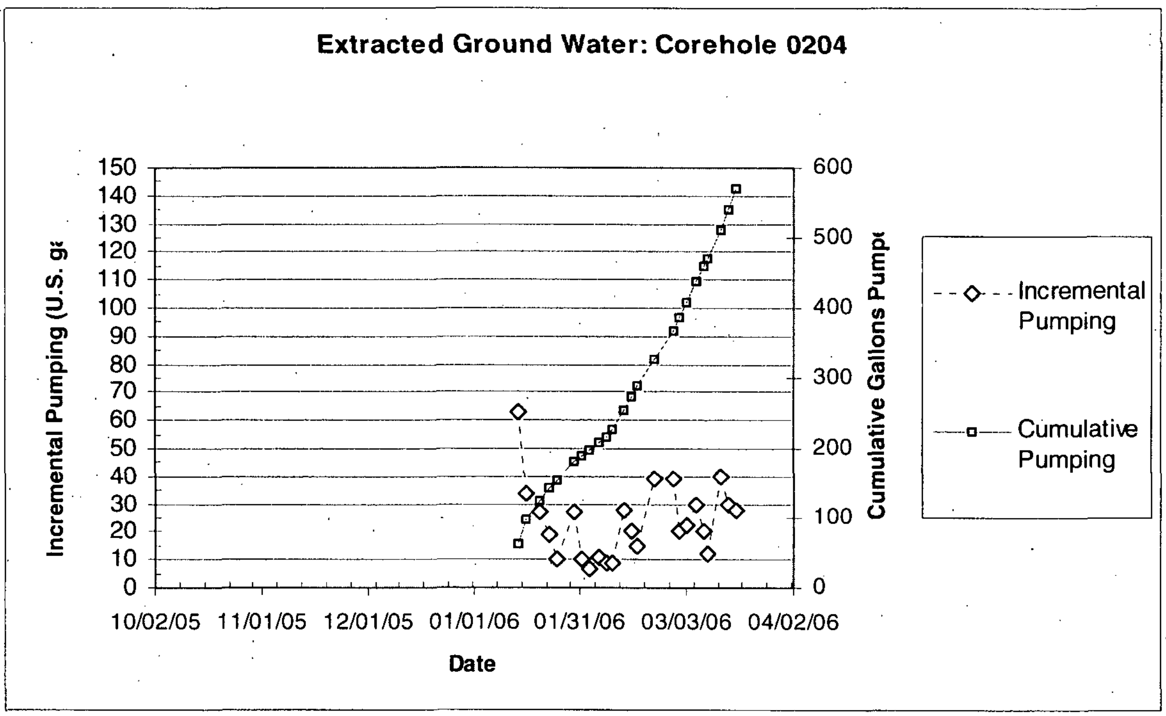


Figure 5. Ground Water Withdrawal from Corehole 0204, Crescent Junction, Utah, Disposal Site

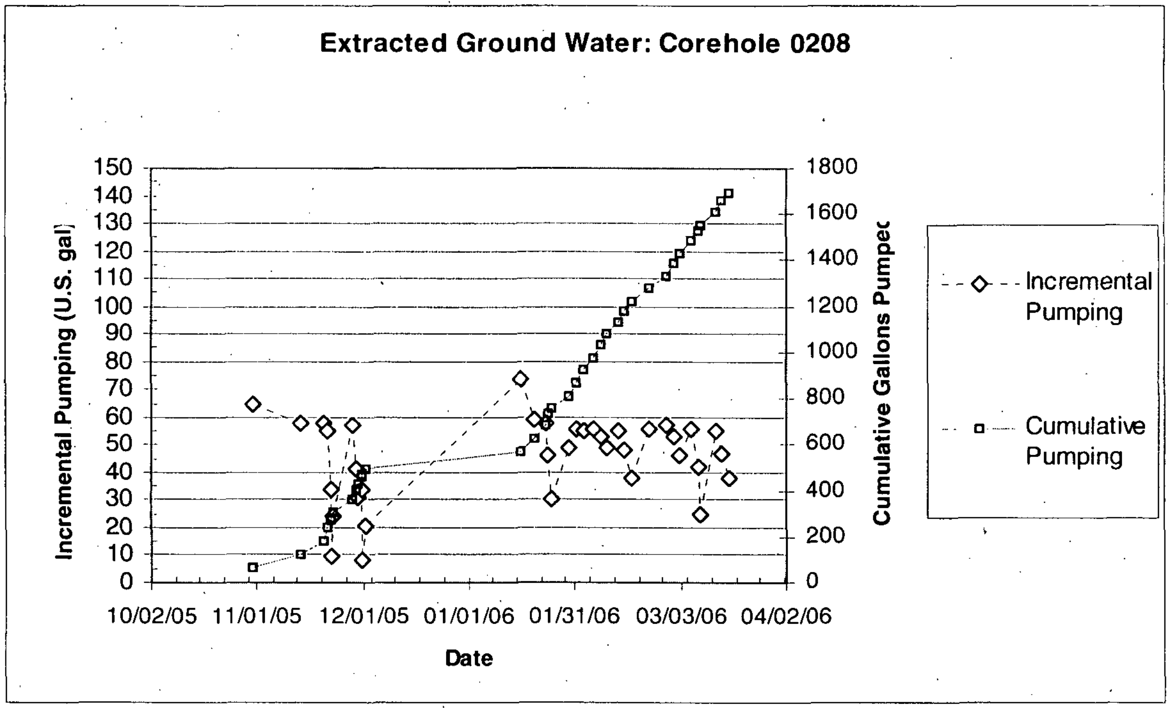


Figure 6. Ground Water Withdrawal from Corehole 0208, Crescent Junction, Utah, Disposal Site

Discussion:

N/A

Conclusion and Recommendations:

The purpose of pumping connate water from the coreholes at the Crescent Junction Disposal Site has been to test the concept that the water occurs in discontinuous and isolated zones or porous compartments. Persistent pumping from zones containing limited volumes of trapped water should eventually yield decreased volumes of produced water and a flattening of the cumulative recovery curve. Such behavior would typify incipient source depletion.

As of March 17, 2006, the pumping data have shown that the incremental pumping volumes have declined, and the cumulative recovery curve has begun to flatten at corehole 0202. Coreholes 0201, 0203, 0204, and 0208 have continued to yield water at relatively constant rates, signifying that the connate water intercepted by these coreholes is stored in larger compartments, which will require more pumping to deplete. The continued pumping from these larger compartments is deemed unnecessary because the concept that the connate water is trapped in porous zones with limited volume was already demonstrated at corehole 0202. In addition, coreholes 0206, 0207, and 0209 have never contained any water since the holes were drilled, which further supports the position that the connate water is present in discontinuous pockets.

Other important aspects of the ground water hydrology that should be considered are the static water levels, the ground water chemistry, and the effect that repeated pumping has had on them. Therefore, we recommend that systematic pumping from the coreholes should be permanently discontinued to allow static water levels to recover and to collect additional baseline water samples.

Computer Source:

Microsoft Excel

End of current text

Appendix A

Field Records of Ground Water Pumping

Well #	Date	Gallons Purged	Cumulative Purged
201	01/12/06	50	50
	01/14/06	44	94
	01/16/06	40	134
	01/20/06	45	179
	01/23/06	44	223
	01/25/06	56	279
	01/30/06	48	327
	02/01/06	48	375
	02/03/06	29	404
	02/06/06	30	434
	02/08/06	46	480
	02/10/06	25	505
	02/13/06	24	529
	02/15/06	25	554
	02/17/06	24	578
	02/22/06	24	602
	02/27/06	30	632
	03/01/06	30	662
	03/03/06	40	702
	03/06/06	42	744
	03/08/06	36	780
	03/09/06	32	812
	03/13/06	54	866
	03/15/06	55	921
	03/17/06	35	956

Well #	Date	Gallons Purged	Cumulative Purged
202	01/12/06	86	86
	01/14/06	83	169
	01/16/06	81	250
	01/20/06	80	330
	01/23/06	82	412
	01/24/06	78	490
	01/25/06	66	556
	01/30/06	81	637
	02/01/06	77	714
	02/03/06	74	788
	02/06/06	86	874
	02/08/06	69	943
	02/10/06	53	996
	02/13/06	63	1059
	02/15/06	46	1105
	02/17/06	40	1145
	02/22/06	77	1222
	02/27/06	76	1298
	03/01/06	53	1351
	03/03/06	37	1388
	03/06/06	60	1448
	03/08/06	40	1488
	03/09/06	23	1511
	03/13/06	72	1583
	03/15/06	39	1622
	03/17/06	33	1655

Well #	Date	Gallons Purged	Cumulative Purged
203	11/21/05	120	120
	11/22/05	120	240
	11/22/05	19	259
	11/23/05	98	357
	11/28/05	103	460
	11/29/05	100	560
	11/30/05	97	657
	12/01/05	97	754
	12/01/05	63	817
	12/02/05	97	914
	01/14/06	100	1014
	01/16/06	108	1122
	01/20/06	110	1232
	01/23/06	109	1341
	01/24/06	106	1447
	01/25/06	107	1554
	01/30/06	107	1661
	02/01/06	106	1767
	02/03/06	106	1873
	02/06/06	105	1978
	02/08/06	105	2083
	02/10/06	105	2188
	02/13/06	105	2293
	02/15/06	105	2398
	02/17/06	106	2504
	02/22/06	104	2608
	02/27/06	105	2713
	03/01/06	94	2807
	03/06/06	105	2912
	03/08/06	105	3017
	03/09/06	90	3107
	03/13/06	95	3202
	03/15/06	102	3304
	03/17/06	91	3395

Well #	Date	Gallons Purged	Cumulative Purged
204	01/14/06	63	63
	01/16/06	34	97
	01/20/06	27	124
	01/23/06	19	143
	01/25/06	10	153
	01/30/06	27	180
	02/01/06	10	190
	02/03/06	7	197
	02/06/06	11	208
	02/08/06	9	217
	02/10/06	9	226
	02/13/06	28	254
	02/15/06	20	274
	02/17/06	15	289
	02/22/06	39	328
	02/27/06	39	367
	03/01/06	20	387
	03/03/06	22	409
	03/06/06	30	439
	03/08/06	20	459
	03/09/06	12	471
	03/13/06	40	511
	03/15/06	30	541
	03/17/06	28	569

Well #	Date	Gallons Purged	Cumulative Purged
208	10/31/05	65	65
	11/14/05	58	123
	11/20/05	57.5	180.5
	11/21/05	54.9	235.4
	11/22/05	33.4	268.8
	11/22/05	9.5	278.3
	11/23/05	24	302.3
	11/28/05	57.3	359.6
	11/29/05	41	400.6
	11/30/05	31.1	431.7
	12/01/05	33.6	465.3
	12/01/05	8.3	473.6
	12/02/05	20.8	494.4
	01/16/06	73.6	568
	01/20/06	59	627
	01/23/06	58	685
	01/24/06	46	731
	01/25/06	30	761
	01/30/06	49	810
	02/01/06	56	866
	02/03/06	55	921
	02/06/06	56	977
	02/08/06	53	1030
	02/10/06	49	1079
	02/13/06	55	1134
	02/15/06	48	1182
	02/17/06	38	1220
	02/22/06	56	1276
	02/27/06	57	1333
	03/01/06	53	1386
	03/03/06	46	1432
	03/06/06	56	1488
	03/08/06	42	1530
	03/09/06	25	1555
	03/13/06	55	1610
	03/15/06	47	1657
	03/17/06	38	1695

End of current text

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-05-2006-2-13-00 **Discipline:** Hydrology **No. of Sheets:** 10
Doc. No.: X0173300

Location: Attachment 3, Appendix E

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Hydrologic Characterization – Vertical Travel Time to Uppermost (Dakota) Aquifer

Sources of Data:

Published literature and maps within 30-mile radius of the Crescent Junction Disposal Site (see below).
Water level elevation data for Mancos Shale from SEEPro database.
Remedial Action Plan (RAP) calculations as referenced in the text.

Sources of Formulae and References:

See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: Mark Kautsky 5-31-07
Name Date

Checked by: L Cummins 5/31/07
Name Date

Dave Peterson 5/31/07
Name Date

Approved by: Kent Kuzz 5/31/07
Name Date

Name Date

D Metz 5/31/07
Name Date

No text for this page

Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified a 2,300-acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for a final disposal cell for the Moab uranium mill tailings. The proposed disposal cell would cover approximately 250 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction Disposal Site is being evaluated from several technical aspects including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation set is to estimate the vertical travel time for ground water migrating from the Crescent Junction Disposal Site through the Mancos Shale confining unit to the Dakota aquifer.

Conclusions from these data will be incorporated into the Remedial Action Selection Report of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site.

Method of Solution:

The time required for ground water to migrate from the disposal site through the Mancos Shale to the Dakota aquifer is estimated in this calculation. Figure 1 presents a cross-sectional diagram showing the geologic profile that underlies the proposed Crescent Junction disposal cell. Each of the variables required to analytically assess vertical flow are shown in Figure 1. The average linear velocity, which stems from Darcy's Law, is used to estimate the downward rate of ground water movement. Key elements of the average linear velocity calculation are presented below:

$$V = q/n_e = (-K\ dh/dz)/n_e$$

where

V = average linear velocity (L/T)
q = specific discharge (L^3/L^2T), or simply (L/T)
K = hydraulic conductivity (L/T)
dh/dz = vertical hydraulic gradient (L/L), or simply (dimensionless)
ne = effective porosity (L^3/L^3), or simply (dimensionless)
where L = length units and T = time units

Ground water levels were measured in coreholes 0201, 0202, 0203, 0204, 0205, 0208, and 0210 at the Crescent Junction Disposal Site. After the water level data were gathered, they were entered into the SEEPro database and used to plot the ground water elevations presented in Figure 2. The measured ground water levels in the Mancos Shale, which are given the symbol h_1 in Figure 1, range in elevation from 4,650 to 4,920 feet (ft) above mean sea level. The hydraulic head value of 4,920 ft is used in the calculation because it yields the shortest travel time to the Dakota aquifer.

Ground water levels from the Dakota aquifer are presented in Figure 3, which was modified after Freethey and Cordy (1991). Potentiometric surface contours were extrapolated into the area of the site, which occupies the area 38.96° north by 109.80° west. As shown on Figure 3 the elevation of the potentiometric surface of the Dakota aquifer is approximately 4,700 ft above mean sea level. In Figure 1 the potentiometric surface of the Dakota aquifer is designated with the symbol h_2.

Geological data presented in the "Surficial and Bedrock Geology of the Crescent Junction Disposal Site" calculation (RAP Attachment 2, Appendix B) shows that the vertical distance from the land surface to the top of the Dakota aquifer is approximately 2,400 ft. Because the minimum depth to water in the coreholes at the site is approximately 100 ft, the vertical flow path, which is designated by the letter ℓ, extends from the measured water surface in coreholes to the Dakota aquifer: a distance of approximately 2,300 ft. The time required for drainage to migrate from the bottom of the disposal cell to the first occurrence of ground water is neglected in this calculation.

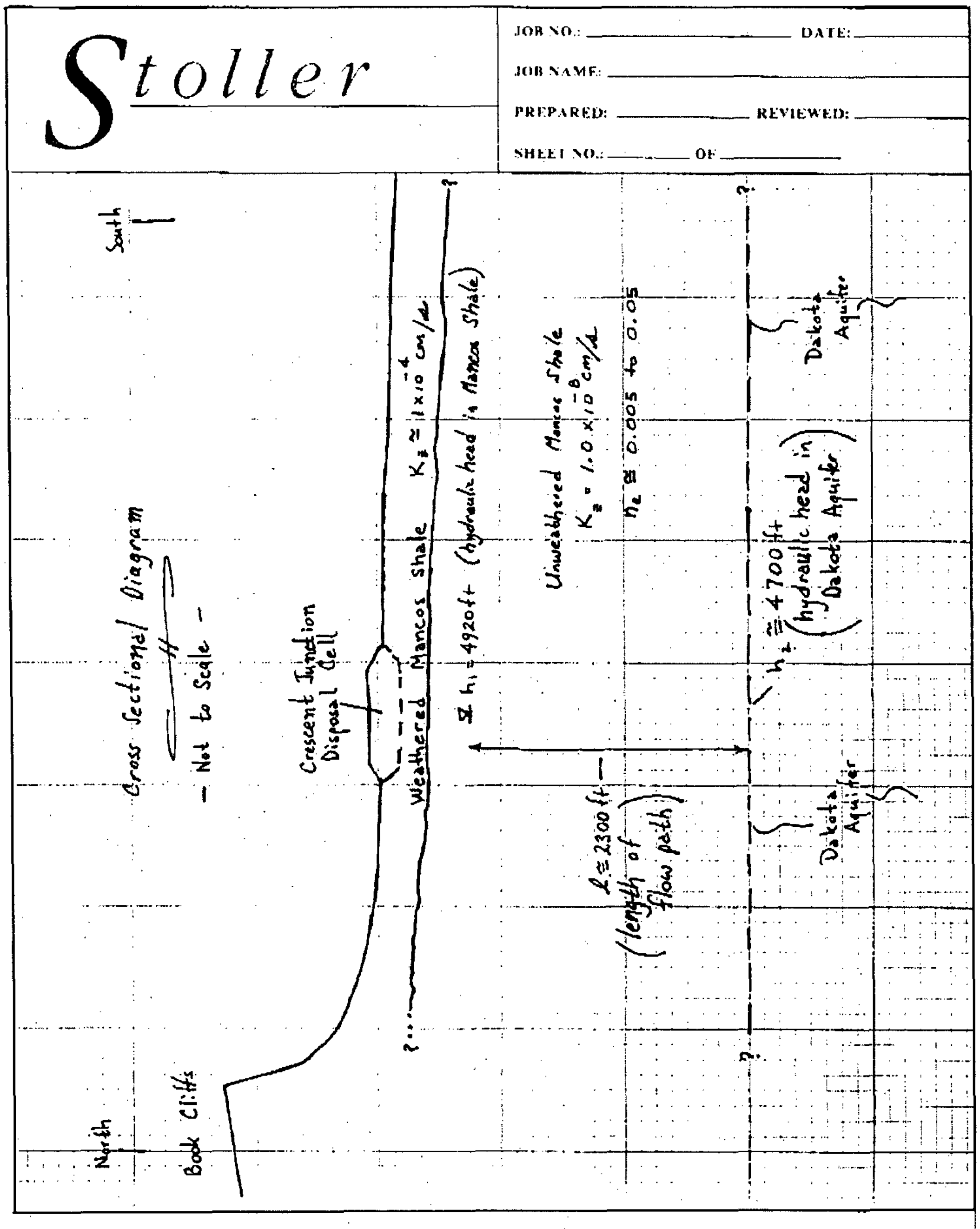


Figure 1. Schematic Cross Section through Crescent Junction, Utah, Disposal Cell

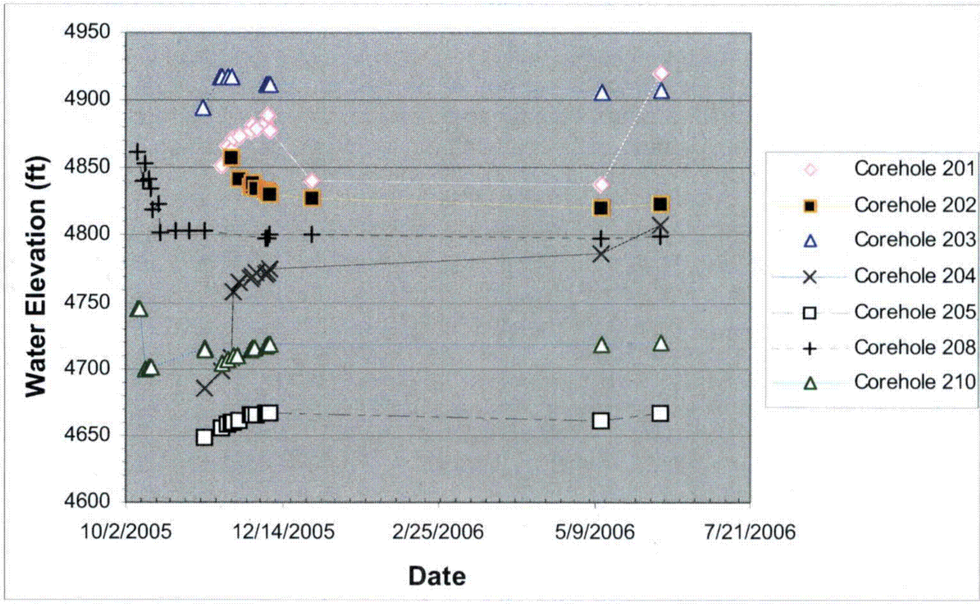


Figure 2. Ground Water Elevations Measured at Crescent Junction Disposal Site, Utah

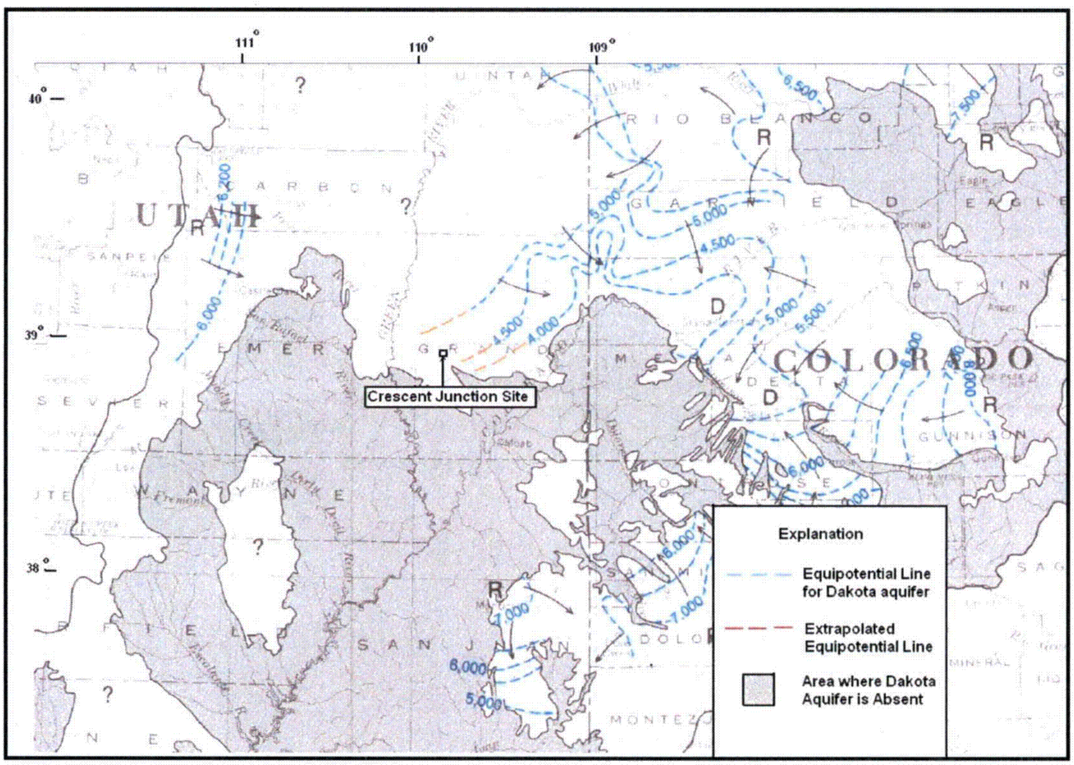


Figure 3. Map showing Generalized Potentiometric Surface and Extrapolated Potentiometric Surface into Crescent Junction Disposal Site (after Freethey and Cordy, 1991, Plate 5)

Effective porosity of the Mancos Shale was not measured at the site during the investigation; consequently, it was estimated from literature values. The Nuclear Regulatory Commission suggests "an effective porosity of 10 percent is assumed conservative (represents the largest flow velocity), unless measured grain size and compaction information support a different value" (NRC 1993, p. 46). Effective porosity values for shale are reported to range from 0.5 to 5 percent (Domenico and Schwartz 1990, p. 26). Because these latter values are more conservative than the 10 percent values suggested by NRC, the effective porosity in this calculation is given the range 0.5 to 5 percent.

Hydraulic conductivity measurements of discrete intervals in the unweathered Mancos Shale were made using dual-packer tests. Results from these tests are presented in Table 1. The hydraulic conductivity data set is insufficient to ascertain its frequency distribution; however, the results are assumed to lie within a log normal distribution because randomly sampled hydraulic conductivity values typically fit a log normal distribution (Domenico and Schwartz 1990, p. 26). Also according to Domenico and Schwartz (1990, p. 66), the "average" value of hydraulic conductivity is represented by the geometric mean. The calculated geometric mean of the hydraulic conductivity data in Table 1 is 3.5×10^{-8} centimeters per second (cm/s).

Table 1. Summary of Field-Permeability "Packer" Test Results for the Crescent Junction Site

Hole ID @ Depth Interval (ft)	Calculated Permeability[1] (cm/s)				
	Test 1	Test 2	Test 3	Test 4	Test 5
Dual-Packer Tests:					
0204 @ 80 to 92	J 1.3×10^{-8}	3.9×10^{-7}	J 9.6×10^{-9}	6.6×10^{-7}	J 1.3×10^{-8}
0204 @ 110 to 122	J 7.5×10^{-9}	9.1×10^{-8}	4.2×10^{-7}	J 9.1×10^{-8}	J 7.5×10^{-9}
0204 @ 283 to 295	J 8.9×10^{-9}	1.2×10^{-6}	2.6×10^{-6}	J 1.1×10^{-8}	J 1.2×10^{-8}
0208 @ 90 to 102	J 6.0×10^{-9}	J 7.7×10^{-9}	J 2.2×10^{-9}	J 7.7×10^{-9}	J 6.0×10^{-9}
0208 @ 121 to 133	J 8.0×10^{-9}	J 1.4×10^{-8}	7.5×10^{-7}	J 1.4×10^{-8}	J 8.0×10^{-9}
0208 @ 282 to 294	6.3×10^{-7}	6.0×10^{-7}	J 6.0×10^{-9}	J 5.7×10^{-9}	2.1×10^{-7}

[1]J flag indicates a *no-flow* packer test in which a maximum hydraulic conductivity is calculated, based on duration of test (see "Field Permeability 'Packer' Test" calculation, RAP Attachment 3, Appendix C, for details).

Assumptions:

- Literature sources are reliable and representative of consensus of opinion.
- Hydraulic conductivity is a log normally distributed function.
- The actual value of effective porosity is within the range 0.005 to 0.05.
- Extrapolated value of hydraulic head for Dakota aquifer is accurate.
- Hydraulic head measurements obtained from the Mancos Shale represent perched, connate ground water without any connection to the Dakota aquifer.

Calculation:

Calculate specific discharge using Darcy's Law and the input values described above.

Specific Discharge Calculation

Calculate specific discharge using hydraulic-head value of 4,920 ft in Mancos Shale:

$$q = -K\ dh/dz = -(3.5 \times 10^{-8}\ \text{cm/sec}) \times (4{,}920\ \text{ft} - 4{,}700\ \text{ft})/(2{,}300\ \text{ft})$$

$$q = -3.35 \times 10^{-9}\ \text{cm/sec (downward flow)}$$

Average Linear Velocity Calculation

Calculate average linear velocity using the downward specific discharge value and the values 0.005 and 0.05 for effective porosity:

Using $n_e = 0.005$:

$$V = q/n_e = (-3.35 \times 10^{-9}\ \text{cm/sec})/(0.005) = 6.70 \times 10^{-7}\ \text{cm/sec}$$

Using $n_e = 0.05$:

$$V = q/n_e = (-3.35 \times 10^{-9}\ \text{cm/sec})/(0.05) = 6.70 \times 10^{-8}\ \text{cm/sec}$$

Travel Time Calculation

Calculate travel time using the above-calculated velocities:

Distance = rate × time; therefore, Time (t) = (distance)/(rate)

Travel time calculated based on velocity from $n_e = 0.005$:

$$\text{Time} = (2{,}300\ \text{ft})/(6.70 \times 10^{-7}\ \text{cm/sec})\ \frac{(1.03 \times 10^{6}\ \text{ft/yr})}{(\text{cm/sec})} = 3{,}330\ \text{yr}$$

Travel time calculated based on velocity from $n_e = 0.05$:

$$\text{Time} = (2{,}300\ \text{ft})/(4.59 \times 10^{-8}\ \text{cm/sec})\ \frac{(1.03 \times 10^{6}\ \text{ft/yr})}{(\text{cm/sec})} = 33{,}300\ \text{yr}$$

Discussion:

The travel time developed in this calculation for ground water to migrate from the disposal site through the Mancos Shale to the Dakota aquifer ranges from 3,330 to 33,300 years. An order-of-magnitude estimate seems appropriate for this calculation because uncertainties associated with three variables could have a strong effect on the outcome, namely: (1) the hydraulic gradient between the Mancos Shale and the Dakota aquifer, (2) the geometric mean hydraulic conductivity, and (3) the effective porosity. These variables are discussed briefly below.

(1) Hydraulic gradient between Mancos Shale and Dakota aquifer

Ground water levels from the Dakota aquifer are presented in Figure 3, which was modified after Freethey and Cordy (1991). Potentiometric surface contours were extrapolated into the area of the site. As shown on Figure 3 the elevation of the potentiometric surface of the Dakota aquifer is approximately 4,700 ft above mean sea level. The maximum hydraulic head of 4920 ft was measured at corehole 0201 (Figure 2) and the minimum hydraulic head of 4648 ft was measured at corehole 0205. Because the elevation of the extrapolated potentiometric surface of the Dakota aquifer is within the range of the measured heads in the Mancos Shale, there is some basis to suspect that the Mancos heads are expressing the potentiometric surface of the underlying Dakota aquifer. If this were the case, then the vertical hydraulic gradient across the Mancos Shale would be effectively zero and no potential would exist for vertical flow between the unstressed Mancos Shale system and the Dakota aquifer. Therefore, the estimated vertical travel times of 3,330 to 33,300 years are conservative.

(2) Geometric mean hydraulic conductivity

Site-specific packer tests in selected coreholes were used to arrive at a population of measured hydraulic conductivity values for the Mancos Shale. The sample population was then used to develop an estimate of the geometric-mean hydraulic conductivity for the layers comprising the Mancos Shale. Measured values of hydraulic conductivity in the Mancos Shale at the Crescent Junction Disposal Site are similar to the measured values of hydraulic conductivity in the Mancos Shale at the Grand Junction Disposal Site (DOE 1991, Calculations GRJ-08-89-14-01, Sheet 9; GRJ-12-89-12-06-00b, Sheet 52/58) and to those reported for the Mancos Shale near the Green River, Utah, Landfill site (Infill Companies, 2003, p. 17).

Vertical hydraulic conductivity values presented in Table 1 are strongly biased toward the high end of the potential range because 20 of the packer tests resulted in no-flow conditions. If more precise measurements were made of the hydraulic conductivity the true hydraulic conductivity values would lower the calculated geometric mean hydraulic conductivity. In more precise studies made by the U.S. Geological Survey of the Mancos Shale and its equivalent the Pierre Shale, the vertical hydraulic conductivity ranged from 1.0×10^{-8} to 1.9×10^{-12} cm/s (Frenzel and Lyford, 1982, p. 17 and pp. 30–31; Bredehoeft et al., 1983, pp. 28–29). Based on these literature results, the true geometric mean hydraulic conductivity at the Crescent Junction Site could be 0.5 to 2 orders of magnitude lower than the one used in this calculation. Recomputing the travel time calculation with the lower mean hydraulic conductivities would yield a travel time ranging from 23,500 to 11,750,000 years. Therefore, a hydraulic conductivity value of 2.3×10^{-8} cm/sec yields a conservative (minimum) range of travel times.

(3) Effective porosity

Using the conservatively low literature-derived values of 0.005 to 0.05 for effective porosity also leads to a conservative approximation of travel time. Effective porosity values vary over a relatively limited range and consequently have less effect on potential error propagation. The minimum literature value for effective porosity value of 0.005 would embody a reasonable measure of conservatism.

Conclusion and Recommendations:

Hydraulic head measurements obtained from the Mancos Shale represent perched, connate ground water without any connection to the Dakota aquifer. The absolute age of the connate ground water has not been determined for the Crescent Junction Site; however, Briant Kimball (personal communication, April 11, 2006) states, "any brine in Mancos would be older than the ages that could be determined by carbon-14". This would signify that the minimum age of the brine is late Pleistocene, which provides a credible basis to the notion that the vertical travel times calculated herein are a conservative estimate.

With the vertical travel time between the Mancos Shale and the Dakota aquifer estimated to range from 3,330 to 33,300 years, the construction of the Crescent Junction Disposal Cell would pose no adverse impact on ground water resources in the area.

Computer Source:

Not applicable.

References:

Bredehoeft, J.D., C.E. Neuzil, and P.C.D. Milly, 1983. *Regional Flow in the Dakota Aquifer: A Study of the Role of Confining Layers*, U.S. Geological Survey Water-Supply Paper 2237.

DOE (U.S. Department of Energy), 1991. *Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Grand Junction, Colorado,* Appendix A to Attachment 3, Vols. 1 and 2, UMTRA-DOE/AL-050505.000.

Domenico, P.A., and F.W. Schwartz, 1990. *Physical and Chemical Hydrogeology*, John Wiley and Sons, New York.

Freethey, G.W., and G.E. Cordy, 1991. *Geohydrology of Mesozoic Rocks in the Upper Colorado River Basin in Arizona, Colorado, New Mexico, Utah, and Wyoming, Excluding the San Juan Basin*, U.S. Geological Survey Professional Paper 1411-C, 6 Plates.

Frenzel, P.F., and F.P. Lyford, 1982. *Estimates of Vertical Hydraulic Conductivity and Regional Ground Water Flow Rates in Rocks of Jurassic and Cretaceous Age, San Juan Basin, New Mexico and Colorado,* U.S. Geological Survey Water-Resources Investigations Report 82-4015.

Infill Companies, 2003. *Class V Landfill Application*, prepared for Green River Landfill, LLC, April.

Kimball, Briant, A., April 11, 2006. Personal Communication, U. S. Geological Survey, Salt Lake City, Utah, office.

Nuclear Regulatory Commission (NRC), 1993. *Final Standard Review Plan for the Review and Remedial Action of Inactive Mill Tailings Sites under Title I of the Uranium Mill Railings Radiation Control Act, Revision 1.*

End of current text

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-02-2007-3-01-00 Doc. No.: X0203900	Discipline: Geochemical Properties	No. of Sheets: 6

Location: Attachment 3, Appendix F

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Geochemical Characterization – Radiocarbon Age Determinations for Ground Water Samples Obtained From Wells 0203 and 0208

Sources of Data:

Radiocarbon age determinations for ground water samples obtained from wells 0203 and 0208.

Sources of Formulae and References:

Clark, I.D., and P. Fritz, 1997. *Environmental Isotopes in Hydrogeology*, CRC Press, Boca Raton, Florida.

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No.

Author: Name Date 5-31-07

Approved by: Name Date 5/31/07

Checked by: Name Date 5/31/07

Name Date 31 May 07

Name Date 31 May 07

Name Date MAY 31, 07

No text for this page

Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor, S.M. Stoller Corporation, has identified a 2,300-acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for final disposal of the Moab uranium mill tailings. The proposed disposal cell would cover approximately 250 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction Disposal Site is being evaluated from several technical aspects, including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation is to present the radiocarbon-estimated age of the ground water, found in two of the 300-foot (ft) coreholes (wells) underlying the Crescent Junction Disposal Site.

Ground water beneath the Crescent Junction Disposal Site occurs in several, but not all, of the 10 coreholes that were advanced to a depth of 300 ft. The ground water is briny in composition and, because of its limited spatial extent, is hypothesized to be very old water and effectively "trapped" in the Mancos Shale. The radiocarbon age dating was performed in order to test this hypothesis.

These data will be incorporated into Attachment 3 of the *Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at Crescent Junction, Utah, Site* (RAP) and summarized in the *Remedial Action Selection* (RAS) report for the Moab Site.

Method of Solution:

General procedures for sample collection and sample preparation were obtained from Clark and Fritz (1997). According to these procedures, a sufficient sample volume is collected to yield a minimum of 3 grams (g) of pure carbon from each sample. Wells 0203 and 0208 at the Crescent Junction Disposal Site were selected for radiocarbon age determination primarily because ground water from these wells was known to contain the highest alkalinity concentrations measured at the site, and secondarily because they could readily yield the volume of water required for a radiocarbon sample. Highly elevated alkalinity concentrations are important to radiocarbon sampling because the carbon required for the analysis is contained in the dissolved carbonate and bicarbonate species in the water sample.

Prior to sample collection, the required sample volume was estimated from the measured alkalinity of the ground water and the laboratory requirement of a minimum of 3 g of pure carbon for the analysis. The volume of ground water required for an adequate sample is obtained by dividing the 3 g pure carbon required by the laboratory by the carbon concentration in the water sample. In wells 0203 and 0208, the total alkalinity (expressed as $CaCO_3$) is known to be 1,400 milligrams per liter (mg/L) and 1,700 mg/L, respectively. Therefore, the sample-volume calculation indicates that a minimum volume of 17.9 liters (L) and 14.7 L would be required from wells 0203 and 0208, respectively. Details of the sample volume calculations for samples from wells 0203 and 0208 are presented in Appendix A of this calculation.

Ground water at the Crescent Junction Site was assumed to be very old and, consequently, isolated from atmospheric sources of so-called *modern carbon*. To control the introduction of modern carbon into the ground water sample, all sample collection, sample transfer, and sample handling operations were done under a blanket of nitrogen gas. The nitrogen gas was introduced above the water column to completely displace all atmospheric gas from the well bore. Reintroduction of atmospheric gas into the headspace of the well was prevented during the traditional ground water purging step by continuously passing nitrogen gas into the well bore. The nitrogen gas was slowly injected in a "bottom-up" direction through a hose that extended almost to the static water level.

Boyle's Law was used to calculate the volume of nitrogen gas required to displace all the atmospheric gas from the headspace in the well. Boyle's Law describes the change in gas volume in response to pressure. Measurements taken at the pressure regulator were used to ensure that a sufficient volume of nitrogen gas was injected into the headspace of the well. Following the purge, when the water level began to recover, the flow of nitrogen gas was shut off because the recovering water level, acting as a piston, would force the nitrogen gas out from the borehole and prevent atmospheric gas from reentering the borehole.

An example of the Boyle's Law calculation used to estimate the volume of gas required to displace atmospheric gas from the corehole is shown next:

$$P_1V_1 = P_2V_2$$

Where

P_1 = pressure of nitrogen in cylinder (pounds per square inch [psi])
V_1 = volume of cylinder (2.5 cubic feet [ft^3])
P_2 = atmospheric pressure (14.7 psi)
V_2 = volume of air-filled portion of borehole (ft^3)

$P_1 = (P_2V_2) / V_1$
$P_1 = (14.7 \text{ psi} \times 15 \text{ ft}^3) / 2.5 \text{ ft}^3$
$P_1 = 88$ psi

The quantity P_1 indicates that a pressure of 88 psi is required to evacuate atmospheric gas from the corehole when the water level in corehole 0208 is 185 ft below ground surface. Therefore, 200 psi was injected into the corehole to evacuate a minimum of 2 corehole volumes. Similar computations are used to show that approximately 110 psi is injected to evacuate 2 borehole volumes when the water level in corehole 0203 is 110 ft below the surface. The nitrogen hose was lowered to just above the water level, and the nitrogen gas was injected using a regulator setting of 20 psi to slowly displace the atmospheric gas from the well prior to the purge.

Nitrogen was also injected during the traditional ground water purge step. The injection rate of nitrogen gas into the borehole was designed to exceed the displacement of the water level in the well and prevent the "pulling" of atmospheric gas into the corehole. Each well was equipped with a dedicated 5-gallon-per-minute (gpm)-capacity pump. A pumping rate of 5 gpm is equivalent to 0.67 ft^3 per minute. Thus, according to Boyle's Law,

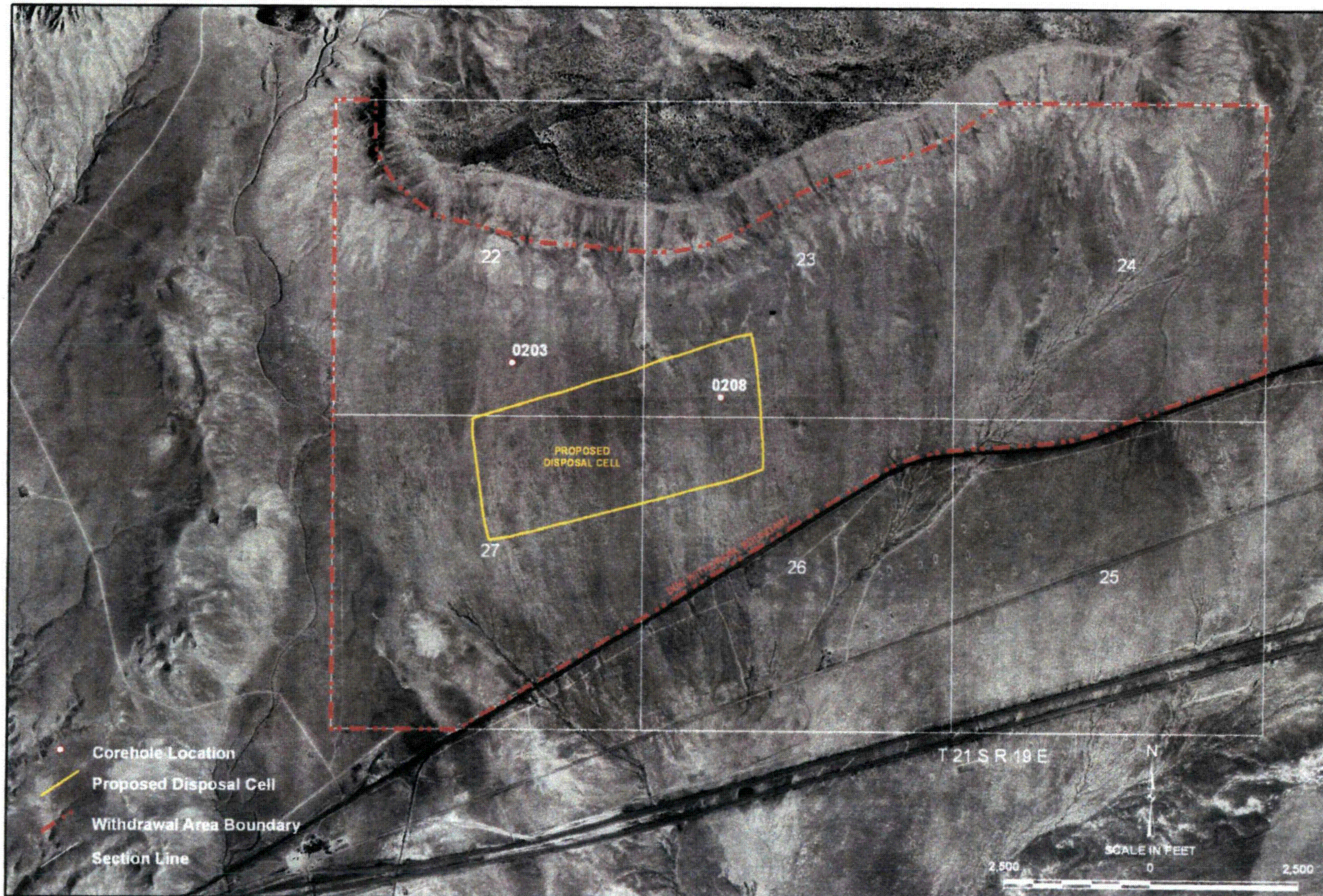
$P_1 = (P_2V_2) / V_1$
$P_1 = (14.7 \text{ psi} \times 0.67 \text{ ft}^3) / 2.5 \text{ ft}^3$
$P_1 = 3.9$ psi

The quantity P_1 signifies that 3.9 psi per minute is required to eliminate the pulling of atmospheric gas into the corehole during the traditional ground water purge. During the radiocarbon ground water sampling at the Crescent Junction Disposal Site, the injection rate of nitrogen gas during sampling was maintained at 20 psi.

Nitrogen gas was also used to purge atmospheric gas from the sample containers. After the sample containers were filled with the required sample volume they were transported to the Environmental Sciences Laboratory to precipitate the available carbonate in the sample to $BaCO_3$. This was accomplished by adding approximately 30 milliliters of carbonate-free NaOH to the sample in order to raise the pH above 11. The amount of Ba^{+2}, added as $BaCl_2 \cdot 2H_2O$, required to precipitate all of the carbonate must be sufficient to also precipitate all SO_4. As presented in Appendix A of this calculation, the amounts of $BaCl_2 \cdot 2H_2O$ required for wells 0203 and 0208 were 401 g and 421 g, respectively. After the chemicals were added, the sample containers were left in the laboratory for the precipitated carbonate to settle to the bottom.

The supernatant was then drained off of the precipitate using the bottom spigot on the sample container. To avoid introducing atmospheric carbon into the sample container, a rubber bung equipped with an Ascarite (CO_2-absorbing compound) and Drierite (moisture-absorbing compound) trap was inserted into the top of the sample container. The remaining sludge was transferred into nitrogen-filled, 1-L Nalgene narrow-mouth containers and packaged for sample shipment.

All samples were analyzed at GEOCHRON Laboratories, Cambridge, MA. Analytical results from the laboratory are presented in Appendix B of this calculation.



N:\MOA\999\0020\07\009\X02035\X0203500.mxd coatesc 5/22/2007 8:15:18 AM

X0203500

Figure 1. Location of Wells 0203 and 0208 at the Crescent Junction Disposal Site

Assumptions:

- Ground water at the Crescent Junction Site is isolated from atmospheric sources of so-called modern carbon.
- Samples drawn from wells 0203 and 0208 are representative of site conditions. Water samples from other wells at the site will yield similar radiocarbon ages to those obtained at 0203 and 0208.
- Applying a blanket of nitrogen gas on the ground water sample effectively excludes all modern-carbon contamination.

Calculation:

Laboratory results are presented in Appendix B. Table 1 presents a summary of the age dates.

Table 1. Summary of Radiocarbon Age Determination

Corehole	Sample Name	^{14}C Years (Before Present[1])
0203	NFA256	≥41,090
	NFA257	$38,650^{+7450}_{-3800}$
	NFA258	≥44,560
0208	NFA259	≥40,180
	NFA260	≥40,180
	NFA261	≥38,540

[1]The age before present is referenced to the year 1950.

Discussion:

Radiocarbon sampling methods appear to have been successful in excluding modern carbon from the ground water samples; however, minor contamination with modern carbon may be the cause of the error bands assigned to the result for sample NFA257. Based on the preponderance of sample results, the age of the ground water beneath the site appears to be at least 40,000 years before present.

Conclusion and Recommendations:

Ground water age determination at the Crescent Junction Disposal Site indicates that the briny ground water beneath the site is at least as old as late Pleistocene. This determination provides supporting evidence that travel times for vertical (and horizontal) ground water movement would be very long, as predicted in the "Hydrologic Characterization–Vertical Travel Time to Uppermost (Dakota) Aquifer" calculation (RAP Attachment 3, Appendix E). Based on these radiocarbon ages, the shallow ground water at the site would pose no adverse risk to deeper water resources.

Computer Source: Not Applicable

Appendix A

Calculation Sheets

7-13-06

Stoller

JOB: Crescent Jct. ^{14}C determination

PREPARED: M. Kautsky REVIEWED:

SHEET NO.: 1 OF

1.0 Prepare Carbon-free NaOH solution
15N NaOH solution – 5mg / liter jug. to ppt. all CO_3.

2.0 Sample wells. 202, 203, & 208

well	SO4 (mg/L)	Total Alkalinity ~~HCO3~~ @ CaCO3 (mg/L)
202	<25	430
203	4500	1400
208	5900	1700

3.0 Need 3 g C.

Groundwater sample size required to yield 3 g C is...

well 202

$$\text{mg C/liter} = \left(\frac{12\text{ mg C}}{100\text{ mg CaCO}_3}\right)\left(\frac{430\text{ mg CaCO}_3}{L}\right) = 51.6\text{ mg C/liter}$$

$$\frac{3\text{ g C}}{0.0516\text{ g C/liter}} = 58\text{ liters from well 202}$$

Because 58 L won't fit in 25 L sample container, don't sample well 202

well 203

$$\text{mg C/l} = \left(\frac{12\text{ mg C}}{100\text{ mg CaCO}_3}\right)\left(\frac{1400\text{ mg}}{L}\right) = 168\text{ mg C/liter}$$

$$\frac{3\text{ g C}}{0.168\text{ g C/l}} = 17.9\text{ liters from well 203}$$

well ~~204~~ 208

$$\frac{\text{mg C}}{l} = \left(\frac{12\text{ mg C}}{100\text{ mg CaCO}_3}\right)\left(\frac{1700\text{ mg CaCO}_3}{L}\right) = 204\text{ mg C/l}$$

$$\therefore \frac{(3\text{ g C})}{\left(\frac{0.204\text{ g C}}{L}\right)} = 14.7\text{ L from well } \cancel{204}\ 208$$

Calculation Sheet 1 showing how sample volumes are estimated from alkalinity for coreholes 0202, 0203, and 0208.

Stoller

7-13-06

Crescent Jct ^{14}C determination

PREPARED: M. Kautsky REVIEWED: ______

SHEET NO. 2 OF ___

~~well 203~~

Amount of $BaCl_2$ required to precipitate all dissolved carbon
Assume all carbon species are in the form CO_3^{2-}

Amount of $BaCl_2$ should be in excess to precipitate both $BaCO_3$ and $BaSO_4$ *

Moles of CO_3^{2-} will be estimated from analytical results from previous groundwater samples.
Moles of SO_4^{2-} will be estimated from analytical results from previous groundwater samples.

Amount of SO_4^{2-} in well 203

$$17.9\ L \left(\frac{4.5\,g\ SO_4^{2-}}{L}\right)\left(\frac{1\ mole\ SO_4^{2-}}{96\,g\ SO_4^{2-}}\right) = 0.84\ moles\ SO_4^{2-}$$

Amount of $CaCO_3$ in well 203

$$17.9\ L \left(\frac{1.4\,g\ CaCO_3}{L}\right)\left(\frac{1\ mole\ CaCO_3}{100\,g\ CaCO_3}\right) = 0.25\ moles\ CaCO_3$$
$$(= 0.25\ moles\ CO_3^{2-})$$

Moles SO_4^{2-} + moles CO_3^{2-} = 0.84 + 0.25 = 1.1 moles

Moles $BaCl_2$ req'd = 1.1

1.1 moles $BaCl_2$ = 1.1 moles $BaCl_2 \cdot 2H_2O$

unit		unit		extended
gfw Ba	=	137 g	=	137 g
gfw Cl	=	35.4 g	=	70.8 g
gfw H	=	1.0 g	=	4 g
gfw O	=	16.0 g	=	32 g
		Total gfw $BaCl_2 \cdot 2H_2O$	=	243.8 g

Minimum mass of $BaCl_2 \cdot 2H_2O$ req'd = 1.1 (243.8 g) = 263 g

* $\boxed{1.5\ excess\ (263\,g\ BaCl_2 \cdot 2H_2O) = 401\,g\ BaCl_2 \cdot 2H_2O}$

Calculation Sheet 2 showing the determination of amount of $BaCl_2 \cdot 2H_2O$, required to precipitate all of the carbonate and sulfate from water in well 0203.

7-13-06

Stoller

Project: Cement Jet ¹⁴C determination

PREPARED BY: M. Kautsky REVIEWED:

SHEET NO. 3 OF

Well ~~204~~ 208

Amount of $BaCl_2$ req'd to ppt all dissolved carbon ...(cont)

Amount SO_4^{2-} in well ~~204~~ 208

$$14.7\,L \left(\frac{\cancel{0.044}\ 5.9\ g\ SO_4^{2-}}{L}\right)\left(\frac{1\ mole\ SO_4^{2-}}{96\ g\ SO_4^{2-}}\right) = \cancel{0.006}\ 0.903\ moles\ SO_4^{2-}$$

Amount $CaCO_3$ in well ~~204~~ 208

$$14.7\,L \left(\frac{\cancel{0.846}\ 1.7\ g\ CaCO_3}{L}\right)\left(\frac{1\ mole\ CaCO_3}{100\ g\ CaCO_3}\right) = \cancel{0.123}\ 0.25\ moles\ CaCO_3$$

$$\left(= \cancel{0.123}\ moles\ CO_3^{2-}\right)$$

$$moles\ SO_4^{2-} + moles\ CO_3^{2-} = \cancel{0.006 + 0.123}\ 0.903 + 0.25 = \cancel{0.129}\ 1.153$$

$$Moles\ BaCl_2 \cdot 2H_2O = \cancel{0.129}\ 1.153$$

$$GFW\ BaCl_2 \cdot 2H_2O = 243.8\ g$$

$$Minimum\ mass\ BaCl_2 \cdot 2H_2O\ req'd = \left(\cancel{0.129}\ 1.153\ mole\right)\left(243.8\ g/mole\right) = \cancel{31.3}\ 281\ g\ BaCl_2 \cdot 2H_2O$$

$$1.5\ excess\ \left(\cancel{31.3}\ 281\ g\ BaCl_2 \cdot 2H_2O\right) = \cancel{47}\ 421\ g\ BaCl_2 \cdot 2H_2O$$

Calculation Sheet 3 showing the determination of amount of $BaCl_2 \cdot 2H_2O$, required to precipitate all of the carbonate and sulfate from water in well 0208.

End of current text

Appendix B

Laboratory Results of Radiocarbon Sampling

GEOCHRON LABORATORIES

a division of Krueger Enterprises, Inc.

711 Concord Avenue ✦ Cambridge, Massachusetts 02138-1002 ✦ USA
t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32612**	Date Received:	07/31/2006
Your Reference:	PO # 2989	Date Reported:	08/09/2006

Submitted by: Mark Kautsky
S.M. Stoller Corp.
2597 B ¾ Road
Grand Junction, CO 81503

Sample Name: **Crescent Junction NFA 256**

AGE = **$\geq$ 41090 ^{14}C years BP (^{13}C corrected)**
$\leq$ 0.50 % of the modern (1950) ^{14}C activity

Description: Sample of ground water

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-1.6 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GEOCHRON LABORATORIES
a division of Krueger Enterprises, Inc.
711 Concord Avenue ♦ Cambridge, Massachusetts 02138-1002 ♦ USA
t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32613**	Date Received:	07/31/2006
Your Reference:	PO # 2989	Date Reported:	08/09/2006

Submitted by: Mark Kautsky
S.M. Stoller Corp.
2597 B ¾ Road
Grand Junction, CO 81503

Sample Name: **Crescent Junction NFA 257**

AGE = **38650^{+7450}_{-3800} ^{14}C years BP (^{13}C corrected)**
0.81 ± 0.49 % of the modern (1950) ^{14}C activity

Description: Sample of ground water

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-3.5 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GEOCHRON LABORATORIES

a division of Krueger Enterprises, Inc.

711 Concord Avenue ✦ Cambridge, Massachusetts 02138-1002 ✦ USA
t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32614**	Date Received:	07/31/2006
Your Reference:	PO # 2989	Date Reported:	08/09/2006

Submitted by: Mark Kautsky
S.M. Stoller Corp.
2597 B ¾ Road
Grand Junction, CO 81503

Sample Name: **Crescent Junction NFA 258**

AGE = **$\geq$ 44560 ^{14}C years BP (^{13}C corrected)**
$\leq$ 0.42 % of the modern (1950) ^{14}C activity

Description: Sample of ground water

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = -1.5 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GEOCHRON LABORATORIES

a division of Krueger Enterprises, Inc.

711 Concord Avenue ✦ Cambridge, Massachusetts 02138-1002 ✦ USA
t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32615**	Date Received:	07/31/2006
Your Reference:	PO # 2989	Date Reported:	08/09/2006

Submitted by: Mark Kautsky
S.M. Stoller Corp.
2597 B ¾ Road
Grand Junction, CO 81503

Sample Name: **Crescent Junction NFA 259**

AGE = **$\geq$ 40180 ^{14}C years BP (^{13}C corrected)**
$\leq$ 0.51 % of the modern (1950) ^{14}C activity

Description: Sample of ground water

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-2.3 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GEOCHRON LABORATORIES
a division of Krueger Enterprises, Inc.
711 Concord Avenue ✦ Cambridge, Massachusetts 02138-1002 ✦ USA
t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32616**	Date Received:	07/31/2006
Your Reference:	PO # 2989	Date Reported:	08/09/2006

Submitted by: Mark Kautsky
S.M. Stoller Corp.
2597 B ¾ Road
Grand Junction, CO 81503

Sample Name: **Crescent Junction NFA 260**

AGE = **$\geq$ 40180 ^{14}C years BP (^{13}C corrected)**
$\leq$ 0.51 % of the modern (1950) ^{14}C activity

Description: Sample of ground water

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-2.7 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GEOCHRON LABORATORIES

a division of Krueger Enterprises, Inc.

711 Concord Avenue ✦ Cambridge, Massachusetts 02138-1002 ✦ USA
t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32617**	Date Received:	07/31/2006
Your Reference:	PO # 2989	Date Reported:	08/09/2006

Submitted by: Mark Kautsky
S.M. Stoller Corp.
2597 B ¾ Road
Grand Junction, CO 81503

Sample Name: **Crescent Junction NFA 261**

AGE = **$\geq$ 38540 ^{14}C years BP (^{13}C corrected)**
$\leq$ 0.53 % of the modern (1950) ^{14}C activity

Description: Sample of ground water

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-1.7 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

NFA 256

Project Crescent Junction

Site ______ Location 0203 ~ Sample 1

Date 7-28-06 Time ______ Matrix GW

Interval ______ Sampler ______

Comments ______

Analyte(s)	Container Type	Number Collected	Filtered	Preservative
^{14}C	~~25 L carboy~~	2	Y	No
	1L HDPE			

GJ 1854 7/2004

White copy to Project Manager; canary to laboratory; pink remains in ticket book

NFA 257

Project Crescent Junction

Site 8 Location 0203 - Sample 2

Date 7-26-06 Time Matrix

Interval Sampler

Comments

Analyte(s)	Container Type	Number Collected	Filtered	Preservative
^{14}C	1 L HDPE	2	Y	No

GJ 1854
7/2004

White copy to Project Manager; canary to laboratory; pink remains in ticket book

NFA 258

Project Crescent Junction

Site ______ Location 0203 - Sample 3

Date 7-28-06 Time ______ Matrix GW

Interval ______ Sampler ______

Comments ______

Analyte(s)	Container Type	Number Collected	Filtered	Preservative
14C	1L HDPE	2	Y	No

GJ 1864
7/2004

White copy to Project Manager; canary to laboratory; pink remains in ticket book

NFA 259

Project Crescent Junction

Site ______ Location 0208 - Sample 1

Date 7-28-06 Time ______ Matrix Gw

Interval ______ Sampler ______

Comments ______

Analyte(s)	Container Type	Number Collected	Filtered	Preservative
^{14}C	1L HDPE	2	y	No

GJ 1854
7/2004

White copy to Project Manager; canary to laboratory; pink remains in ticket book

NFA 260

Project Crescent Junction

Site ______ Location 0208 Sample 2

Date 7-28-06 Time ______ Matrix GW

Interval ______ Sampler ______

Comments ______

Analyte(s)	Container Type	Number Collected	Filtered	Preservative
^{14}C	1L HDPE	2	Y	No

GJ 1854 7/2004

White copy to Project Manager; canary to laboratory; pink remains in ticket book

NFA 261

Project Crescent Junction

Site ______ Location 0208 Sample 3

Date 7-28-06 Time ______ Matrix GW

Interval ______ Sampler ______

Comments ______

Analyte(s)	Container Type	Number Collected	Filtered	Preservative
^{14}C	1L HDPE	2	Y	No

GJ 1954
7/2004

White copy to Project Manager; canary to laboratory; pink remains in ticket book

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-06-2007-2-14-00 **Discipline:** Hydrology **No. of Sheets:** 12
Doc. No.: X0173700

Location: Attachment 3, Appendix G

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Hydrologic Characterization – Lateral Spreading of Leachate

Sources of Data:

RAP calculations as referenced in text.

Sources of Formulae and References:

Bear, J. 1979. *Hydraulics of Groundwater,* McGraw-Hill, Inc.

Carslaw, H.S., and J.C. Jaeger, 1986. *Conduction of Heat in Solids*, 2nd Edition, Clarendon Press, Oxford.

Hantush, M.S., 1967. *Growth and Decay of Groundwater Mounds in Response to Uniform Percolation,* Water Resources Research, 3(1), pp. 227–234.

Lambe, W.T., and R.V. Whitman, 1969. *Soil Mechanics,* John Wiley and Sons, New York.

NRC, 1993. *Final Standard Review Plan for the Review and Remedial Action of Inactive Mill Tailings Sites Under Title I of the Uranium Mill Tailings Remediation Control Act,* Revision 1, June 1993.

Walvoord, M.A., and B.R. Scanlon, 2004. "Hydrologic Processes in Deep Vadose Zones in Interdrainage Arid Environments," in Hogan, J.F., F.M. Phillips, and B.R. Scanlon, Editors, *Groundwater Recharge in a Desert Environment: The Southwestern United States,* American Geophysical Union Water Science Application 9.

Preliminary Calc. **Final Calc.** X **Supersedes Calc. No.**

Author: Mark Kautsky 6-20-07
Name Date

Checked by: Art Strachan 20 June 07
Name Date
Dave Peterson 6-20-07
Name Date
LE Cummings 6-20-07
Name Date
D.R. Metzler 6-21-2007
Name Date

Approved by: John Elmer for Ken Karp
Name Date 6-20-07

No text for this page

Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified a 2,300-acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for a final disposal cell for the Moab uranium mill tailings. The proposed disposal cell would cover approximately 250 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction Disposal Site is being evaluated from several technical aspects, including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation set is to examine potential scenarios in which tailings-derived leachate could spread laterally in the weathered Mancos Shale at the base of the disposal cell prior to infiltrating into the unweathered Mancos Shale.

Conclusions from this calculation will be incorporated into Attachment 3 (Ground Water Hydrology) of the *Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site* (RAP), and summarized in the *Remedial Action Selection Report* (RAS) for the Moab Site.

Method of Solution:

Two solution methods are presented in this calculation: a method based on conservative assumptions, which is equivalent to assuming steady-state seepage rate of 1×10^{-7} centimeters per second (cm/s) (NRC 1993) through the tailings pile; and a method based on realistic assumptions, which is based on a seepage rate of less than 3.5×10^{-8} cm/s through the tailings pile. In this calculation, the method of conservative assumptions is shown to be protective of human health and environment; therefore, the method of realistic assumptions is also protective.

Conservative Assumptions:

Under steady-state conditions, the vertical percolation rate is conservatively assumed to be 1×10^{-7} cm/s (NRC 1993). The thickness of the weathered Mancos Shale is approximately 50 feet (ft). The leachate will migrate to the base the weathered Mancos Shale, becoming perched above the unweathered Mancos Shale, whose geometric mean hydraulic conductivity is 3.5×10^{-8} cm/s. With its downward movement impeded at the base of the weathered Mancos Shale, the leachate will gradually spread laterally away from the edge of the disposal cell. As it spreads, the leachate will be consumed by slow vertical leakage into the unweathered Mancos Shale. This calculation estimates the height to which the leachate might rise, both at the center and the edges of the disposal cell; it also estimates the length of lateral spreading of leachate from the edges and corners of the disposal cell.

- It is physically reasonable to combine the transient two-dimensional solution of Hantush (1967) (to obtain hydraulic head within the footprint of the disposal cell) with the steady-state one-dimensional solution of Bear (1979) (to obtain length of lateral spreading outside the footprint of the disposal cell).
- Beneath the footprint of the disposal cell, the unweathered bedrock is assumed to be impervious. (This assumption is a requirement of the Hantush [1967] solution; however, it calculates a thicker accumulation of leachate beneath the disposal cell because the actual hydraulic conductivity of the unweathered bedrock is greater than zero and would allow some vertical seepage to enter into the unweathered Mancos Shale.)
- Leachate mounding beneath the disposal cell is assumed to be symmetrical; consequently, the calculated height of the mound along any edge is identical to the mounding at the opposite edge. Similarly, the calculated height of mounding at any corner is identical to the mounding at any other corner.
- Outside the footprint of the disposal cell, the hydraulic conductivity of the unweathered bedrock is assumed to be uniformly equal to the geometric mean value of 3.5×10^{-8}cm/s (RAP Attachment 3, Appendix C, Table 1).
- Phreatic flow conditions with leakage can be used to describe the lateral-flow conditions that would exist beyond the envelope of the disposal cell.
- Leachate will spread laterally along the contact between weathered and unweathered Mancos Shale.

- The geometric mean hydraulic conductivity of 2.0×10^{-3} cm/s (2,059 feet per year [ft/yr]) (RAP Attachment 3, Appendix C, Table 1) of the weathered Mancos Shale is used as an upper-bounding estimate in this conservative calculation.
- The geometric mean **vertical** hydraulic conductivity of 1.2×10^{-4} cm/s (124 ft/yr) (RAP Attachment 3, Appendix A) is used as lower-bounding estimate in this conservative calculation.
- The thickness of the weathered zone in the Mancos Shale is approximately 50 ft.
- The weathered Mancos Shale is assumed to be homogeneous and isotropic.
- The shape of the disposal cell can be approximated by a rectangle having the dimensions 2,200 × 5,000 ft.
- The steady-state vertical percolation rate through the cover of the disposal cell is assumed to be 1×10^{-7} cm/s (NRC 1993).
- Natural recharge of (7.3 × 10–9 cm/s) through the undisturbed desert soils is a factor of 100 less than the average annual precipitation (7.3 × 10–7 cm/s; or 9.1 inch/yr).
- Because no ground water found in the weathered Mancos Shale during the site investigation, the initial hydraulic head in the weathered shale is assumed to be zero everywhere, (RAP Attachment 5, Appendixes A, B, and D).

Conservative Calculation:

This calculation is based on the conservative assumptions and solved by coupling two analytical solutions. The Hantush (1967) solution is used to estimate the height of a leachate mound that forms entirely within the weathered zone of the Mancos Shale beneath the footprint of the disposal cell. The mound heights are calculated for the following locations:

- Center of the disposal cell, where the leachate mound attains its maximum height (h_{max}): detailed calculation in Appendix A1 of this section, pages 2 through 5.
- Center of both the northern and southern edges of the disposal cell (h_0): detailed calculation in Appendix A2 of this section, pages 2 through 7.
- Center of both the eastern and western edges of the disposal cell (h_0): detailed calculation in Appendix A3 of this section, pages 2 through 7.
- Corners of the disposal cell (h_0): detailed calculation in Appendix A4 of this section, pages 2 through 7.

The calculated height of leachate, mounded at the perimeter of the disposal cell and known as the Hydraulic head, is obtained from the Hantush (1967) solution and given the symbol h_0. Because the accumulation of leachate above the unweathered bedrock is a transient phenomenon, the Hantush (1967) method is used to calculate the height of the mound at three times: 10 years, 200 years, and 1,000 years.

The second analytical solution (Bear 1979; pp. 181–183; Equation 5-219) describes the length of lateral spreading that will propagate away from the edges and corners of the disposal cell. This steady-state solution assumes phreatic flow with downward leakage, and is used to describe the lateral spreading of leachate that will exist in the weathered Mancos Shale beyond the footprint of the disposal cell. Natural recharge through arid region desert soils of the southwestern United Sates is reported to range from approximately 0.01 to 0.1 mm/yr (3.17×10^{-11} to 3.17×10^{-10} cm/s) (Walvoord and Scanlon 2004). Per the assumptions developed for this calculation, the natural recharge rate is taken to be 1/100th of the average annual precipitation in the areas outside the footprint of the disposal cell, which is reasonable based on the fact that no free ground water is encountered above the depth of weathered bedrock at the site (RAP Attachment 5, Appendixes A, B, and D). The rate of vertical leakage through the unweathered Mancos Shale is a function of its geometric-mean hydraulic conductivity and the distance between the top of the unweathered Mancos Shale and the uppermost ground water. Based on depths to the uppermost ground water at the site, the thickness of the leaky layer (unweathered Mancos Shale) is taken to be 2,400 ft.

The Bear (1979) solutions are developed in the following locations:

- Beyond the northern and southern edges of the disposal cell (h_0): detailed calculation in Appendix A2 of this section, pp. 8–13.
- Beyond the eastern and western edges of the disposal cell (h_0): detailed calculation in Appendix A3 of this section, pp. 8–13.
- Beyond the corners of the disposal cell (h_0): detailed calculation in Appendix A4 of this section, pp. 8-13.

Hantush (1967) Solution

The maximum rise of the mound beneath the disposal cell occurs directly beneath the center of the disposal cell; the solution is obtained using Hantush (1967; equation 17):

$$h_{\max}^2 - h_i^2 = (2\omega / K)\nu t S^*\left(\frac{l}{\sqrt{4\nu t}}, \frac{a}{\sqrt{4\nu t}}\right) \tag{1}$$

where:

h_i = height of the water table that would have existed under natural conditions in the weathered Mancos Shale. In the case of the Crescent Junction Disposal Site, this value is zero, because there is no initial water table.

$h_{\max}$ = height [L] of the water table at its maximum level, which forms at the center of the disposal cell.

$\omega =$ constant rate of seepage through the cover [L/T].

$K =$ hydraulic conductivity [L/T].

$\nu = \dfrac{K\bar{b}}{\varepsilon}$, where $\varepsilon =$ specific yield (dimensionless) and $\bar{b}$ = constant of linearization (unity).

$t =$ time since infiltration began (T).

S^* = function. $S^*(\alpha, \beta) = \int_0^1 erf\left\{\frac{\alpha}{\sqrt{\tau}}\right\}, erf\left(\frac{\beta}{\sqrt{\tau}}\right) dr$

Values of this function are tabularized in Hantush (1967). In some cases, Carslaw and Jaeger (1986, Appendix II, Table 1) was required to obtain the head solution to the analytical expression.

The height of the leachate mound is not as high along the edges of the disposal cell as it is at the center. Along the edges, the height of the leachate mound is computed using a Cartesian coordinate system to demarcate the locations where the head value is desired. Equation (2) is used to solve for the head distribution at three critical locations along the edges of the disposal cell:

$$h^2 - h_i^2 = \left(\frac{\omega}{2K}\right)(\nu t)\bullet\left[S^*\left(\frac{l+x}{\sqrt{4\nu t}}\right),\left(\frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}\right),\left(\frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{(l-x)}{\sqrt{4\nu t}}\right),\left(\frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}\right),\left(\frac{a-y}{\sqrt{4\nu t}}\right)\right] \tag{2}$$

Where l = half-length of Crescent Junction disposal cell (2,500 ft), a = half-width of Crescent Junction Disposal Cell (1,100 ft), x and y are distances along the x and y axes [with (0,0) located at the center of the disposal cell], and the remaining terms were defined above in equation (1). The three critical locations are at the midpoints of the western and eastern perimeters, the midpoints of the southern and northern perimeters, and at the corners of the disposal cell. Solutions to equations (1) and (2) are presented in Appendix A1 through A4 of this section.

Bear (1979) Solution

After obtaining the hydraulic head of the leachate mound along the perimeter of the disposal cell, equation 5-219 (Bear 1979; pp. 181-183) is used to compute the length of lateral spreading. The h_0 term in the Bear solution is obtained from the Hantush solutions (Equation 2 of this calculation) along the perimeter of the disposal cell. The length of spreading of the leachate is obtained using the following expression (Bear 1979; pp. 181-183):

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_0 + B\right)^{\frac{1}{2}} - B^{\frac{1}{2}}\right] \quad (3)$$

where the constants A and B are defined as:

$$A = \frac{1}{K\sigma'};\ B = \frac{B' - N\sigma'}{K\sigma'}$$

and where:

K = hydraulic conductivity of the weathered Mancos Shale [L/T].

$$\sigma' = \frac{B'}{K'}$$

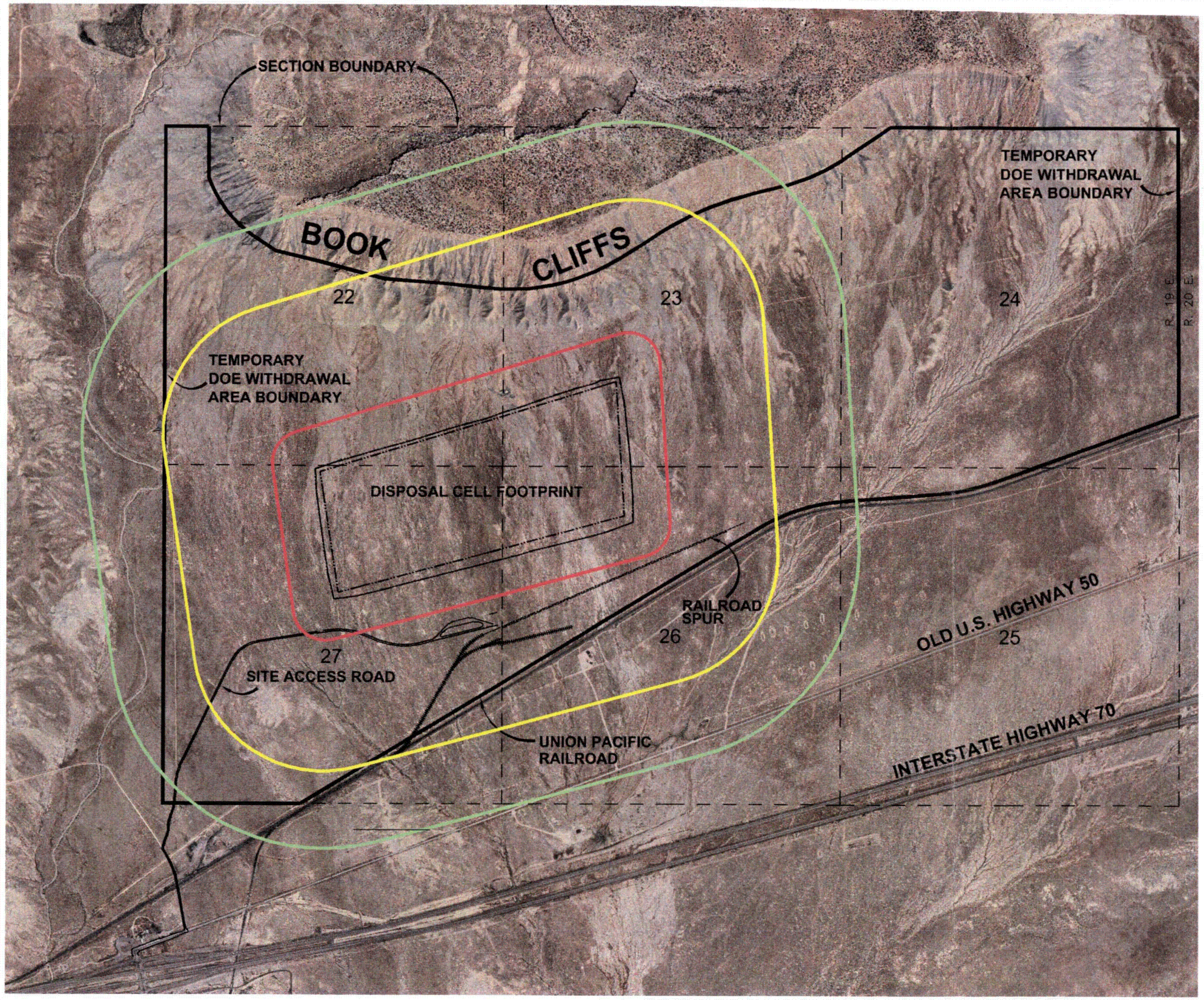
B' = thickness of the unweathered Mancos Shale (approximately 2,400 ft from top of unweathered Mancos Shale to uppermost water).

K' = hydraulic conductivity of unweathered Mancos Shale (geometric mean value; 3.5 x 10^{-8} cm/s).

h_0 = hydraulic head at perimeter of disposal cell (L).

N = recharge rate (L/T).

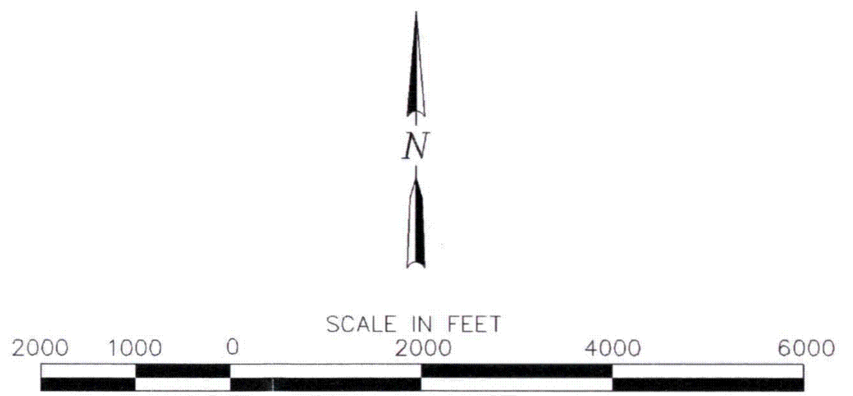
The calculations are performed using the both the upper-bounding and lower-bounding geometric mean hydraulic conductivities. As referenced in the assumptions, these hydraulic conductivities were obtained from field tests in the weathered Mancos Shale. The calculations are presented in Appendixes A2 through A4 of this section. Table 1 contains a summary of the results of these calculations. Figures 1 and 2 present the estimated limits of the conservatively estimated leachate plume as it spreads laterally.



Time	hmax (ft.)	L (ft.) NS Edge	L (ft.) EW Edge	L (ft.) Corner
10 yrs	3.69	694	718	501
200yrs	11.6	2717	2364	2042
1000yrs	16.2	3932	3635	3338

hmax = MAXIMUM HEIGHT OF SATURATED ZONE UNWEATHERED MANCOS SHALE @ CENTER OF DISPOSAL CELL

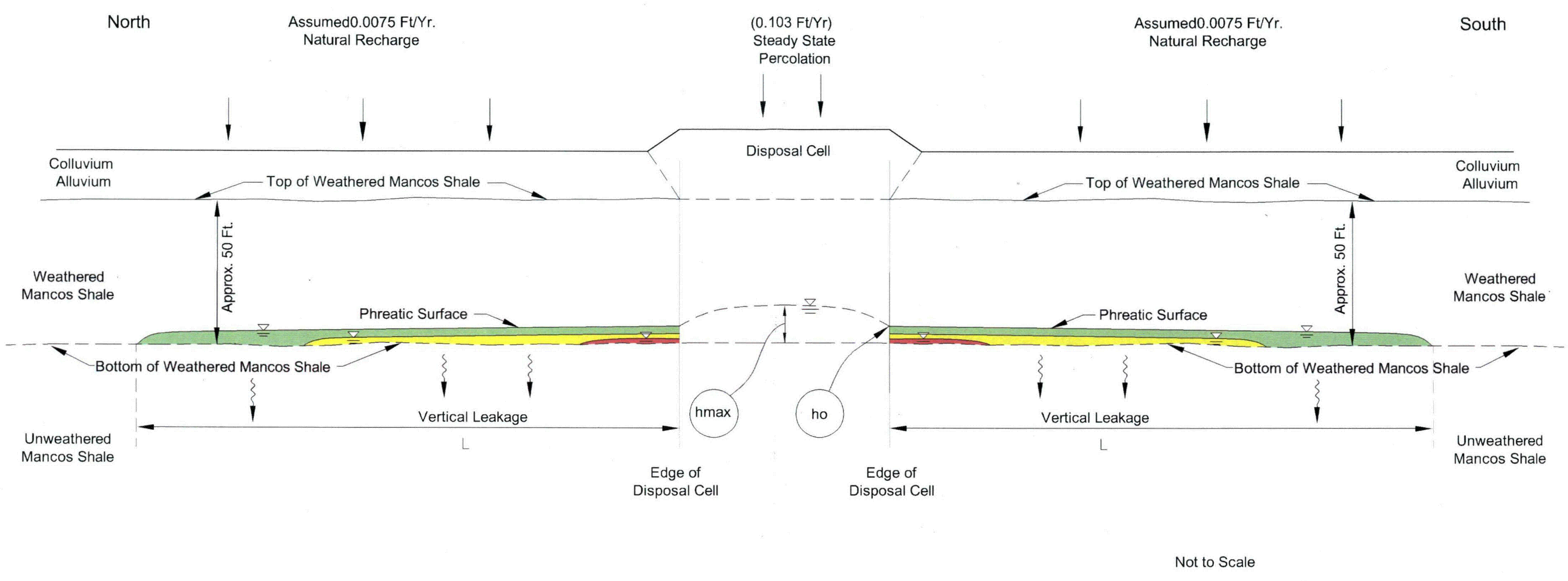
L = MAXIMUM LENGTH OF LATERAL SPREADING OF LEACHATE FROM EDGE OF DISPOSAL CELL



U.S. DEPARTMENT OF ENERGY GRAND JUNCTION, COLORADO	Work Performed by S.M. Stoller Corporation Under DOE Contract No. DE-AC01-02GJ79491
Figure 1	Approximate Limits of Lateral Spreading of Leachate Crescent Junction
DATE PREPARED: JUNE 20, 2007	FILENAME: X0220500

N:\MOA\999\0020\07\009\X02205\X0220500.DWG 06/20/07 12:41pm whitneyj

Figure 1. Approximate Limits of Lateral Spreading of Leachate, Crescent Junction



Time	hmax (ft.)	ho (ft.)	L (ft.)
10 yrs	3.69	2.58	694
200yrs	11.6	10.0	2717
1000yrs	16.2	14.5	3932

N:\MOA\999\0020\07\009\X02204\X0220400.DWG 06/20/07 1:04pm whitneyj

U.S. DEPARTMENT OF ENERGY GRAND JUNCTION, COLORADO	Work Performed by S.M. Stoller Corporation Under DOE Contract No. DE-AC01-02GJ79491
Figure 2	North-South Schematic Cross-Section of the Crescent Junction Disposal Site
DATE PREPARED: JUNE 20, 2007	FILENAME: X0220400

Figure 2. North-South Schematic Cross-Section of the Crescent Junction Disposal Site

Table 1. Summary of Conservatively Estimated Leachate-Mound Dimensions for 10, 200, and 1,000 Years After Onset of Steady Drainage through the Crescent Junction Disposal Cell Cover

Hydrologic Unit	Prediction Interval (yrs)	Hydraulic Conductivity (ft/yr)	h_{max}	Midpoint: (South and North Edge)		Midpoint: (East and West Edge)		Corner	
				h_0 (ft)	L (ft)	h_0 (ft)	L (ft)	h_0 (ft)	L (ft)
Weathered Mancos Shale	10	124	3.71	2.62	173	2.6	166	1.8	113
		2059	3.69	2.58	694	2.6	718	1.8	501
	200	124	16.4	11.7	774	11.6	762	8.3	543
		2,059	11.6	10.0	2,717	8.69	2,364	7.5	2,042
	1,000	124	32.8	25.7	1,693	23.3	1,535	18.2	1,198
		2,059	16.2	14.5	3,932	13.4	3,635	12.3	3,338

h_{max} and h_0 values were obtained using the solutions of Hantush (1967).
L = lateral length-of-spreading values were obtained using the solution of Bear (1979).

Discussion of Conservative Solution:

Down slope of the Crescent Junction Disposal Cell, Kendall Wash incises through Quaternary alluvial and colluvial mud deposits and exposes the contact with the top of the underlying weathered Mancos Shale. Drill-hole logs and borehole geophysical logs have shown that higher permeability zones in the Mancos Shale extend approximately 50 ft into the bedrock. Because gravity drainage will cause leachate to perch along the transition between the weathered and unweathered zones in the Mancos Shale, the conservative case predicts that lateral spreading will occur along this transition zone. Because the transition between weathered and unweathered bedrock is approximately 50 ft below the top of the Mancos Shale, leachate migrating through the weathered bedrock is projected to underflow all ephemeral surface water systems along its path. There is practically no risk of the plume reaching the surface. The leachate is projected to spread laterally until it is entirely consumed by vertical infiltration into the unweathered Mancos Shale.

Two conservative solutions are presented for each time horizon. Each solution corresponds to the upper and lower limits of the hydraulic conductivity in the weathered Mancos Shale. Comparison of the two solutions shows that the smaller hydraulic conductivity produces thicker mounding and shorter distances of lateral spreading. The larger hydraulic conductivity produces less vertical mounding and longer lateral spreading. When using the upper-bounding estimate of hydraulic conductivity of 2059 ft/yr (2.0×10^{-3} cm/s) in the conservative calculation, the maximum thickness of the leachate mound attained at the center of the disposal cell after 1000 years is 16.2 ft, which is small relative to the 50-ft thickness of the weathered bedrock zone. Lateral spreading of the leachate is projected to extend beyond the withdrawal area of the disposal cell, and beyond the surface drainage features of Kendall Wash; however, because the transported leachate would be located at the base of the weathered Mancos Shale, it is unlikely that the leachate plume would ever surface within Kendall Wash.

Realistic Assumptions

Under steady-state conditions, the vertical percolation rate is realistically assumed to be less than 3.5×10^{-8} cm/s. The thickness of the weathered Mancos Shale is approximately 50 ft. The leachate, if any, will migrate to the base the weathered Mancos Shale, continue migrating into the unweathered Mancos Shale, whose geometric mean hydraulic conductivity is 3.5×10^{-8} cm/s. With its downward movement unimpeded at the base of the weathered Mancos Shale, the leachate will migrate vertically beneath the disposal cell.

- If natural recharge at the Crescent Junction Disposal Site were greater than the geometric mean hydraulic conductivity of the unweathered Mancos Shale, there would be a perched water table in the in the Mancos Shale above the top of the unweathered zone.

- Because there is no perched ground water above the top of the unweathered zone of the Mancos Shale, the steady-state natural recharge must be less than 3.5×10^{-8} cm/s, which is the calculated geometric mean of the packer test data for the unweathered Mancos Shale (RAP Attachment 3, Appendix C, Table 1).
- The natural recharge conditions assumed for the Crescent Junction Site are corroborated by published recharge values, which range from 0.01 to 0.1 mm/yr (3.17×10^{-11} to 3.17×10^{-10} cm/s) for arid and semi arid regions (Walvoord and Scanlon 2004).
- If active recharge at the Crescent Junction Site were occurring, the uppermost ground water at the site would be young, relatively fresh ground water.
- RAP Attachment 3, Appendix F, shows that the uppermost ground water at the Crescent Junction Site is greater than 40,000 years in age and is highly saline; therefore, natural recharge at the Crescent Junction Site is practically zero.
- Measured saturated hydraulic conductivity of the weathered Mancos Shale radon barrier material, compacted to 92 percent of ASTM D-1557 ranges from 5.9×10^{-9} cm/s to 1.4×10^{-12} cm/s (RAP Attachment 5, Appendix K).
- The laboratory tests are an indication of the reductions in permeability that are possible when placing compacted fill; however, they are not being used as an indication of the field-scale reductions that are possible. As stated in NRC (1993), the laboratory measured values of permeability may underestimate the field-scale permeabilities by one order of magnitude or more. Nevertheless, compaction will minimize the void ratio of the engineered materials (Lambe and Whitman 1969) and the hydraulic conductivity of the material that comprises the radon barrier.
- Precipitation events at the Crescent Junction Site are infrequent.
- Fine grained desert soils at the Crescent Junction Site cause meteoric water to run off, primarily as sheet flow, and not to infiltrate. Construction of the disposal cell will cause run-on drainage to be shed laterally in perimeter channels, thereby lessening the volume of sheet flow available for infiltration. Maintaining a 2-percent grade on the top of the disposal cell will cause runoff to be shed from the top of the disposal cell, again lessening the volume of water available for infiltration.
- The steady-state vertical percolation rate through the cover of the disposal cell could be equal to or less than 7.3×10^{-9} cm/s. This rate vertical percolation is a factor of 100 less than the average annual precipitation.
- Steady-state percolation rate through the cover of the disposal cell is insufficient to form a water table above the unweathered bedrock, therefore; there will be no mounding and no lateral spreading.
- Because there is no risk of mounding or lateral spreading above the unweathered bedrock, there is no need for a calculation.

Calculation:

Not Applicable

Discussion of Realistic Assumptions:

By invoking realistic assumptions, there would be no mounding and no lateral spreading of leachate during long-term steady-state conditions. Natural recharge conditions at the site, which are also at steady state, are incapable of forming a perched water table above the unweathered bedrock. If the steady-state recharge rate were larger than it is presently, and were to exceed the geometric mean hydraulic conductivity of the unweathered bedrock, then a shallow ground water table could become perched in the weathered Mancos Shale. Drilling at the disposal site has demonstrated that there is no ground water in the weathered Mancos Shale. The ground water that was encountered at the disposal site was (1) in the unweathered Mancos Shale; (2) a minimum of 130 ft beneath the land surface; (3) very saline, indicating that it is isolated from sources of meteoric recharge; and (4) found to be in excess of 40,000 years in age, indicating that it entered the bedrock during wetter paleoclimatic conditions, possibly during Late Pleistocene time.

Average annual precipitation at the Crescent Junction Disposal Site is 9.1 inches per year (7.3×10^{-7} cm/s), most of which runs off from the land surface. Practically the entire remainder of the meteoric water is stored near the surface and evaporates shortly thereafter. Based on this information, precipitation events at the Crescent Junction Site are decidedly infrequent. Sporadic precipitation events are the primary reason that the disposal cell would seldom be exposed to wetting rains.

The Crescent Junction disposal cell will be constructed using fine-grained silts, clays, and weathered Mancos Shale to shed surface water and prevent long-term steady-state percolation. Engineered compaction of the silt, clay, and weathered Mancos Shale materials will be used to lower the hydraulic conductivity of the engineered cover. Laboratory tests of weathered Mancos Shale radon barrier material, compacted to 92 percent of ASTM D-1557, have shown that the hydraulic conductivity ranges from 5.9×10^{-9} cm/s to 1.4×10^{-12} cm/s (RAP Attachment 5, Appendix K). These test results demonstrate that the compacted weathered Mancos Shale and its residual material will be an effective barrier to steady-state infiltration.

Conclusions and Recommendations:

The conservative assumptions in this calculation are used to show how steady-state leachate could accumulate as a mound above the unweathered bedrock and migrate laterally away from the disposal cell. Figure 1 presents the area where the lateral spreading is conservatively estimated to occur. As conceptualized in this conservative calculation, the leachate becomes perched above the unweathered Mancos Shale and spreads laterally away from the disposal cell. The length of lateral spreading is equal in all directions because homogeneous and isotropic properties are assumed to exist in the weathered Mancos Shale, through which the lateral spreading occurs. Mounding of leachate beneath the footprint of the disposal cell, and lateral spreading of leachate beyond the disposal cell, are entirely contained within the 50-ft thick zone of weathered Mancos Shale.

Estimates of mounding at the center of the disposal cell, after 1,000 years of steady-state seepage, could range from approximately 16 to 33 ft, depending on the hydraulic conductivity of the weathered Mancos Shale. Mounding at the midpoint of the southern edge of the disposal cell, after 1,000 years of steady-state seepage, could range from 14 to 26 ft, depending on the hydraulic conductivity of the weathered Mancos Shale. Lateral spreading beyond the center of the southern edge of the disposal cell, after 1,000 years of steady-state seepage, could range from 1,700 to 3,900 linear ft, depending on the hydraulic conductivity of the weathered Mancos Shale. Vertical mounding of leachate and lateral spreading would occur entirely within the 50-ft-thick weathered zone of Mancos Shale, and so-called "bathtubbing" would be prevented. In addition, the risk of the leachate plume discharging to adjacent surface drainage features is unlikely.

The technical approach to this calculation is simplified yet conservative, because it does not consider several factors that could potentially affect the actual mounding and distance of lateral spreading of leachate. The factors that could limit the mounding and lateral spreading of leachate are listed below:

- Precipitation events at the Crescent Junction Site are few and far between.
- Annual precipitation at the Crescent Junction Site is 9.1 inches per year (7.3×10^{-7} cm/s).
- Most of the precipitation runs off the surface in the form of sheet flow. The small portion of the precipitation that is stored in the near surface evaporates shortly thereafter.
- Natural infiltration of meteoric water at the Crescent Junction Site is probably less than the geometric mean hydraulic conductivity of the unweathered Mancos Shale (3.5×10^{-8} cm/s).
- Steady state recharge at the site is presently insufficient to form perched ground water above the unweathered Mancos Shale.
- The design and construction of the disposal cell will be biased to forming runoff, rather than infiltration, during the infrequent precipitation events that will occur during its performance life.
- Construction of the Crescent Junction Disposal Site will reduce the steady-state recharge to less than what it is under natural conditions.
- (Walvoord and Scanlon 2004) estimate actual recharge in the desert southwestern United States to be approximately 0.01 to 0.1 mm/yr (3.17×10^{-11} to 3.17×10^{-10} cm/s).

- Assuming 1×10^{-7} cm/s to be the long-term seepage rate through the cover of the disposal cell is excessively conservative.
- After steady-state conditions are reestablished, moisture movement through the disposal cell will occur as unsaturated flow.
- Actual steady-state percolation through the disposal cell will equal, or be less than, the present steady-state percolation.
- Steady state percolation will continue to be insufficient to form perched ground water above the unweathered Mancos Shale ($<3.5 \times 10^{-8}$ cm/s).
- The contact between the weathered and unweathered Mancos Shale probably gains in elevation toward the north; consequently, the spreading of leachate, if it were to form, would be impeded as it spreads northward.
- Regardless of the direction of lateral spreading, if it were to form, the gradual consumption of leachate by vertical seepage into the underlying unweathered Mancos Shale could occur preferentially along bedding planes, which dip to the north.

These factors suggest that the realistic assumptions are more likely to influence the steady-state movement of leachate through the disposal cell. Under the influence of the realistic assumptions, and careful adherence to the quality assurance requirements mentioned here and elsewhere, steady-state leachate will percolate vertically into the Mancos Shale, without spreading laterally.

The following recommendations are proposed to assure that the disposal cell will perform as intended:

- Engineered fill should be placed to a relative compaction of 90 percent of Modified Proctor at optimum moisture ± 2 percent, and in lifts spread no thicker than 8 inches.
- Field engineers representing the DOE will be responsible for quality assurance oversight of all aspects of construction and shall have reporting responsibilities and the authority to require rework of areas where engineered fill is being placed outside the acceptable tolerances.
- Quality control will be exercised using nuclear density testing equipment, subject to calibration and third party verification.
- Up to three piezometers (standpipes) are recommended to monitor the accumulation of leachate within the footprint of the disposal cell, during the transient drainage period, to verify that bathtubbing dissipates as steady-state conditions are achieved. In addition, the piezometers may be used to monitor subsurface hydrologic conditions after steady-state drainage is achieved.

Computer Source:

Not applicable.

Appendix A

Attachment A1

Stoller

Calculation of height of mound @ center of disposal cell (0,0)

JOB NO. NA DATE 5-31-07

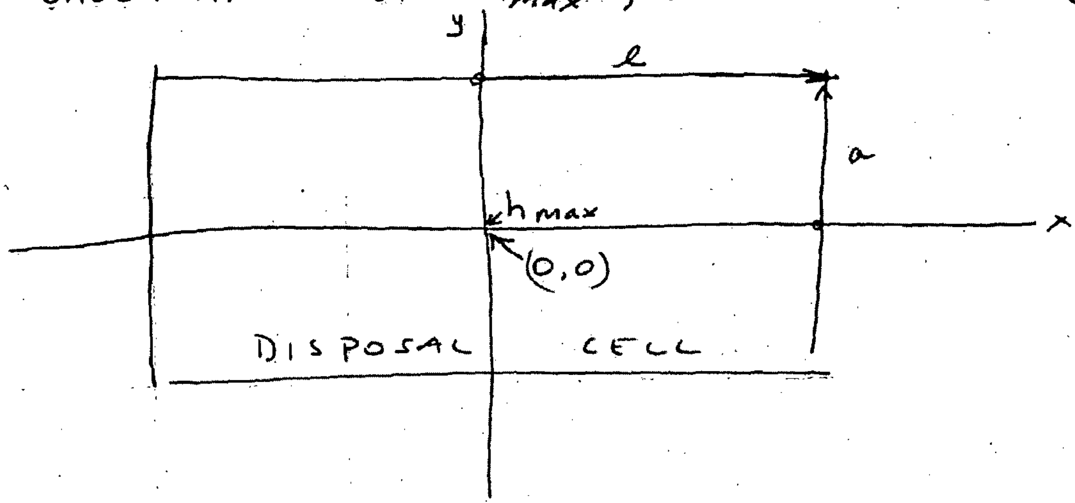
JOB NAME MOAB-RAP

PREPARED mw CHECKED

SHEET NO. A1-1 OF 5

Summary Page:

CALCULATION OF h_{max}, which occurs @ (0,0)



K = 124. ft/yr @ 10 yrs ; h = 3.71 ft

K = 2059 ft/yr @ 10 yrs ; h = 3.69 ft

K = 124 ft/yr @ 200 yrs ; h = 16.4 ft

K = 2059. ft/yr @ 200 yrs ; h = 11.6 ft

K = 124 ft/yr @ 1000 yrs ; h = 32.8 ft

K = 2059. ft/yr @ 1000 yrs ; h = 16.2 ft

Stoller

Calculate flow parameters in Hantush 1967 solution.

JOB NO. N/A

JOB NAME: MOAB RAP

PREPARED: MWE

SHEET NO. A1-7 OF 5

For $K = 124$ ft/yr $(1.2 \times 10^{-4}$ cm/s) → geometric mean AEP Data

Parameter ν : $\nu = \frac{K\bar{b}}{\varepsilon}$

where K = hydraulic conductivity [L/T]

$\bar{b}$ = constant of linearization (L)

$\boxed{\bar{b} \simeq 1 \text{ ft (assumed value)}}$

ε = specific yield (dim)

$\boxed{\varepsilon \simeq 0.15 \text{ (dim) assumed value}}$

$$\therefore \nu = \frac{(124 \text{ ft/yr}) \cdot (1 \text{ ft})}{0.15}$$

$$\boxed{\nu = 827 \text{ ft}^2/\text{yr}}$$

... And $\sqrt{4\nu t} = \sqrt{4(827 \text{ ft}^2/\text{yr}) \cdot t(\text{yrs})}$

- @ 10 yrs = 182 ft
- @ 200 yrs = 813 ft
- @ 1000 yrs = 1819 ft

For $K = 2059$ ft/yr $(1.99 \times 10^{-3}$ cm/s) → geometric mean of packer test data

where K = hydraulic conductivity [L/T]

$\bar{b}$ = constant of linearization [L]

$\boxed{\bar{b} \simeq 1 \text{ ft}}$ – assumed value

ε = specific yield

$\boxed{\varepsilon \simeq 0.15 \text{ (dim) assumed value}}$

$$\therefore \nu = \frac{(2059 \text{ ft/yr}) \cdot (1 \text{ ft})}{0.15}$$

$$\boxed{\nu = 13{,}727 \text{ ft}^2/\text{yr}}$$

... And $\sqrt{4\nu t} = \sqrt{4(13{,}727 \text{ ft}^2/\text{yr}) \cdot t(\text{yrs})}$

- @ 10 yrs = 741 ft
- @ 200 yrs = 3314 ft
- @ 1000 yrs = 7410 ft

For conservative assumptions:

ω = percolation rate $(1 \times 10^{-7}$ cm/s)

$$\boxed{\omega = 0.103 \text{ ft/yr}}$$

N/A 5-31-07

MOAB-RAP

A1-3 5

Calculate height of mound @ center of disposal cell (0,0) @ 10yrs (Conservative Assumptions)

- Calculate h & h_{max} for Quadrant I, obtain remaining unknowns by symmetry.

h_{max} (0,0)

$$h^2 = \frac{2w}{K} \nu t \, S^*\left(\overset{(\alpha)}{\frac{l}{\sqrt{4\nu t}}}, \overset{(\beta)}{\frac{a}{\sqrt{4\nu t}}}\right)$$

where $\sqrt{4\nu t} = 182$ @ 10yrs (see sheet A1-1)

- For K = 124 ft/yr & 10 yrs

$$h^2 = \frac{2(0.103 \text{ ft/yr})}{(124 \text{ ft/yr})}(827 \text{ ft}^2/\text{yr})(10\text{ yr}) \, S^*\left(\frac{2500 \text{ ft}}{182 \text{ ft}}, \frac{1100 \text{ ft}}{182 \text{ ft}}\right)$$

$$h^2 = 13.74 \text{ ft}^2 S^*(13.7, 6.04)$$

from Hantush 1967; p.233 ... if $\alpha \geq 3$ and $\beta \geq 3$, $S^*(\alpha,\beta) \cong 1$

$$\therefore \quad h^2 = 13.74 \text{ ft}^2$$

$$h_{max} = 3.71 \text{ ft} \text{ @ 10yrs for } K = 124 \text{ ft/yr}$$

For K = 2059 ft/yr @ 10yrs ... $\sqrt{4\nu t} = 741$ ft @ 10yrs (see sheet A1-1)

$$h^2 = \frac{2(0.103 \text{ ft/yr})}{2059 \text{ ft/yr}}(13{,}727 \text{ ft}^2/\text{yr})(10\text{yr}) \, S^*\left(\frac{2500 \text{ ft}}{741 \text{ ft}}, \frac{1100 \text{ ft}}{741 \text{ ft}}\right)$$

$$h^2 = 13.73 \text{ ft}^2 \, S^*(3.37, 1.48)$$

per Hantush 1967, $S^*(\alpha,\beta) \simeq 1 - 4i^2\text{erfc}(\beta)$ if $\alpha \geq 3$

$$h^2 = 13.73 \text{ ft}^2 (0.991)$$

$$h^2 = 13.6 \text{ ft}^2$$

$$h = 3.69 \text{ ft}$$

per Carslaw & Jaeger App II, TABLE I

for $\beta = 1.48$, $1 - 4i^2\text{erfc}(\beta) = 1 - 0.009 = 0.991$

N/A 5-31-07

MOAB-RAP

A1-4 5

Calculate height of Mound @ center of disposal cell (0,0) @ 200yrs (Conservative Assumptions)

- Calculate h / h_{max} for Quadrant 1, obtain remaining unknowns by symmetry.

h_{max} (0,0) $$h^2 = \frac{2w}{K} \nu t \; S^*\left(\underset{(\alpha)}{\frac{l}{\sqrt{4\nu t}}}, \underset{(\beta)}{\frac{a}{\sqrt{4\nu t}}}\right).$$

where $\sqrt{4\nu t}$ = 813 @ 200yrs (see sheet A1-1)

- For K = 124 ft/yr & 200 yrs

$$h^2 = \frac{2\,(0.103\ ft/yr)}{(124\ ft/yr)} \left(827\ ft^2/yr\right)(200yr)\; S^*\left(\frac{2500\ ft}{813\ ft}, \frac{1100\ ft}{813\ ft}\right)$$

$$h^2 = 274.8\ ft^2\, S^*(3.075,\ 1.35)$$

Per Hantush 1967; $S^*(\alpha,\beta) \simeq 1 - 4i^2erfc(\beta)$ if $\alpha \geq 3$
Per Carslaw & Jaeger, Appx II, Table 1
for $\beta = 1.35$, $1 - 4i^2erfc(\beta) = 1 - 0.015 = 0.985$

$$h^2 = 274.8\ ft^2(0.985)$$

$$\therefore \quad h^2 = 270\ ft^2$$

h_{max} = 16.4 ft @ 200 yrs for K = 124 ft/yr

For K = 2059 ft/yr @ 200 yrs ... $\sqrt{4\nu t}$ = 3314 ft @200yrs (see sheet A1-1)

$$h^2 = \frac{2\,(0.103\ ft/yr)}{2059\ ft/yr} \left(13,727\ ft^2/yr\right)(200\ yr)\; S^*\left(\frac{2500\ ft}{3314\ ft}, \frac{1100\ ft}{3314\ ft}\right)$$

$$h^2 = 274.7\ ft^2\ S^*(0.754,\ 0.332)$$ per Hantush 1967, Table (p. 230)

$$h^2 = 274.7\ ft^2\,(0.49)$$

$$h^2 = 134.6\ ft^2$$

$$h = 11.6\ ft$$

N/A 5-31-07

MOAB-RAP

A1-5 5

Calculate height of mound @ center of disposal cell (0,0) @1000 yrs (Conservative Assumptions)

- Calculate h / h_{max} for Quadrant I, obtain remaining unknowns by symmetry.

h_{max} (0,0) $$h^2 = \frac{2w}{K} \nu t \; S^*\left(\overset{(\alpha)}{\frac{l}{\sqrt{4\nu t}}} , \overset{(\beta)}{\frac{a}{\sqrt{4\nu t}}}\right)$$

where $\sqrt{4\nu t} = 1819$ ft (see sheet A1-1)

- For $K = 124$ ft/yr & 1000 yrs

$$h^2 = \frac{2\,(0.103 \text{ ft/yr})}{(124 \text{ ft/yr})} \left(827 \text{ ft}^2/\text{yr}\right)(1000\text{yr}) \; S^*\left(\frac{2500 \text{ ft}}{1819 \text{ ft}} , \frac{1100 \text{ ft}}{1819 \text{ ft}}\right)$$

$$h^2 = 1374 \text{ ft}^2 \, S^*\left(1.37 , 0.605\right)$$

from Hantush 1967; Table (p. 230)

$$\therefore \quad h^2 = 1075 \text{ ft}^2 \quad 0.782$$

h_{max} = 32.8 ft @ 1000 yrs for K = 124 ft/yr

For K = 2059 ft/yr @ 1000 yrs ... $\sqrt{4\nu t}$ = 7410 ft @ 1000 yrs (see sheet A1-1)

$$h^2 = \frac{2\,(0.103 \text{ ft/yr})}{2059 \text{ ft/yr}} \left(13{,}727 \text{ ft}^2/\text{yr}\right)(1000 \text{ yr}) \; S^*\left(\frac{2500 \text{ ft}}{7410 \text{ ft}} , \frac{1100 \text{ ft}}{7410 \text{ ft}}\right)$$

$$h^2 = 1373 \text{ ft}^2 \; S^*\left(0.337 , 0.148\right)$$ per Hantush 1967, Table (p. 230)

$$h^2 = 1373 \text{ ft}^2 (0.192)$$

$$h^2 = 263.6 \text{ ft}^2$$

$$h = 16.2 \text{ ft}$$

Attachment A2

Stoller

Calculate height of mound @ south & north midpoint of cell

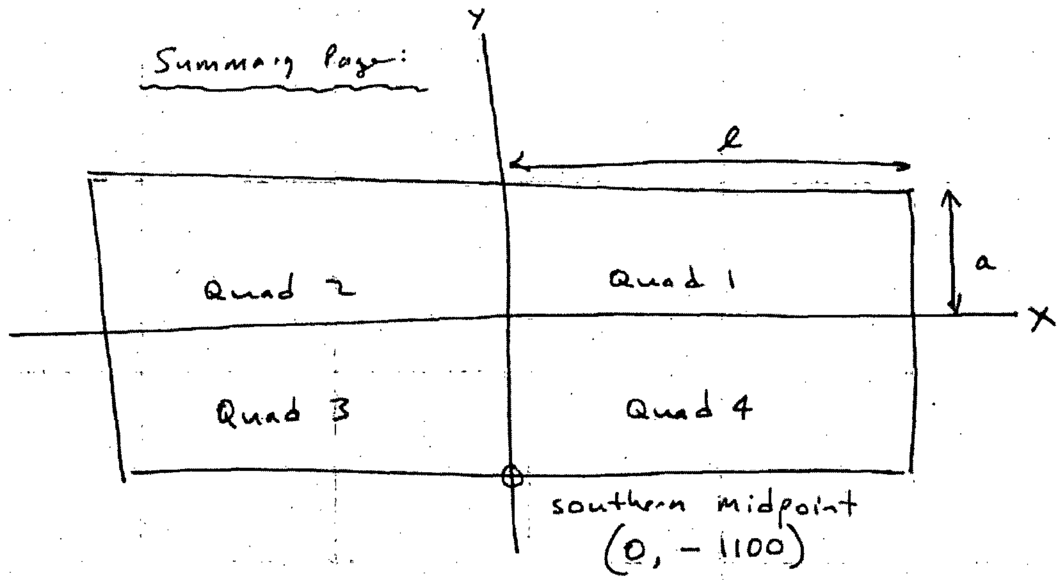
JOB NO. N/A DATE 5-31-07

JOB NAME MOAB RAP

PREPARED [illegible] REVIEWED

SHEET NO. A2-1 OF 13

Summary Page:



- Calculate heads for southern midpoint
- obtain heads for northern midpoint by symmetry.

K = 124 ft/yr @ 10 yrs ; h = 2.62 ft ; L = 173 ft

K = 2059 ft/yr @ 10 yrs ; h = 2.58 ft ; L = 694 ft

K = 124 ft/yr @ 200 yrs ; h = 11.7 ft ; L = 774 ft

K = 2059 ft/yr @ 200 yrs ; h = 10.0 ft ; L = 2717 ft

K = 124 ft/yr @ 1000 yrs ; h = 25.7 ft ; L = 1693 ft

K = 2059 ft/yr @ 1000 yrs ; h = 14.5 ft ; L = 3932 ft

N/A 5-31-07

MOAB RAP

A2-2 13

Mounding @ southern midpoint of cell @ 10 yrs for K = 124 ft/yr

K = 124 ft/yr

Compute $h_{(x,y)}$ @ 10 yrs :

$$h^2 = \frac{\omega}{2K} vt \cdot \left\{ S^* \left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}} \right) + S^* \left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}} \right) + S^* \left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}} \right) \right.$$

$$\boxed{\text{Coord location } (x,y) = (0, -1100)} \qquad \left. + S^* \left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}} \right) \right\}$$

A, B, C, D

Recall from Sheet A1-2 @10yrs, $\sqrt{4vt}$ = 182 ft

A $S^* \left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}} \right) = S^* \left(\frac{2500 \cancel{ft}}{182 \cancel{ft}}, \frac{0 \cancel{ft}}{182 \cancel{ft}} \right) = S^*(13.7, 0)$ = 0 (per Hantush)

B $S^* \left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}} \right) = S^* \left(\frac{2500 \cancel{ft}}{182 \cancel{ft}}, \frac{2200 \cancel{ft}}{182 \cancel{ft}} \right) = S^*(13.7, 12.1)$ = 1 (per Hantush)

C $S^* \left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}} \right) = S^* \left(\frac{2500 \cancel{ft}}{182 \cancel{ft}}, \frac{0 \cancel{ft}}{182 \cancel{ft}} \right) = S^*(13.7, 0)$ = 0 (per Hantush)

D $S^* \left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}} \right) = S^* \left(\frac{2500 \cancel{ft}}{182 \cancel{ft}}, \frac{2200 \cancel{ft}}{182 \cancel{ft}} \right) = S^*(13.7, 12.1)$ = 1 (per Hantush)

$$h^2 = \frac{0.103 \cancel{ft/yr}}{2\,(124 \cancel{ft/yr})} \left(827\ ft^2/\cancel{yr}\right)\left(10 \cancel{yr}\right)\left(\overset{A}{0} + \overset{B}{1} + \overset{C}{0} + \overset{D}{1}\right)$$

h^2 = 6.87 ft^2

h = 2.62 ft

N/A

5-31-07

MOAB RAP

Mounding @ southern midpoint of cell @ 200 yrs for K = 2059 ft/yr.

A2-5 13

$K = 2059 \ ft/yr$

Compute $h_{(x,y)}$ @ 200 yrs:

$$h^2 = \frac{\omega}{2K} \nu t \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) \right\}$$

A B C D

$\boxed{\text{Coord. location } (0, -1100)}$

Recall from Sheet A1-2
$\sqrt{4\nu t} = 3314 \ ft$
& $\nu = 13{,}727 \ ft^2/yr$

A $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \ ft}{3314 \ ft}, \frac{0 \ ft}{3314 \ ft}\right) = S^*(0.754, 0)$
$= 0$ (per Hantush)

B $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \ ft}{3314 \ ft}, \frac{2200 \ ft}{3314 \ ft}\right) = S^*(0.754, 0.664)$
$\simeq 0.73$ (per Hantush)

C $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \ ft}{3314 \ ft}, \frac{0 \ ft}{3314 \ ft}\right) = S^*(0.754, 0)$
$\simeq 0$ (per Hantush)

D $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \ ft}{3314 \ ft}, \frac{2200 \ ft}{3314 \ ft}\right) = S^*(0.754, 0.664)$
$\simeq 0.73$ (per Hantush)

$$h^2 = \frac{0.103 \ ft/yr}{2\,(2059 \ ft/yr)} (13{,}727 \ ft^2/yr)(200 \ yr)\,(\overset{A}{0} + \overset{B}{0.73} + \overset{C}{0} + \overset{D}{0.73})$$

$h^2 = 100.2 \ ft^2$

$h = 10.0 \ ft$

Mounding @ southern midpoint of cell @ 1000 yrs for K = 124 ft/yr.

$K = 124 \text{ ft/yr}$

Compute $h_{(x,y)}$ @ 1000 yrs:

$$h^2 = \frac{\omega}{2K} \nu t : \left\{ S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) \right\}$$

A B C D

$\boxed{\text{Coordinate Location } 0, -1100}$

Recall from Sheet A1-2
$\sqrt{4\nu t} = 1819 \text{ ft}$
& $\nu = 827$

(A) $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \text{ ft}}{1819 \text{ ft}}, \frac{0 \text{ ft}}{1819 \text{ ft}}\right) = S^*(1.37, 0) \simeq 0$ (per Hantush)

(B) $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \text{ ft}}{1819 \text{ ft}}, \frac{2200 \text{ ft}}{1819 \text{ ft}}\right) = S^*(1.37, 1.21) \simeq 0.96$ (per Hantush)

(C) $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \text{ ft}}{1819 \text{ ft}}, \frac{0 \text{ ft}}{1819 \text{ ft}}\right) = S^*(1.37, 0) \simeq 0$ (Hantush)

(D) $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{2500 \text{ ft}}{1819 \text{ ft}}, \frac{2200 \text{ ft}}{1819 \text{ ft}}\right) = S^*(1.37, 1.21) = 0.96$ (Hantush)

$$h^2 = \frac{0.103 \text{ ft/yr}}{2\,(124 \text{ ft/yr})} \left(827 \text{ ft}^2/\text{yr}\right)(1000 \text{ yr}) \left(\overset{A}{0} + \overset{B}{0.96} + \overset{C}{0} + \overset{D}{0.96}\right)$$

$h^2 = 659 \text{ ft}^2$

$h = 25.7 \text{ ft}$

N/A 5-31-07

MOAB RAP

[illegible]

A2-7 13

Mounding at southern midpoint of cell
@1000 yrs for K = 2059. ft/yr

K = 2059 ft/yr

Compute $h_{(x,y)}$ @ 1000 yrs:

$$h^2 = \frac{\omega}{2K} vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

(A) (B) (C) (D)

$\boxed{\text{Coord Loc. } (0, -1100)}$

Recall from sheet A1-2
$\sqrt{4vt}$ = 7410 ft
& v = 13,727 ft²/yr

(A) $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{2500\ \cancel{ft}}{7410\ \cancel{ft}}, \frac{0\ \cancel{ft}}{7410\ \cancel{ft}}\right) = S^*(0.337, 0)$
$\simeq 0$ (Hantush)

(B) $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{2500\ \cancel{ft}}{7410\ \cancel{ft}}, \frac{2200\ \cancel{ft}}{7410\ \cancel{ft}}\right) = S^*(0.337, 0.297)$
$\simeq 0.305$ (Hantush)

(C) $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{2500\ \cancel{ft}}{7410\ \cancel{ft}}, \frac{0\ \cancel{ft}}{7410\ \cancel{ft}}\right) = S^*(0.337, 0)$
$\simeq 0$ (Hantush)

(D) $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{2500\ \cancel{ft}}{7410\ \cancel{ft}}, \frac{2200\ \cancel{ft}}{7410\ \cancel{ft}}\right) = S^*(0.337, 0.297)$
$\simeq 0.305$ (Hantush)

$$h^2 = \frac{0.103\ \cancel{ft/yr}}{2\ (2059\ \cancel{ft/yr})} (13{,}727\ ft^2/\cancel{yr}) (1000\ \cancel{yrs}) \left(\underset{A}{0} + \underset{B}{0.305} + \underset{C}{0} + \underset{D}{0.305} \right)$$

h^2 = 209 ft²

h = 14.5 ft

Length of Spreading of Leachate @ 10yrs from edge of disposal cell
↑ southern midpoint (0, -1100)

$$L = \frac{3}{A}\left[\left(\frac{2}{3}A h_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67\times10^{4} \text{ yr}$$

$$A = \frac{1}{(124 \text{ ft/yr})(6.67\times10^{4}\text{ yr})}$$

$$\boxed{A = 1.21\times10^{-7}\text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5\times10^{-3}\text{ ft/yr} \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400\text{ ft} - (7.5\times10^{-3}\text{ ft/yr} \cdot 6.67\times10^{4}\text{ yr})}{(124\text{ ft/yr})(6.67\times10^{4}\text{ yr})}$$

$$\boxed{B = 2.30\times10^{-4}\text{ dim}}$$

$$L = \frac{3}{1.21\times10^{-7}\text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(1.21\times10^{-7}\text{ ft}^{-1} \cdot 2.62\text{ ft}\right) + 2.30\times10^{-4}\right)^{1/2} + \left(2.30\times10^{-4}\right)^{1/2}\right.$$

$$L = \frac{3}{1.21\times10^{-7}\text{ ft}^{-1}}\left(1.5173\times10^{-2} - 1.5166\times10^{-2}\right)$$

$L = 173$ ft

Stoller

Length of Spreading of Leachate @ 200 yrs from edge of disposal cell
southern midpoint $(0, -1100)$

N/A

Moab RAP

5-31-07

A2-9 13

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$

from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4 \text{ yr}$$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 11.7 \text{ ft}) + 2.30 \times 10^{-4}\right)^{1/2} + (2.30 \times 10^{-4})^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.520 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 774$ ft

Length of Spreading of Leachate @ 1000yrs from edge of disposal cell
southern midpoint (0, -1100)

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4$ yr

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \cong N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.03 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 25.7 \text{ ft}\right) + 2.30 \times 10^{-4}\right)^{1/2} + \left(2.30 \times 10^{-4}\right)^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.5234 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 1693$ ft

Length of Spreading of Leachate (@ 10 yrs) from edge of disposal cell
↑ southern edge (0, 1100)

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4$ yr

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \simeq N}$

$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$

$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 2.58 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.716 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$L = 694$ ft

Stoller

Length of Spreading of Leachate from edge of disposal cell

N/A 5-31-07

MOAB RAP

mm

42-12 13

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$

from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059.$ ft/yr

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

$$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^{4} \text{ yr}$$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(2059. \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^{4} \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 10.0 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7214 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$$L = 2717 \text{ ft}$$

Length of Spreading of Leachate from edge of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^{4} \text{ yr}$$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^{4} \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 14.5 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7243 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$$L = 3932 \text{ ft}$$

Attachment A3

Stoller

Calculate height of mound @ west & east midpoint of cell Bdy

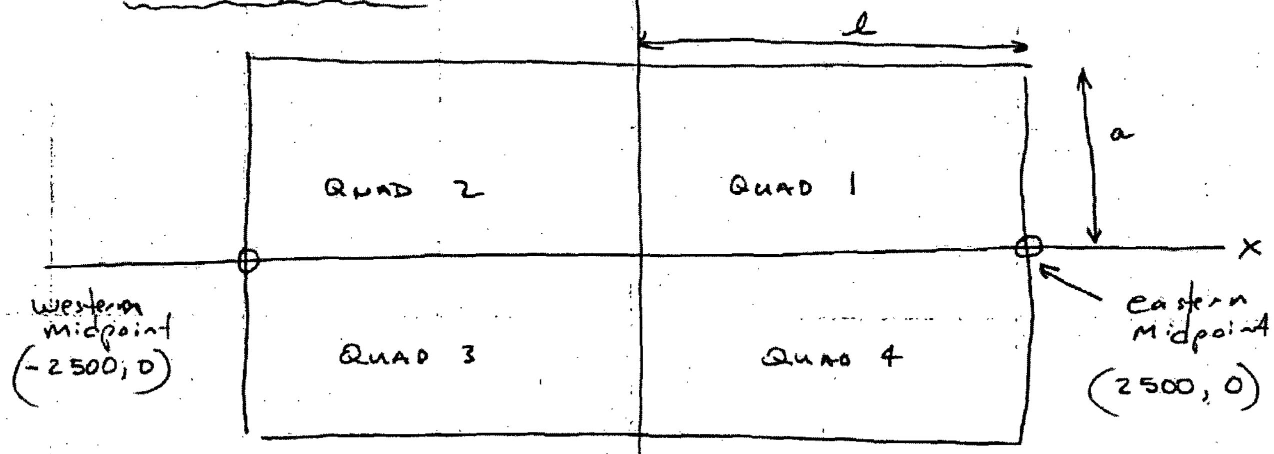
JOB NO. N/A DATE 5-31-07

JOB NAME: MOAB-RAP

PREPARED: ML REVIEWED:

SHEET NO. A3-1 OF 13

Summary Page



- Calculate heads for eastern midpoint
- obtain western midpoint heads by symmetry.

K = 124 ft/yr @ 10 yrs ; h = 2.6 ft L = 166 ft

K = 2059 ft/yr @ 10 yrs ; h = 2.6 ft ; L = 718 ft.

K = 124 ft/yr @ 200 yrs ; h = 11.6 ft ; L = 762 ft

K = 2059 ft/yr @ 200 yrs ; h = 8.69 ; L = 2364 ft.

K = 124 ft/yr @ 1000 yrs ; h = 23.3 ft ; L = 1535 ft.

K = 2059 ft/yr @ 1000 yrs ; h = 13.4 ft ; L = 3635 ft

N/A 5-31-07

MOAB RAP

ML

A3-2 13

Mounding @ east mid-point of cell @ 10 yrs for Condition; K = 124 ft/yr

K = 124 ft/yr

Compute $h_{(x,y)}$ @ 10 yrs:

$$h^2 = \frac{\omega}{2K} \nu t \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) \right\}$$

(A) (B) (C) (D)

Location (x, y) = (2500, 0)

Recall from Sheet A1-2
$\sqrt{4\nu t} = 182$ ft
& $\nu = 827$ ft²/yr

(A) $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \cancel{ft}}{182 \cancel{ft}}, \frac{1100 \cancel{ft}}{182 \cancel{ft}}\right) = S^*(27.5, 6.04)$
= 1 (per Hantush)

(B) $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \cancel{ft}}{182 \cancel{ft}}, \frac{1100 \cancel{ft}}{182 \cancel{ft}}\right) = S^*(27.5, 6.04)$
= 1 (per Hantush)

(C) $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \cancel{ft}}{182 \cancel{ft}}, \frac{1100 \cancel{ft}}{182 \cancel{ft}}\right) = S(0, 6.04)$
= 0 (per Hantush)

(D) $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \cancel{ft}}{182 \cancel{ft}}, \frac{1100 \cancel{ft}}{182 \cancel{ft}}\right) = S(0, 6.04)$
= 0 (per Hantush)

$$h^2 = \frac{0.103 \cancel{ft/yr}}{2\,(124 \cancel{ft/yr})} \left(827\ ft^2/\cancel{yr}\right)\left(10\ \cancel{yr}\right)\left(\overset{A}{1} + \overset{B}{1} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 6.87$ ft²

$h = 2.6$ ft

Mounding @ east midpoint of cell
@ 10 yrs for condition $K = 2059$ ft/yr.

$K = 2059$ ft/yr

Compute $h_{(x,y)}$ @ 10 yrs :

$$h^2 = \frac{\omega}{2K} vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

$\boxed{\text{coordinate } (x,y) = (2500, 0)}$

Recall from sheet A1-2 @ 10 yrs
$\sqrt{4vt} = 741$ ft
$v = 13{,}727$ ft²/yr

A $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \cancel{ft}}{741 \cancel{ft}}, \frac{1100 \cancel{ft}}{741 \cancel{ft}}\right) = S^*(6.75, 1.48) \cong 1$ (per Hantush)

B $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \cancel{ft}}{741 \cancel{ft}}, \frac{1100 \cancel{ft}}{741 \cancel{ft}}\right) = S^*(6.75, 1.48) \cong 1$ (per Hantush)

C $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \cancel{ft}}{741 \cancel{ft}}, \frac{1100 \cancel{ft}}{741 \cancel{ft}}\right) = S^*(0, 1.48) \cong 0$ per Hantush

D $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \cancel{ft}}{741 \cancel{ft}}, \frac{1100 \cancel{ft}}{741 \cancel{ft}}\right) = S^*(0, 1.48) \cong 0$ (per Hantush)

$$h^2 = \frac{0.103 \text{ ft/yr}}{2\,(2059 \text{ ft/yr})} \left(13{,}727 \text{ ft}^2/\text{yr}\right)(10 \text{ yr}) \left(\overset{A}{1} + \overset{B}{1} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 6.86$ ft²

$h = 2.6$ ft

N/A 5-31-07

MOAB RAP

A3-4 13

Mounding @ east midpoint of cell
@ 200 yrs for condition K = 124 ft/yr.

K = 124 ft/yr

Compute $h_{(x,y)}$ @ 200 yrs :

$$h^2 = \frac{\omega}{2K} \nu t \cdot \left\{ S^* \left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}} \right) + S^* \left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}} \right) + S^* \left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}} \right) \right.$$

$$\left. + S^* \left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}} \right) \right\}$$

$\boxed{\text{Coord location: } (x,y) = (2500, 0)}$

Recall from Sheet A1-2 ...
$\sqrt{4\nu t} = 813$ ft
$\nu = 827\ ft^2/yr$

A $S^* \left(\frac{2500 + x}{\sqrt{4\nu t}}, \frac{1100 + y}{\sqrt{4\nu t}} \right) = S^* \left(\frac{5000 \text{ ft}}{813 \text{ ft}}, \frac{1100 \text{ ft}}{813 \text{ ft}} \right) = S^*(6.15, 1.35)$
$\cong$ 0.9861 (per Hantush, of Carslaw & Jaeger)

B $S^* \left(\frac{2500 + x}{\sqrt{4\nu t}}, \frac{1100 - y}{\sqrt{4\nu t}} \right) = S^* \left(\frac{5000 \text{ ft}}{813 \text{ ft}}, \frac{1100 \text{ ft}}{813 \text{ ft}} \right) = S^*(6.15, 1.35)$
$\cong$ 0.986 (per Hantush, of Carslaw & Jaeger)

C $S^* \left(\frac{2500 - x}{\sqrt{4\nu t}}, \frac{1100 + y}{\sqrt{4\nu t}} \right) = S^* \left(\frac{0}{813}, \frac{1100}{813} \right) = S^*(0, 1.35)$
$\cong$ 0 (per Hantush)

D $S^* \left(\frac{2500 - x}{\sqrt{4\nu t}}, \frac{1100 - y}{\sqrt{4\nu t}} \right) = S^* \left(\frac{0}{813}, \frac{1100}{813} \right) = S^*(0, 1.35)$
$\cong$ 0 (per Hantush)

$$h^2 = \frac{0.103 \text{ ft/yr}}{2\,(124 \text{ ft/yr})} \left(827 \ ft^2/yr \right) \left(200 \text{ yr} \right) \left(\overset{A}{0.986} + \overset{B}{0.986} + \overset{C}{0} + \overset{D}{0} \right)$$

$h^2 = 135\ ft^2$

$h = 11.6$ ft

Mounding @ east midpoint of cell @ 200 yrs for condition: $K = 2059$ ft/yr

$K = 2059$ ft/yr

Compute $h_{(x,y)}$ @ 200 yrs:

$$h^2 = \frac{\omega}{2K} \nu t \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) \right\}$$

$$\boxed{(x,y) \text{ location}: (2500, 0)}$$

Recall from Sheet A1-2
$\sqrt{4\nu t} = 3314$ ft
& $\nu = 13,727$ ft²/yr

A $$S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \text{ ft}}{3314 \text{ ft}}, \frac{1100 \text{ ft}}{3314 \text{ ft}}\right) = S^*(1.51, 0.332) \cong 0.55 \text{ (per Hantush)}$$

B $$S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \text{ ft}}{3314 \text{ ft}}, \frac{1100 \text{ ft}}{3314 \text{ ft}}\right) = S^*(1.51, 0.332) \simeq 0.55 \text{ (per Hantush)}$$

C $$S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \text{ ft}}{3314 \text{ ft}}, \frac{1100 \text{ ft}}{3314 \text{ ft}}\right) = S^*(0, 0.332) = 0 \text{ (per Hantush)}$$

D $$S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \text{ ft}}{3314 \text{ ft}}, \frac{1100 \text{ ft}}{3314 \text{ ft}}\right) = S^*(0, 0.332) = 0 \text{ (per Hantush)}$$

$$h^2 = \frac{0.103 \text{ ft/yr}}{2\,(2059 \text{ ft/yr})} (13,727 \text{ ft}^2/\text{yr})(200 \text{ yr}) \left(\overset{A}{0.55} + \overset{B}{0.55} + \overset{C}{0} + \overset{D}{0}\right)$$

$$h^2 = 75.5 \text{ ft}^2$$

$$h = 8.69 \text{ ft}$$

N/A 5-31-07

MOAB RAP

A3-6 13

Mounding @ east mid point of cell @ 1000 yrs for condition ; K = 124 ft/yr

$K = 124 \ ft/yr$

Compute $h_{(x,y)}$ @ 1000 yrs :

$$h^2 = \frac{\omega}{2K} \, vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

A B C D

$$\boxed{\text{Coord Location } (x, y) = (2500, 0)}$$

Recall from Sheet A1-2 : $\sqrt{4vt} = 1819 \ ft$ & $v = 827 \ ft$

A $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \ \cancel{ft}}{1819 \ \cancel{ft}}, \frac{1100 \ \cancel{ft}}{1819 \ \cancel{ft}}\right) = S^*(2.75, 0.605) \simeq 0.79$ (per Hantush)

B $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \ \cancel{ft}}{1819 \ \cancel{ft}}, \frac{1100 \ \cancel{ft}}{1819 \ \cancel{ft}}\right) = S^*(2.75, 0.605) \simeq 0.79$ (per Hantush)

C $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \ \cancel{ft}}{1819 \ \cancel{ft}}, \frac{1100 \ \cancel{ft}}{1819 \ \cancel{ft}}\right) = S^*(0, 0.605) = 0$ (per Hantush)

D $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \ \cancel{ft}}{1819 \ \cancel{ft}}, \frac{1100 \ \cancel{ft}}{1819 \ \cancel{ft}}\right) = S^*(0, 0.605) = 0$ (per Hantush)

$$h^2 = \frac{0.103 \ \cancel{ft/yr}}{2 \ (124 \ \cancel{ft/yr})} \left(827 \ ft^2/\cancel{yr}\right)(1000 \ \cancel{yr}) \left(\overset{A}{0.79} + \overset{B}{0.79} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 542 \ ft^2$

$h = 23.3 \ ft.$

mounding @ east mid point of cell
@ 1000 yrs for condition K = 2059 ft/yr

K = 2059 ft/yr

Compute $h_{(x,y)}$ @ 1000 yrs:

$$h^2 = \frac{\omega}{2K}\,\nu t \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) \right\}$$

(A) (B) (C) (D)

$$\boxed{\begin{array}{c}\text{Coord loc } (x,y) \\ = (2500, 0)\end{array}}$$

Recall from sheet A1-2
$\sqrt{4\nu t} = 7410$ ft
$\nu = 13{,}727$ ft²/yr

(A) $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \text{ ft}}{7410 \text{ ft}}, \frac{1100 \text{ ft}}{7410 \text{ ft}}\right) = S^*(0.675, 0.148)$
$\cong 0.26$ (per Hantush)

(B) $S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \text{ ft}}{7410 \text{ ft}}, \frac{1100 \text{ ft}}{7410 \text{ ft}}\right) = S^*(0.675, 0.148)$
$\simeq 0.26$ (per Hantush)

(C) $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \text{ ft}}{7410 \text{ ft}}, \frac{1100 \text{ ft}}{7410 \text{ ft}}\right) = S^*(0, 0.148)$
$= 0$ (per Hantush)

(D) $S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \text{ ft}}{7410 \text{ ft}}, \frac{1100 \text{ ft}}{7410 \text{ ft}}\right) = S^*(0, 0.148)$
$= 0$ (per Hantush)

$$h^2 = \frac{0.103 \text{ ft/yr}}{2\,(2059 \text{ ft/yr})}\left(13{,}727 \text{ ft}^2/\text{yr}\right)\left(1000 \text{ yr}\right)\left(\overset{(A)}{0.26} + \overset{(B)}{0.26} + \overset{(C)}{0} + \overset{(D)}{0}\right)$$

$h^2 = 178$ ft²

$h = 13.4$ ft

Stoller

Length of Spreading of Leachate @ 10 yrs from edge of disposal cell
eastern center (2500, 0)

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^{4} \text{ yr}$$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^{4} \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 2.6 \text{ ft}) + 2.30 \times 10^{-4}\right)^{1/2} + (2.30 \times 10^{-4})^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.5173 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 166$ ft

N/A 5-31-07

Moab RAP

A3-9 13

Length of Spreading of Leachate @ 10 yrs
from edge of disposal cell
(eastern center (2500, 0)

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^{4}$ yr

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} = N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^{4} \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 11.6 \text{ ft}) + 2.30 \times 10^{-4}\right)^{1/2} + (2.30 \times 10^{-4})^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.5197 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 762$ ft

N/A   5-31-07

Moab RAP

A3-10   13

Length of Spreading of Leachate @ 10 yrs from edge of disposal cell (eastern center (2600, 0))

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$\therefore \sigma' = \frac{2400\ ft}{0.036\ ft/yr} = 6.67 \times 10^4\ yr$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(124\ ft/yr)(6.67 \times 10^4\ yr)}$$

$$\boxed{A = 1.21 \times 10^{-7}\ ft^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3}\ ft/yr \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400\ ft - (7.5 \times 10^{-3}\ ft/yr \cdot 6.67 \times 10^4\ yr)}{(124\ ft/yr)(6.67 \times 10^4\ yr)}$$

$$\boxed{B = 2.30 \times 10^{-4}\ \text{dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7}\ ft^{-1}}\left[\left(\frac{2}{3}\left(1.21 \times 10^{-7}\ ft^{-1} \cdot 23.3\ ft\right) + 2.30 \times 10^{-4}\right)^{1/2} + \left(2.30 \times 10^{-4}\right)^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7}\ ft^{-1}}\left(1.5228 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 1535$ ft

Stoller

Length of Spreading of Leachate @10yrs from edge of disposal cell (center of eastern.

N/A

5-31-07

MOAB RAP

A3-11 13

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$

from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4 \text{ yr}$$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 2.6 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7165 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$L = 718$ ft.

Length of Spreading of Leachate @10yrs from edge of disposal cell (center of cell?).

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

$$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4 \text{ yr}$$

$$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 8.69 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7205 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$$L = 2364 \text{ ft}$$

N/A 5-31-07

MOAB RAP

A3-13 13

Length of Spreading of Leachate @10yrs from edge of disposal cell (center of canton).

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)
K' = hydraulic conductivity of semipervious unit

$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4$ yr

K' = 0.036 ft/yr

h_o = head at edge of disposal cell

$A = \frac{1}{(2059 \text{ ft/yr})(6.67\times10^4 \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5\times10^{-3} \text{ ft/yr} \cdot 6.67\times10^4 \text{ yr})}{(2059 \text{ ft/yr})(6.67\times10^4 \text{ yr})}$

$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$

$$L = \frac{3}{7.28\times10^{-9}\text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28\times10^{-9}\text{ft}^{-1} \cdot 13.4 \text{ ft}\right) + 1.38\times10^{-5}\right)^{1/2} - \left(1.38\times10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28\times10^{-9}\text{ ft}^{-1}}\left(3.7236\times10^{-3} - 3.7148\times10^{-3}\right)$$

L = 3635 ft

Attachment A4

Stoller

calculate height of mound @ corner of Quadrant 1

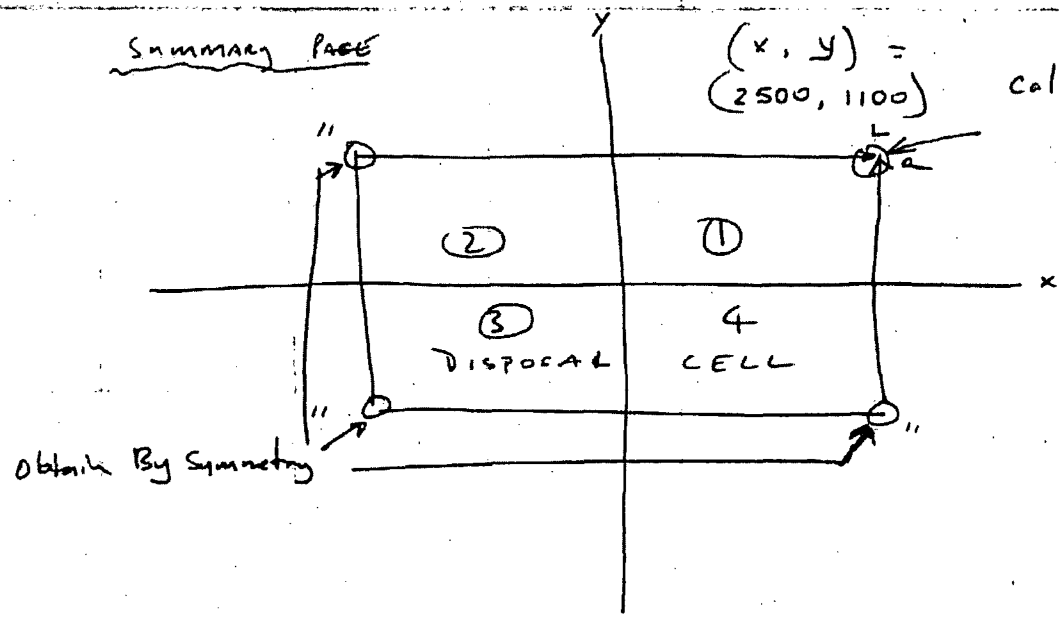
JOB NO: N/A DATE 5-31-07

JOB NAME MOAB-RAP

PREPARED BY [illegible] REVIEWED

SHEET NO. A4-1 OF 13

Summary Page



Calculate h at corner of Quadrant 1, obtain all other h @ corners by symmetry

K = 124 ft/yr. @ 10 yrs ; h = 1.8 ft ; L = 113 ft

K = 2059 ft/yr @ 10 yrs ; h = 1.8 ft ; L = 501 ft

K = 124 ft/yr @ 200 yrs ; h = 8.3 ft. ; L = 543 ft

K = 2059 ft/yr @ 200 yrs ; h = 7.5 ft ; L = 2042 ft

K = 124 ft/yr @ 1000 yrs ; h = 18.2 ft ; L = 1198 ft

K = 2059 ft/yr @ 1000 yrs ; h = 12.3 ft. ; L = 3338 ft

N/A 5-31-07

MOAB RAP

A4-2 13

Calculate mound @ corner of cell @ 10yr

obtain all other corner values of h by symmetry.

$K = 124 \; ft/yr$

Compute $h_{(x,y)}$ @ 10 yrs:

$$h^2 = \frac{\omega}{2K} \, vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

(A), (B), (C), (D)

$\boxed{\text{For } (x, y) = (2500, 1100)}$

Recall from Sheet A1-2

$\sqrt{4vt} = 182 \; ft$

& $v = 827 \; ft^2/yr$

(A) $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \cancel{ft}}{182 \cancel{ft}}, \frac{2200 \cancel{ft}}{182 \cancel{ft}}\right) = S^*(27.5, 12.1)$
$= 1$ (per Handbook)

(B) $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \cancel{ft}}{182 \cancel{ft}}, \frac{0 \cancel{ft}}{182 \cancel{ft}}\right) = S^*(27.5, 0)$
$= 0$ (per Handbook)

(C) $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \cancel{ft}}{182 \cancel{ft}}, \frac{2200 \cancel{ft}}{182 \cancel{ft}}\right) = S^*(0, 12.1)$
$= 0$ (per Handbook)

(D) $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \cancel{ft}}{182 \cancel{ft}}, \frac{0 \cancel{ft}}{182 \cancel{ft}}\right) = S^*(0, 0)$
$= 0$ (per Handbook)

$$h^2 = \frac{0.103 \; \cancel{ft/yr}}{2 \left(124 \; \cancel{ft/yr}\right)} \left(827 \; ft^2/\cancel{yr}\right) \left(10 \; \cancel{yr}\right) \left(\overset{A}{1} + \overset{B}{0} + \overset{C}{0} + \overset{D}{0} \right)$$

$h^2 = 3.43 \; ft^2$

$h = 1.8 \; ft$

N/A 5-31-07

MOAB RAP

A4-3 13

Mounding @ Corner of cell @ 10 yrs
for condition: K = 2059 ft/yr

K = 2059 ft/yr

Compute $h_{(x,y)}$ @ 10 yrs:

$$h^2 = \frac{\omega}{2K} vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

(A), (B), (C), (D)

$\boxed{@\ (x,y) = (2500, 1100)}$

Recall from Sheet A1-2
$\sqrt{4vt}$: 741 ft
& v = 13,727 ft²/yr

(A) $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000\ \cancel{ft}}{761\ \cancel{ft}}, \frac{2200\ \cancel{ft}}{761\ \cancel{ft}}\right) = S^*(6.57, 2.89)$
$\cong 1$ per Hantush & Carslaw / Jaeger

(B) $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000\ \cancel{ft}}{761\ \cancel{ft}}, \frac{0\ \cancel{ft}}{761\ \cancel{ft}}\right) = 0$ per Hantush

(C) $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0\ \cancel{ft}}{761\ \cancel{ft}}, \frac{2200\ \cancel{ft}}{761\ \cancel{ft}}\right) = S^*(0, 2.89)$
$= 0$ (per Hantush)

(D) $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0\ \cancel{ft}}{761\ \cancel{ft}}, \frac{0\ \cancel{ft}}{761\ \cancel{ft}}\right) = S^*(0,0) = 0$
per Hantush

$$h^2 = \frac{0.103\ \cancel{ft/yr}}{2\ (2059\ \cancel{ft/yr})} \left(13{,}727\ ft^2/\cancel{yr}\right)\left(10\ \cancel{yr}\right)\left(\overset{A}{1} + \overset{B}{0} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 3.43\ ft^2$

$h = 1.8\ ft$

Mounding @ corner of cell @ 200yrs
for condition K = 124 ft/yr

$K = 124 \ ft/yr$

Compute $h_{(x,y)}$ @ 200 yrs:

$$h^2 = \frac{\omega}{2K} vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

$$\boxed{\text{Corner location @ } @(x,y) = (2500, 1100)}$$

Recall sheet A1-2
$\sqrt{4vt} = 813 \ ft$
$v = 827 \ ft^2/yr$

A $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \ \cancel{ft}}{827 \ \cancel{ft}}, \frac{2200 \ \cancel{ft}}{827 \ \cancel{ft}}\right) = S^*(6.04, 2.66) \cong 1$ (per Hantush & Carslaw & Jae...)

B $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \ \cancel{ft}}{827 \ \cancel{ft}}, \frac{0 \ \cancel{ft}}{827 \ \cancel{ft}}\right) = S^*(6.04, 0) = 0$ (per Hantush)

C $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \ \cancel{ft}}{827 \ \cancel{ft}}, \frac{2200 \ \cancel{ft}}{827 \ \cancel{ft}}\right) = S^*(0, 2.66) = 0$ (per Hantush)

D $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \ \cancel{ft}}{827 \ \cancel{ft}}, \frac{0 \ \cancel{ft}}{827 \ \cancel{ft}}\right) = S^*(0,0) = 0$ (per Hantush)

$$h^2 = \frac{0.103 \ \cancel{ft}/\cancel{yr}}{2\,(124 \ \cancel{ft}/\cancel{yr})} \left(827 \ ft^2/\cancel{yr}\right)\left(200 \ \cancel{yr}\right) \left(\overset{A}{1} + \overset{B}{0} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 68.7 \ ft^2$

$h = 8.3 \ ft.$

N/4 8-31-07

MOAB RAP

A4.5 13

Mounding @ corner of cell @ 200 yrs
for condition: $K = 2059$ ft/yr.

$K = 2059$ ft/yr

Compute $h_{(x,y)}$ @ 200 yrs:

$$h^2 = \frac{\omega}{2K} vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right)_{A} + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right)_{B} + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right)_{C} + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right)_{D} \right\}$$

location $(x, y) = (2500, 1100)$

Recall from Sheet A1-2
$\sqrt{4vt} = 3314$ ft
& $v = 13{,}727$ ft²/yr

A $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \text{ ft}}{3314 \text{ ft}}, \frac{2200 \text{ ft}}{3314 \text{ ft}}\right) = S^*(1.51, 0.664) \cong 0.82$ (per Hantush)

B $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000 \text{ ft}}{3314 \text{ ft}}, \frac{0 \text{ ft}}{3314 \text{ ft}}\right) = S^*(1.51, 0) = 0$ (per Hantush)

C $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \text{ ft}}{3314 \text{ ft}}, \frac{2200 \text{ ft}}{3314 \text{ ft}}\right) = S^*(0, 0.664) = 0$ (per Hantush)

D $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0 \text{ ft}}{3314 \text{ ft}}, \frac{0 \text{ ft}}{3314 \text{ ft}}\right) = S^*(0, 0) = 0$ (per Hantush)

$$h^2 = \frac{0.103 \text{ ft/yr}}{2\,(2059 \text{ ft/yr})} (13{,}727 \text{ ft}^2/\text{yr})(200 \text{ yr}) \left(\underset{A}{0.82} + \underset{B}{0} + \underset{C}{0} + \underset{D}{0}\right)$$

$h^2 = 56.3$ ft²

$h = 7.50$ ft

N/A

5-31-07

MOAB RAP

A4-6 13

Calculate mound @ corner of cell @ 1000 yrs
for Condition: K = 124 ft/yr

$K = 124\ ft/yr$

Compute $h_{(x,y)}$ @ 1000 yrs:

$$h^2 = \frac{\omega}{2K}\, vt \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{l-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) \right\}$$

Location $(x,y) = (2500, 1100)$

Recall from Sheet A1-2
$\sqrt{4vt} = 1819\ ft$
$v = 827\ ft^2/yr$

A $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000\ ft}{1819\ ft}, \frac{2200\ ft}{1819\ ft}\right) = S^*(2.75, 1.21) = 0.97$ (per Hantush)

B $S^*\left(\frac{2500+x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{5000\ ft}{1819}, \frac{0}{1819\ ft}\right) = 0$ (per Hantush)

C $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100+y}{\sqrt{4vt}}\right) = S^*\left(\frac{0\ ft}{1819\ ft}, \frac{2200\ ft}{1819\ ft}\right) = 0$ (per Hantush)

D $S^*\left(\frac{2500-x}{\sqrt{4vt}}, \frac{1100-y}{\sqrt{4vt}}\right) = S^*\left(\frac{0\ ft}{1819\ ft}, \frac{0\ ft}{1819\ ft}\right) = 0$ (per Hantush)

$$h^2 = \frac{0.103\ ft/yr}{2\ (124\ ft/yr)}\ (827\ ft^2/yr)\ (1000\ yr)\ \left(\overset{A}{0.97} + \overset{B}{0} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 333\ ft^2$

$h = 18.2\ ft.$

Calculate leachate mound @ corner of cell
@ 1000 yrs for condition K = 2059 ft/yr

N/A

5-31-07

MOAB RAP

A4-7 13

$K = 2059$ ft/yr

Compute $h_{(x,y)}$ @ 1000 yrs :

$$h^2 = \frac{\omega}{2K} \nu t \cdot \left\{ S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l+x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a+y}{\sqrt{4\nu t}}\right) + S^*\left(\frac{l-x}{\sqrt{4\nu t}}, \frac{a-y}{\sqrt{4\nu t}}\right) \right\}$$

$\boxed{\text{location: } (x,y) = (2500, 1100)}$

Recall from Sheet A1-2
$\sqrt{4\nu t} = 7410$ ft
$\nu = 13{,}727$ ft

A $$S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \cancel{ft}}{7410 \cancel{ft}}, \frac{2200 \cancel{ft}}{7410 \cancel{ft}}\right) = S^*(0.675, 0.297) \simeq 0.44 \text{ (per Hantush)}$$

B $$S^*\left(\frac{2500+x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{5000 \cancel{ft}}{7410 \cancel{ft}}, \frac{0 \cancel{ft}}{7410 \cancel{ft}}\right) = S^*(0.657, 0) = 0 \text{ (per Hantush)}$$

C $$S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100+y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \cancel{ft}}{7410 \cancel{ft}}, \frac{2200 \cancel{ft}}{7410 \cancel{ft}}\right) = S^*(0, 0.289) = 0 \text{ (per Hantush)}$$

D $$S^*\left(\frac{2500-x}{\sqrt{4\nu t}}, \frac{1100-y}{\sqrt{4\nu t}}\right) = S^*\left(\frac{0 \cancel{ft}}{7410 \cancel{ft}}, \frac{0 \cancel{ft}}{7410 \cancel{ft}}\right) = S^*(0,0) = 0 \text{ (per Hantush)}$$

$$h^2 = \frac{0.103 \cancel{ft}/\cancel{yr}}{2\,(2059 \cancel{ft}/\cancel{yr})} (13{,}727 \text{ ft}^2/\cancel{yr}) (1000 \cancel{yr}) \left(\overset{A}{0.44} + \overset{B}{0} + \overset{C}{0} + \overset{D}{0}\right)$$

$h^2 = 151 \text{ ft}^2$

$h = 12.3$ ft

N/A 5-31-07

Moab RAP

A4-8 13

Length of Spreading of Leachate @ 10 yrs from ~~edge~~ Corner of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

$$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4 \text{ yr}$$

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 1.8 \text{ ft}) + 2.30 \times 10^{-4}\right)^{1/2} + (2.30 \times 10^{-4})^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.5171 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 113$ ft

Length of Spreading of Leachate @ 200 yrs from corner of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979 ; p. 181 - 183 eqn 5-219)

Let $K = 124$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$ where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^{4}$ yr

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^{4} \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 8.3 \text{ ft}\right) + 2.30 \times 10^{-4}\right)^{1/2} + \left(2.30 \times 10^{-4}\right)^{1/2}\right]$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.5188 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 543$ ft

N/A 5-31-07

Moab RAP

A4-10 13

Length of Spreading of Leachate @ 1000yrs from corner of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3}Ah_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear, (1979; p. 181-183 eqn 5-219)

Let $K = 124$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$\therefore \sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4$ yr

$$A = \frac{1}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{A = 1.21 \times 10^{-7} \text{ ft}^{-1}}$$

Assume $N = (0.01) * (\text{avg. annual pcp.}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \simeq N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(124 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 2.30 \times 10^{-4} \text{ dim}}$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left[\left(\frac{2}{3}(1.21 \times 10^{-7} \text{ ft}^{-1} \cdot 18.2 \text{ ft}) + 2.30 \times 10^{-4}\right)^{1/2} + (2.30 \times 10^{-4})^{1/2}\right.$$

$$L = \frac{3}{1.21 \times 10^{-7} \text{ ft}^{-1}}\left(1.5214 \times 10^{-2} - 1.5166 \times 10^{-2}\right)$$

$L = 1198$ ft

N/A 5-31-07

MOAB RAP

A4-11 13

Length of Spreading of Leachate @ 10 yrs from Corner of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)

K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4 \text{ yr}$$

$$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 1.8 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7160 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$L = 501$ ft

N/A 5-31-07

MOAB RAP

AF-12 13

Length of spreading of Leachate @ 200yrs from Corner of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$ from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$A = \frac{1}{K\sigma'}$; $\sigma' = \frac{B'}{K'}$

where B' = thickness of semipervious unit (2400 ft)
K' = hydraulic conductivity of semipervious unit

$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^4 \text{ yr}$

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^4 \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^4 \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 7.5 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7198 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$L = 2042$ ft

N/A

5-31-07

MOAB RAP

A4-13 13

Length of Spreading of Leachate 1000yrs
from corner of disposal cell

$$L = \frac{3}{A}\left[\left(\frac{2}{3} A h_o + B\right)^{1/2} - B^{1/2}\right]$$

from Bear (1979; p 181-183; Equation 5-219)

Let $K = 2059$ ft/yr

$$A = \frac{1}{K\sigma'} \; ; \; \sigma' = \frac{B'}{K'}$$

where B' = thickness of semipervious unit (2400 ft)
K' = hydraulic conductivity of semipervious unit

$K' = 0.036$ ft/yr

h_o = head at edge of disposal cell

$$\sigma' = \frac{2400 \text{ ft}}{0.036 \text{ ft/yr}} = 6.67 \times 10^{4} \text{ yr}$$

$$A = \frac{1}{(2059 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})} = \boxed{7.28 \times 10^{-9} \text{ ft}^{-1} = A}$$

Assume $N = 0.01 * (\text{avg. annual pcp}) = \boxed{7.5 \times 10^{-3} \text{ ft/yr} \approx N}$

$$B = \frac{B' - N\sigma'}{K\sigma'} = \frac{2400 \text{ ft} - (7.5 \times 10^{-3} \text{ ft/yr} \cdot 6.67 \times 10^{4} \text{ yr})}{(2059 \text{ ft/yr})(6.67 \times 10^{4} \text{ yr})}$$

$$\boxed{B = 1.38 \times 10^{-5} \text{ dim}}$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left[\left(\frac{2}{3}\left(7.28 \times 10^{-9} \text{ ft}^{-1} \cdot 12.3 \text{ ft}\right) + 1.38 \times 10^{-5}\right)^{1/2} - \left(1.38 \times 10^{-5}\right)^{1/2}\right]$$

$$L = \frac{3}{7.28 \times 10^{-9} \text{ ft}^{-1}}\left(3.7229 \times 10^{-3} - 3.7148 \times 10^{-3}\right)$$

$L = 3338$ ft