



**Project Name:** 132 Clair Road West, Guelph      **MTE File No.:** C48696-114  
**To:** Mr. Jim Hall, City of Guelph      **Date:** September 11, 2024  
**cc:** Dave Hicks, MTE Consultants      **From:** Kyle Reed, P.Geo.  
Eva Bako, MTE Consultants

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**RE: Groundwater Mounding Calculations – 132 Clair Road West, Guelph**

**Groundwater Mounding**

This groundwater mounding assessment is required to determine the potential rise in groundwater levels beneath the proposed infiltration basin at 132 Clair Road West in Guelph, Ontario. The predicted rise in groundwater levels can be used to ensure appropriate separation is maintained between services and construction footings, and groundwater.

Hantush (1967) developed a widely accepted method for assessing groundwater mounding. The Hantush method presented analytical solutions for transient groundwater mound development beneath a rectangular recharge source with a constant infiltration rate. A spreadsheet tool has been created by the United States Geological Survey (USGS, 2010) to utilize the Hantush method using the following inputs:

**Hydraulic Conductivity of the Aquifer**

The proposed infiltration basin will be located in the sand/sand and gravel sediments that have been identified at the Site. Monitoring location MW110-21 is located near the proposed infiltration cell and is screened in the sands and gravels. Slug testing was conducted at MW110-21 on December 9, 2021 using Midwest Geoscience’s Pneumatic "HI-K" Slug. Seven tests were conducted with one representative test being analyzed using AquiferTest Pro. The analysis resulted in an estimated aquifer hydraulic conductivity of approximately  $5.4 \times 10^{-4}$  m/sec. The location of MW110-21 is presented in **Attachment A**; the results of the slug testing are presented in **Attachment B**.

**Specific Yield**

The specific yield of an unconfined aquifer is defined as the “the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table” (Freeze and Cherry, 1979). A specific yield of 0.25 was selected as being representative of the sands and gravels that make up the aquifer beneath the Site (Fetter, 2001).

**Initial Saturated Thickness**

The saturated thickness within an aquifer is the difference between the groundwater elevation and the bottom elevation of the aquifer. The bottom of the sand/sand and gravel aquifer was not encountered during the drilling program. Well records available from the MECP for nearby wells indicate that the top of the Eramosa aquitard is at an elevation of approximately 294m amsl. Using the highest groundwater elevation observed at MW110-21 of approximately 331m amsl provides an initial saturated thickness of 37m (331m amsl – 294m amsl).



### ***Length and Width of Infiltration Cell***

The proposed infiltration basin will have a length of 57 m and an average width of 22.8 m. The basin bottom surface area will be 1300 m<sup>2</sup>.

### ***Infiltration Rate***

Permeameter testing conducted in the sands and gravels at TP202-21 resulted in an estimated infiltration rate of 170 mm/hr. A conservative factor of safety of 2.5 was used in this assessment to account for assumptions made in estimating the infiltration rate, and for future reductions in infiltration potential from the introduction of fine materials into the native sediments. As such, an infiltration rate of 68 mm/hr was used. The details of the infiltration testing are provided in **Attachment C**.

### ***Duration of Infiltration Period***

The basin design is based on the 100-year storm with a 3-hour duration. During this event, 3047 m<sup>3</sup> of runoff will drain into the basin and be infiltrated. Given the bottom surface area of the basin (1300 m<sup>2</sup>) and the design infiltration rate (68 mm/hour), the time required for the stormwater to infiltrate is 34.5 hours.

### ***Predicted Groundwater Mound***

The Hantush (1967) method estimates that after 34 hours, the maximum height of the groundwater mound would be ~0.46m above the established groundwater table. This computed theoretical value is measured at the basin centre which will be the highest mounding point. Within 95 m of the basin centre, the groundwater mound would be ~12cm above the established groundwater table.

The elevation of the base of the infiltration basin is 336.1m amsl. The predicted mound of 0.46m would raise the observed high water table to an elevation of 331.46m amsl, resulting in a separation from groundwater of 4.6m.

The Hantush calculations are provided in **Attachment D**.

### ***References***

Fetter, C.W. 2001. Applied Hydrogeology, Fourth Edition. Prentice-Hall Inc., New Jersey.

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

USGS, 2010. Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins, Scientific Investigations Report 2010-5102.

KNR:smk

Attach.

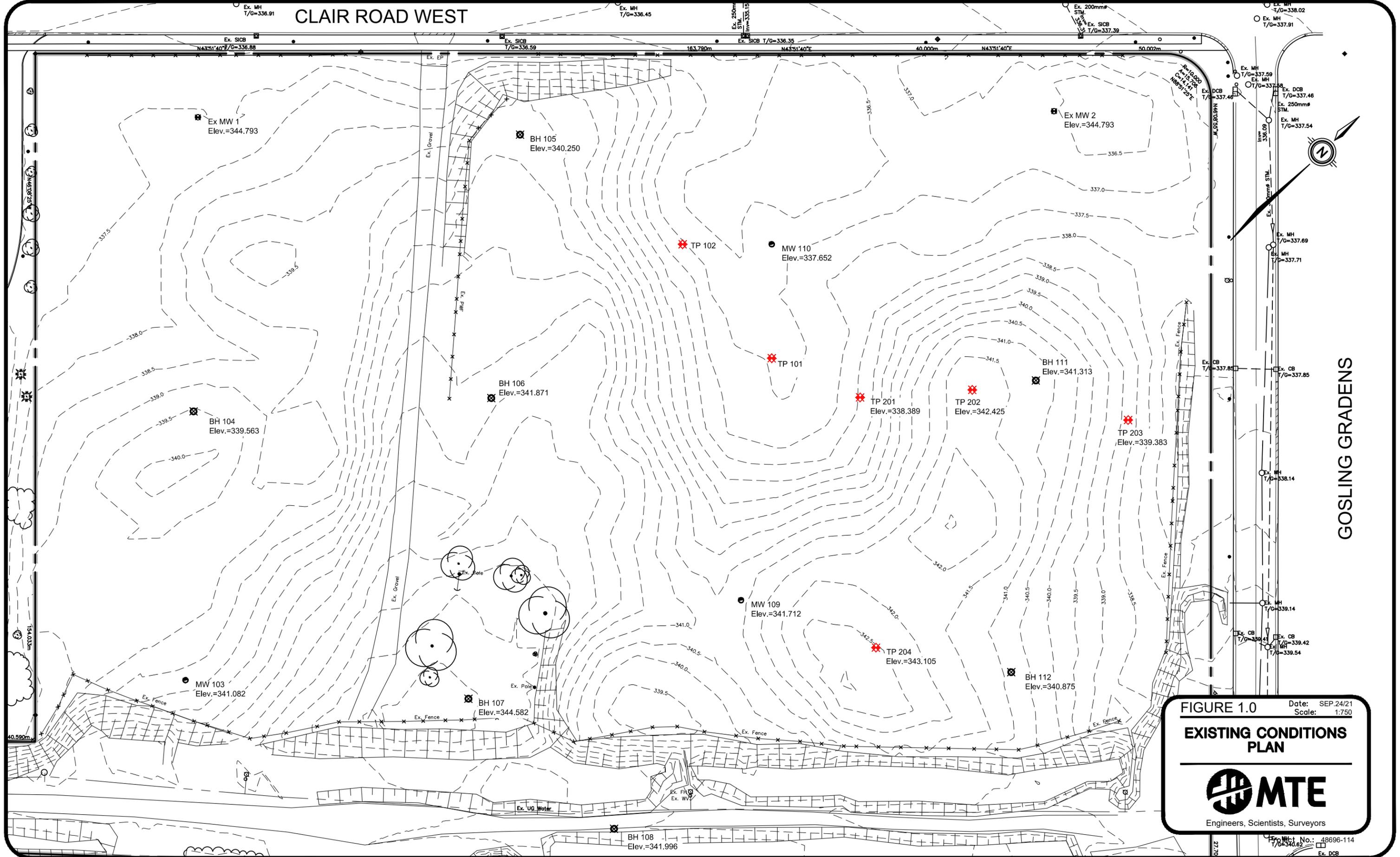
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# Attachment A

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## Monitoring/Testing Locations

# CLAIR ROAD WEST



GOSLING GRADENS

**FIGURE 1.0** Date: SEP 24/21  
Scale: 1:750

**EXISTING CONDITIONS PLAN**



Engineers, Scientists, Surveyors

# Attachment B

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## Single Well Response Testing

## Single Well Response Testing Raw Data



well\_id mw110  
 date 10-Dec-21  
 static 7.65  
 logger\_depth 8.66  
 atmo 996.975

Date/time	Pressure[mH2O]	Temperature[°C]	water_lvl_corr	cumulative deviation	h/ho	
12/10/21 10:28	10.89058	10.24	7.74	0	-0.09	0.9075
12/10/21 10:28	10.92542	10.247	7.70	0.5	-0.06	0.5591
12/10/21 10:28	10.94742	10.247	7.68	1	-0.03	0.3391
12/10/21 10:28	10.95842	10.24	7.67	1.5	-0.02	0.2291
12/10/21 10:28	10.96667	10.24	7.66	2	-0.01	0.1466
12/10/21 10:28	10.9685	10.23	7.66	2.5	-0.01	0.1283
12/10/21 10:28	10.974	10.23	7.66	3	-0.01	0.0733
12/10/21 10:28	10.974	10.24	7.66	3.5	-0.01	0.0733
12/10/21 10:28	10.974	10.247	7.66	4	-0.01	0.0733
12/10/21 10:30	10.81908	10.24	7.81	0	-0.16	0.81585
12/10/21 10:30	10.84383	10.24	7.79	0.5	-0.14	0.6921
12/10/21 10:30	10.89333	10.24	7.74	1	-0.09	0.4446
12/10/21 10:30	10.92817	10.247	7.70	1.5	-0.05	0.2704
12/10/21 10:30	10.94467	10.247	7.69	2	-0.04	0.1879
12/10/21 10:30	10.95842	10.24	7.67	2.5	-0.02	0.11915
12/10/21 10:30	10.96667	10.24	7.66	3	-0.02	0.0779
12/10/21 10:30	10.9685	10.24	7.66	3.5	-0.01	0.06875
12/10/21 10:30	10.97033	10.247	7.66	4	-0.01	0.0596
12/10/21 10:30	10.97308	10.24	7.66	4.5	-0.01	0.04585
12/10/21 10:30	10.97308	10.247	7.66	5	-0.01	0.04585
12/10/21 10:30	10.97583	10.24	7.65	5.5	-0.01	0.0321
12/10/21 10:31	10.91258	10.24	7.72			
12/10/21 10:31	10.90983	10.23	7.72	0	-0.07	0.6875
12/10/21 10:31	10.9355	10.247	7.69	0.5	-0.04	0.4308
12/10/21 10:31	10.95383	10.24	7.68	1	-0.02	0.2475
12/10/21 10:31	10.96392	10.247	7.67	1.5	-0.01	0.1466
12/10/21 10:31	10.96758	10.24	7.66	2	-0.01	0.11
12/10/21 10:31	10.97033	10.24	7.66	2.5	-0.01	0.0825
12/10/21 10:31	10.97308	10.24	7.66	3	-0.01	0.055
12/10/21 10:31	10.97583	10.24	7.65	3.5	0.00	0.0275
12/10/21 10:31	10.974	10.24	7.66	4	0.00	0.0458
12/10/21 10:31	10.97583	10.24	7.65	4.5	0.00	0.0275
12/10/21 10:31	10.974	10.247	7.66	5	0.00	0.0458
12/10/21 10:31	10.97675	10.23	7.65	5.5	0.00	0.0183
12/10/21 10:31	10.97675	10.24	7.65	6	0.00	0.0183

## Single Well Response Testing Raw Data



12/10/21 10:32	10.82917	10.24	7.80	0	-0.15	0.75165
12/10/21 10:32	10.88417	10.24	7.75	0.5	-0.10	0.47665
12/10/21 10:32	10.919	10.24	7.71	1	-0.06	0.3025
12/10/21 10:32	10.94375	10.24	7.69	1.5	-0.04	0.17875
12/10/21 10:32	10.95658	10.247	7.67	2	-0.02	0.1146
12/10/21 10:32	10.96667	10.24	7.66	2.5	-0.01	0.06415
12/10/21 10:32	10.97033	10.24	7.66	3	-0.01	0.04585
12/10/21 10:32	10.97308	10.247	7.66	3.5	-0.01	0.0321
12/10/21 10:32	10.97583	10.24	7.65	4	0.00	0.01835
12/10/21 10:32	10.974	10.24	7.66	4.5	-0.01	0.0275
12/10/21 10:32	10.97308	10.24	7.66	5	-0.01	0.0321
12/10/21 10:34	10.85667	10.24	7.77	0	-0.12	0.812733
12/10/21 10:34	10.88417	10.24	7.75	0.5	-0.09	0.6294
12/10/21 10:35	10.92083	10.223	7.71	1	-0.06	0.385
12/10/21 10:35	10.941	10.247	7.69	1.5	-0.04	0.250533
12/10/21 10:35	10.95658	10.24	7.67	2	-0.02	0.146667
12/10/21 10:35	10.96483	10.23	7.66	2.5	-0.01	0.091667
12/10/21 10:35	10.97033	10.24	7.66	3	-0.01	0.055
12/10/21 10:35	10.97125	10.24	7.66	3.5	-0.01	0.048867
12/10/21 10:35	10.974	10.24	7.66	4	0.00	0.030533
12/10/21 10:35	10.97308	10.23	7.66	4.5	-0.01	0.036667
12/10/21 10:35	10.97308	10.24	7.66	5	-0.01	0.036667
12/10/21 10:35	10.974	10.24	7.66	5.5	0.00	0.030533
12/10/21 10:35	10.974	10.24	7.66	6	0.00	0.030533
12/10/21 10:36	10.74208	10.24	7.89	0	-0.24	0.7914
12/10/21 10:36	10.82917	10.23	7.80	0.5	-0.15	0.5011
12/10/21 10:36	10.88692	10.24	7.74	1	-0.09	0.3086
12/10/21 10:36	10.92083	10.24	7.71	1.5	-0.06	0.195567
12/10/21 10:36	10.94375	10.24	7.69	2	-0.04	0.119167
12/10/21 10:36	10.95383	10.24	7.68	2.5	-0.03	0.085567
12/10/21 10:36	10.96208	10.24	7.67	3	-0.02	0.058067
12/10/21 10:36	10.9685	10.24	7.66	3.5	-0.01	0.036667
12/10/21 10:36	10.97033	10.24	7.66	4	-0.01	0.030567
12/10/21 10:36	10.97125	10.24	7.66	4.5	-0.01	0.0275
12/10/21 10:36	10.97308	10.24	7.66	5	-0.01	0.0214
12/10/21 10:36	10.97308	10.24	7.66	5.5	-0.01	0.0214
12/10/21 10:36	10.97308	10.24	7.66	6	-0.01	0.0214
12/10/21 10:36	10.97125	10.24	7.66	6.5	-0.01	0.0275
12/10/21 10:36	10.97125	10.223	7.66	7	-0.01	0.0275
12/10/21 10:36	10.974	10.24	7.66	7.5	-0.01	0.018333
12/10/21 10:36	10.974	10.24	7.66	8	-0.01	0.018333

## Single Well Response Testing Raw Data



12/10/21 10:36	10.85667	10.24	7.77	0	-0.12	0.818867
12/10/21 10:36	10.90158	10.24	7.73	0.5	-0.08	0.519467
12/10/21 10:37	10.93275	10.24	7.70	1	-0.05	0.311667
12/10/21 10:37	10.94833	10.24	7.68	1.5	-0.03	0.2078
12/10/21 10:37	10.96117	10.24	7.67	2	-0.02	0.1222
12/10/21 10:37	10.96667	10.247	7.66	2.5	-0.01	0.085533
12/10/21 10:37	10.9685	10.23	7.66	3	-0.01	0.073333
12/10/21 10:37	10.97125	10.24	7.66	3.5	-0.01	0.055
12/10/21 10:37	10.974	10.247	7.66	4	-0.01	0.036667
12/10/21 10:37	10.974	10.24	7.66	4.5	-0.01	0.036667
12/10/21 10:37	10.974	10.24	7.66	5	-0.01	0.036667
12/10/21 10:37	10.97675	10.24	7.65	5.5	0.00	0.018333
12/10/21 10:38	10.78975	10.23	7.84	0	-0.19	0.6386
12/10/21 10:38	10.85575	10.24	7.77	0.5	-0.13	0.4186
12/10/21 10:38	10.90158	10.253	7.73	1	-0.08	0.265833
12/10/21 10:38	10.93	10.23	7.70	1.5	-0.05	0.1711
12/10/21 10:38	10.94833	10.24	7.68	2	-0.03	0.11
12/10/21 10:38	10.95933	10.23	7.67	2.5	-0.02	0.073333
12/10/21 10:38	10.96392	10.24	7.67	3	-0.02	0.058033
12/10/21 10:38	10.9685	10.24	7.66	3.5	-0.01	0.042767
12/10/21 10:38	10.97033	10.24	7.66	4	-0.01	0.036667
12/10/21 10:38	10.97125	10.24	7.66	4.5	-0.01	0.0336
12/10/21 10:38	10.97308	10.24	7.66	5	-0.01	0.0275
12/10/21 10:38	10.974	10.23	7.66	5.5	-0.01	0.024433
12/10/21 10:38	10.97583	10.24	7.65	6	-0.01	0.018333

**Slug Test Analysis Report**

Project: 132 Clair Road West & Poppy Dr. W SWM

Number: 48696-114

Client: Coldwell Banker Neumann Real Estate Brokerage

Location: Geulph, ON

Slug Test: Test 7

Test Well: MW110

Test Conducted by: JAK

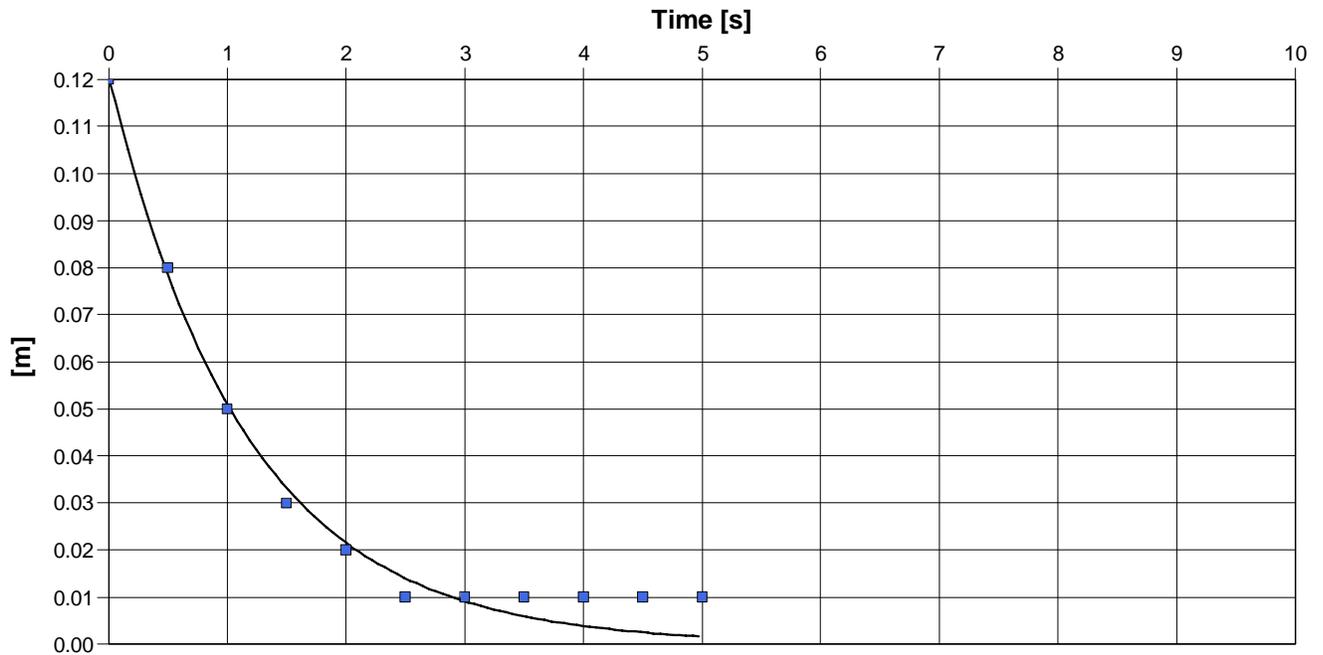
Test Date: 12/10/2021

Analysis Performed by: mde

butler high k

Analysis Date: 12/10/2021

Aquifer Thickness: 2.87 m



Calculation using Butler High-K

Observation Well	tD/t	Hydraulic Conductivity m/s	CD
MW110	$1.00 \times 10^1$	$5.33 \times 10^{-4}$	$1.17 \times 10^1$

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Test Well: MW110

Test Conducted by: JAK

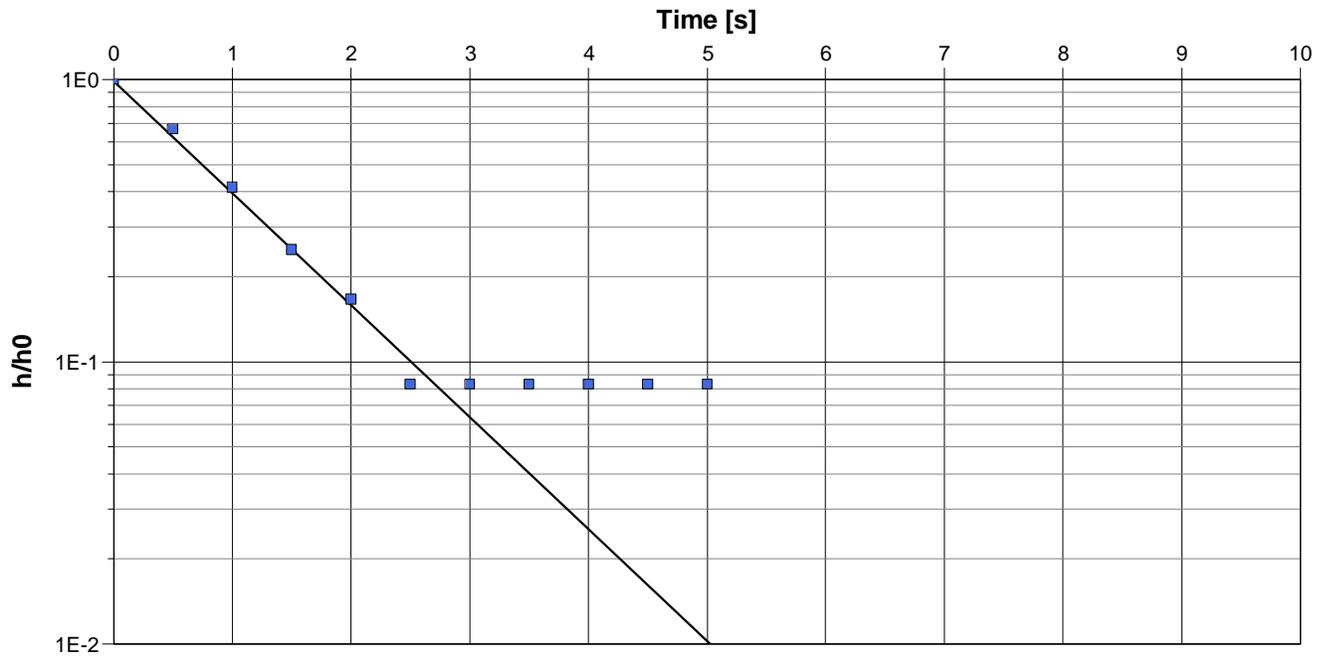
Test Date: 12/10/2021

Analysis Performed by: mde

bower and rice

Analysis Date: 12/10/2021

Aquifer Thickness: 2.87 m



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
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MW110	$5.71 \times 10^{-4}$
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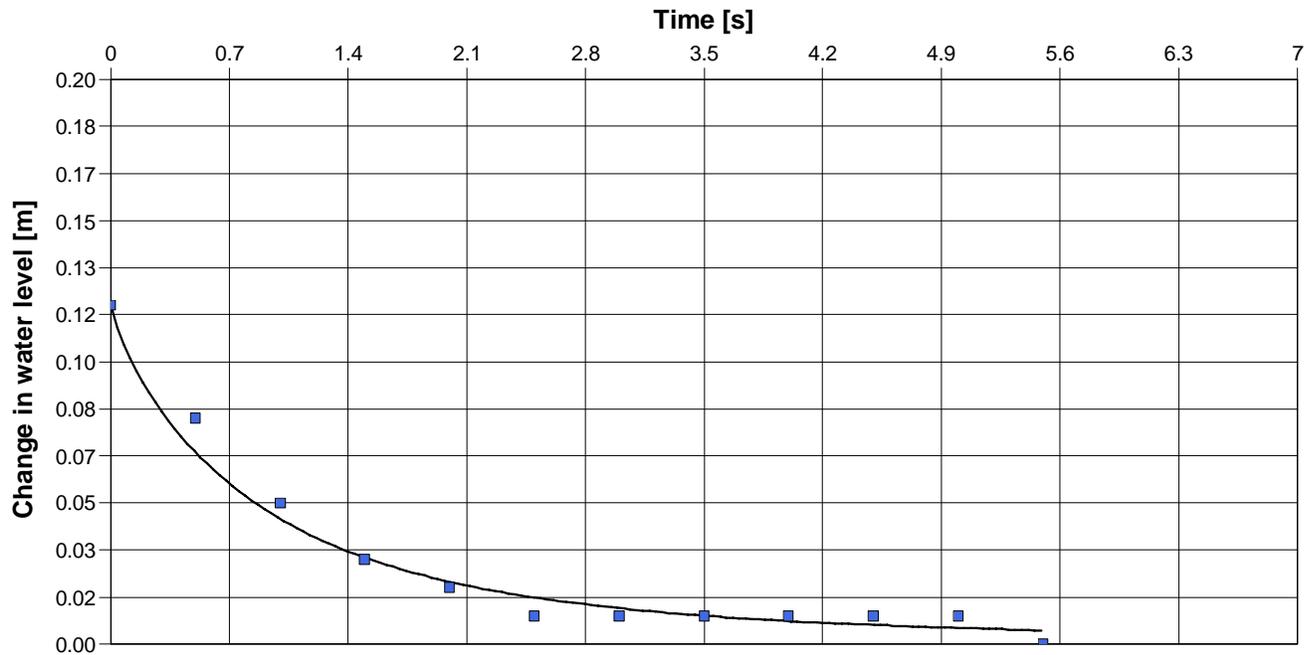
**Slug Test Analysis Report**

Project: 132 Clair Road West & Poppy Dr. W SWM

Number: 48696-114

Client: Coldwell Banker Neumann Real Estate Brokerage

Location: Geulph, ON	Slug Test: Test 7	Test Well: MW110
Test Conducted by: JAK		Test Date: 12/10/2021
Analysis Performed by:	New analysis 3	Analysis Date: 12/10/2021
Aquifer Thickness: 2.87 m		



Calculation using Cooper-Bredehoeft-Papadopoulos

Observation Well	Transmissivity [m <sup>2</sup> /s]	Hydraulic Conductivity [m/s]	Well-bore storage coefficient
MW110	$1.30 \times 10^{-3}$	$4.54 \times 10^{-4}$	$9.52 \times 10^{-4}$

# Attachment C

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## Infiltration Testing



# Guelph Permeameter Calculations

Input  
Result

Support: ali@soilmoisture.com

## Test #1

Reservoir Type (enter "1" for Combined and "2" for Inner reservoir): **1**  
 Enter water Head Height ("H" in cm): **10**  
 Enter the Borehole Radius ("a" in cm): **3**

Enter the soil texture-structure category (enter one of the below numbers): **4**

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropores, etc

Steady State Rate of Water Level Change ("R" in cm/min): **23.0000**

Res Type 35.22  
 H 10  
 a 3  
 H/a 3.333  
 a\* 0.36  
 C0.01 1.218  
 C0.04 1.29  
 C0.12 1.288  
 C0.36 1.288  
 C 1.288  
 R ######  
 Q 13.5  
 pi 3.142

$\alpha^* = 0.36 \text{ (cm}^{-1}\text{)}$   
 $C = 1.287543$   
 $Q = 13.501$

$K_{fs} = 2.07E-02 \text{ cm/sec}$   
 $1.24E+00 \text{ cm/min}$   
 $2.07E-04 \text{ m/sec}$   
 $4.89E-01 \text{ inch/min}$   
 $8.15E-03 \text{ inch/sec}$

$\Phi_m = 5.75E-02 \text{ (cm}^2\text{/min)}$

## Test #2

Reservoir Type (enter "1" for Combined and "2" for Inner reservoir): **1**  
 Enter water Head Height ("H" in cm): **5**  
 Enter the Borehole Radius ("a" in cm): **3**

Enter the soil texture-structure category (enter one of the below numbers): **4**

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropores, etc

Steady State Rate of Water Level Change ("R" in cm/min): **5.5000**

Res Type 35.22  
 H 5  
 a 3  
 H/a 1.66667  
 a\* 0.36  
 C0.01 0.80949  
 C0.04 0.84206  
 C0.12 0.80315  
 C0.36 0.80315  
 C 0.80315  
 R 5.500  
 Q 3.2285  
 pi 3.1415

$\alpha^* = 0.36 \text{ (cm}^{-1}\text{)}$   
 $C = 0.803154$   
 $Q = 3.2285$

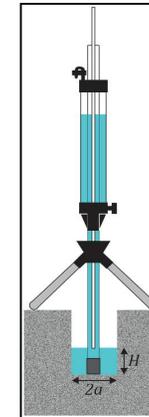
$K_{fs} = 9.71E-03 \text{ cm/sec}$   
 $5.83E-01 \text{ cm/min}$   
 $9.71E-05 \text{ m/sec}$   
 $2.29E-01 \text{ inch/min}$   
 $3.82E-03 \text{ inch/sec}$

$\Phi_m = 2.70E-02 \text{ (cm}^2\text{/min)}$

## Average

$K_{fs} = 1.52E-02 \text{ cm/sec}$   
 $9.13E-01 \text{ cm/min}$   
 $1.52E-04 \text{ m/s}$   
 $3.59E-01 \text{ inch/min}$   
 $5.99E-03 \text{ inch/sec}$

$\Phi_m = 4.23E-02 \text{ (cm}^2\text{/min)}$



Calculation formulas related to shape factor (C). Where  $H_1$  is the first water head height (cm),  $H_2$  is the second water head height (cm),  $a$  is borehole radius (cm) and  $a^*$  is microscopic capillary length factor which is decided according to the soil texture-structure category. For one-head method, only  $C_1$  needs to be calculated while for two-head method,  $C_1$  and  $C_2$  are calculated (Zhang et al, 1995).

Soil Texture-Structure Category	$\alpha^* \text{ (cm}^{-1}\text{)}$	Shape Factor
Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.	0.01	$C_1 = \left( \frac{H_1/a}{2.102 + 0.118(H_1/a)} \right)^{0.655}$ $C_2 = \left( \frac{H_2/a}{2.102 + 0.118(H_2/a)} \right)^{0.655}$
Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.	0.04	$C_1 = \left( \frac{H_1/a}{1.992 + 0.091(H_1/a)} \right)^{0.683}$ $C_2 = \left( \frac{H_2/a}{1.992 + 0.091(H_2/a)} \right)^{0.683}$
Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.	0.12	$C_1 = \left( \frac{H_1/a}{2.074 + 0.093(H_1/a)} \right)^{0.754}$ $C_2 = \left( \frac{H_2/a}{2.074 + 0.093(H_2/a)} \right)^{0.754}$
Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macro pores, etc.	0.36	$C_1 = \left( \frac{H_1/a}{2.074 + 0.093(H_1/a)} \right)^{0.754}$ $C_2 = \left( \frac{H_2/a}{2.074 + 0.093(H_2/a)} \right)^{0.754}$

Calculation formulas related to one-head and two-head methods. Where  $R$  is steady-state rate of fall of water in reservoir (cm/s),  $K_{fs}$  is Soil saturated hydraulic conductivity (cm/s),  $\Phi_m$  is Soil matric flux potential (cm<sup>2</sup>/s),  $\alpha^*$  is Macroscopic capillary length parameter (from Table 2),  $a$  is Borehole radius (cm),  $H_1$  is the first head of water established in borehole (cm),  $H_2$  is the second head of water established in borehole (cm) and  $C$  is Shape factor (from Table 2).

One Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$	$K_{fs} = \frac{C_1 \times Q_1}{2\pi H_1^2 + \pi a^2 C_1 + 2\pi \left( \frac{H_1}{\alpha^*} \right)}$
One Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$	$\Phi_m = \frac{C_1 \times Q_1}{(2\pi H_1^2 + \pi a^2 C_1) a^* + 2\pi H_1}$
Two Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$ $Q_2 = \bar{R}_2 \times 35.22$	$G_1 = \frac{H_2 C_1}{\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $G_2 = \frac{H_1 C_2}{\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $K_{fs} = G_2 Q_2 - G_1 Q_1$ $G_3 = \frac{(2H_1^2 + a^2 C_1) C_1}{2\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$
Two Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$ $Q_2 = \bar{R}_2 \times 2.16$	$G_4 = \frac{(2H_1^2 + a^2 C_1) C_2}{2\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $\Phi_m = G_3 Q_1 - G_4 Q_2$



# Guelph Permeameter Calculations

Input

Result

Support: [all@soilmoisture.com](mailto:all@soilmoisture.com)

## Test #4

Reservoir Type (enter "1" for Combined and "2" for Inner reservoir): **1**  
 Enter water Head Height ("H" in cm): **10**  
 Enter the Borehole Radius ("a" in cm): **3**

Enter the soil texture-structure category (enter one of the below numbers): **4**

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropores, etc

Steady State Rate of Water Level Change ("R" in cm/min): **10.5000**

Res Type 35.22  
 H 10  
 a 3  
 H/a 3.333  
 a\* 0.36  
 C0.01 1.218  
 C0.04 1.29  
 C0.12 1.288  
 C0.36 1.288  
 C 1.288  
 R 10.500  
 Q 6.164  
 pi 3.142

$\alpha^* = 0.36 \text{ (cm}^{-1}\text{)}$   
 $C = 1.287543$   
 $Q = 6.1635$

$K_{fs} = 9.46E-03 \text{ cm/sec}$   
 $5.67E-01 \text{ cm/min}$   
 $9.46E-05 \text{ m/sec}$   
 $2.23E-01 \text{ inch/min}$   
 $3.72E-03 \text{ inch/sec}$

$\Phi_m = 2.63E-02 \text{ (cm}^2\text{/min)}$

## Test #5

Reservoir Type (enter "1" for Combined and "2" for Inner reservoir): **1**  
 Enter water Head Height ("H" in cm): **5**  
 Enter the Borehole Radius ("a" in cm): **3**

Enter the soil texture-structure category (enter one of the below numbers): **4**

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropores, etc

Steady State Rate of Water Level Change ("R" in cm/min): **6.2000**

Res Type 35.22  
 H 5  
 a 3  
 H/a 1.66667  
 a\* 0.36  
 C0.01 0.80949  
 C0.04 0.84206  
 C0.12 0.80315  
 C0.36 0.80315  
 C 0.80315  
 R 6.200  
 Q 3.6394  
 pi 3.1415

$\alpha^* = 0.36 \text{ (cm}^{-1}\text{)}$   
 $C = 0.803154$   
 $Q = 3.6394$

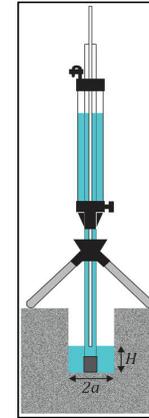
$K_{fs} = 1.09E-02 \text{ cm/sec}$   
 $6.57E-01 \text{ cm/min}$   
 $1.09E-04 \text{ m/sec}$   
 $2.59E-01 \text{ inch/min}$   
 $4.31E-03 \text{ inch/sec}$

$\Phi_m = 3.04E-02 \text{ (cm}^2\text{/min)}$

## Average

$K_{fs} = 1.02E-02 \text{ cm/sec}$   
 $6.12E-01 \text{ cm/min}$   
 $1.02E-04 \text{ m/s}$   
 $2.41E-01 \text{ inch/min}$   
 $4.02E-03 \text{ inch/sec}$

$\Phi_m = 2.83E-02 \text{ (cm}^2\text{/min)}$



Calculation formulas related to shape factor (C). Where  $H_1$  is the first water head height (cm),  $H_2$  is the second water head height (cm),  $a$  is borehole radius (cm) and  $a^*$  is microscopic capillary length factor which is decided according to the soil texture-structure category. For one-head method, only  $C_1$  needs to be calculated while for two-head method,  $C_1$  and  $C_2$  are calculated (Zhang et al., 1996).

Soil Texture-Structure Category	$\alpha^* \text{ (cm}^{-1}\text{)}$	Shape Factor
Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.	0.01	$C_1 = \left( \frac{H_1/a}{2.102 + 0.118(H_1/a)} \right)^{0.655}$ $C_2 = \left( \frac{H_2/a}{2.102 + 0.118(H_2/a)} \right)^{0.655}$
Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.	0.04	$C_1 = \left( \frac{H_1/a}{1.992 + 0.091(H_1/a)} \right)^{0.683}$ $C_2 = \left( \frac{H_2/a}{1.992 + 0.091(H_2/a)} \right)^{0.683}$
Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.	0.12	$C_1 = \left( \frac{H_1/a}{2.074 + 0.093(H_1/a)} \right)^{0.754}$ $C_2 = \left( \frac{H_2/a}{2.074 + 0.093(H_2/a)} \right)^{0.754}$
Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macro pores, etc.	0.36	$C_1 = \left( \frac{H_1/a}{2.074 + 0.093(H_1/a)} \right)^{0.754}$ $C_2 = \left( \frac{H_2/a}{2.074 + 0.093(H_2/a)} \right)^{0.754}$

Calculation formulas related to one-head and two-head methods. Where  $R$  is steady-state rate of fall of water in reservoir (cm/s),  $K_{fs}$  is Soil saturated hydraulic conductivity (cm/s),  $\Phi_m$  is Soil matric flux potential (cm<sup>2</sup>/s),  $a^*$  is Macroscopic capillary length parameter (from Table 2),  $a$  is Borehole radius (cm),  $H_1$  is the first head of water established in borehole (cm),  $H_2$  is the second head of water established in borehole (cm) and  $C$  is Shape factor (from Table 2).

One Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$	$K_{fs} = \frac{C_1 \times Q_1}{2\pi H_1^2 + \pi a^2 C_1 + 2\pi \left( \frac{H_1}{a} \right)}$
One Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$	$\Phi_m = \frac{C_1 \times Q_1}{(2\pi H_1^2 + \pi a^2 C_1) a^* + 2\pi H_1}$
Two Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$ $Q_2 = \bar{R}_2 \times 35.22$	$G_1 = \frac{H_2 C_1}{\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $G_2 = \frac{H_1 C_2}{\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $K_{fs} = G_2 Q_2 - G_1 Q_1$ $G_3 = \frac{(2H_1^2 + a^2 C_1) C_1}{2\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$
Two Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$ $Q_2 = \bar{R}_2 \times 2.16$	$G_4 = \frac{(2H_1^2 + a^2 C_1) C_2}{2\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $\Phi_m = G_3 Q_1 - G_4 Q_2$



# Guelph Permeameter Calculations

Input  
Result

Support: ali@soilmoisture.com

## Test #6

Reservoir Type (enter "1" for Combined and "2" for Inner reservoir): **1**  
 Enter water Head Height ("H" in cm): **5**  
 Enter the Borehole Radius ("a" in cm): **3**

Enter the soil texture-structure category (enter one of the below numbers): **4**

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravelly sands; may also include some highly structured soils with large and/or numerous cracks, macropores, etc

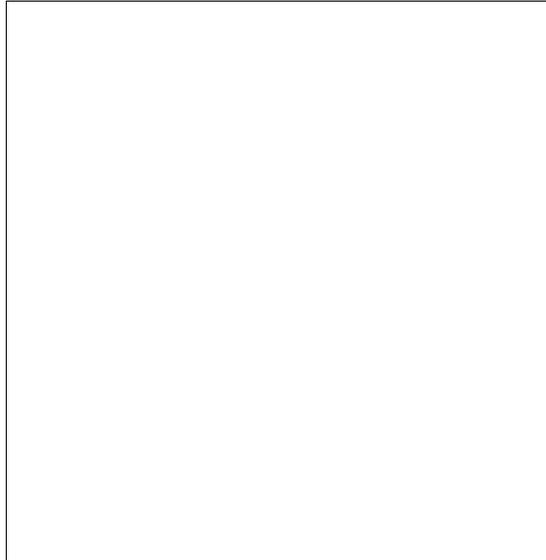
Steady State Rate of Water Level Change ("R" in cm/min): **12.5000**

Res Type: 35.22  
 H: 5  
 a: 3  
 H/a: 1.667  
 a\*: 0.36  
 C0.01: 0.809  
 C0.04: 0.842  
 C0.12: 0.803  
 C0.36: 0.803  
 C: 0.803  
 R: #####  
 Q: 7.338  
 pi: 3.142

$\alpha^* = 0.36 \text{ (cm}^{-1}\text{)}$   
 $C = 0.803154$   
 $Q = 7.3375$

$K_{fs} = 2.21E-02 \text{ cm/sec}$   
 $1.32E+00 \text{ cm/min}$   
 $2.21E-04 \text{ m/sec}$   
 $5.21E-01 \text{ inch/min}$   
 $8.69E-03 \text{ inch/sec}$

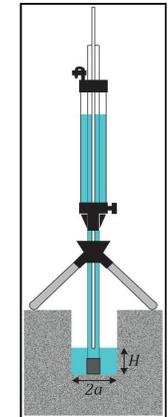
$\Phi_m = 6.13E-02 \text{ (cm}^2\text{/min)}$



## Average

$K_{fs} = 2.21E-02 \text{ cm/sec}$   
 $1.32E+00 \text{ cm/min}$   
 $2.21E-04 \text{ m/s}$   
 $5.21E-01 \text{ inch/min}$   
 $8.69E-03 \text{ inch/sec}$

$\Phi_m = 3.06E-02 \text{ (cm}^2\text{/min)}$



Calculation formulas related to shape factor (C). Where  $H_1$  is the first water head height (cm),  $H_2$  is the second water head height (cm),  $a$  is borehole radius (cm) and  $a^*$  is microscopic capillary length factor which is decided according to the soil texture-structure category. For one-head method, only  $C_1$  needs to be calculated while for two-head method,  $C_1$  and  $C_2$  are calculated (Zhang et al., 1995).

Soil Texture-Structure Category	$\alpha^* \text{ (cm}^{-1}\text{)}$	Shape Factor
Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.	0.01	$C_1 = \left( \frac{H_1/a}{2.102 + 0.118(H_1/a)} \right)^{0.655}$ $C_2 = \left( \frac{H_2/a}{2.102 + 0.118(H_2/a)} \right)^{0.655}$
Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.	0.04	$C_1 = \left( \frac{H_1/a}{1.992 + 0.091(H_1/a)} \right)^{0.683}$ $C_2 = \left( \frac{H_2/a}{1.992 + 0.091(H_2/a)} \right)^{0.683}$
Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.	0.12	$C_1 = \left( \frac{H_1/a}{2.074 + 0.093(H_1/a)} \right)^{0.754}$ $C_2 = \left( \frac{H_2/a}{2.074 + 0.093(H_2/a)} \right)^{0.754}$
Coarse and gravelly sands; may also include some highly structured soils with large and/or numerous cracks, macro pores, etc.	0.36	$C_1 = \left( \frac{H_1/a}{2.074 + 0.093(H_1/a)} \right)^{0.754}$ $C_2 = \left( \frac{H_2/a}{2.074 + 0.093(H_2/a)} \right)^{0.754}$

Calculation formulas related to one-head and two-head methods. Where  $R$  is steady-state rate of fall of water in reservoir (cm/s),  $K_{fs}$  is Soil saturated hydraulic conductivity (cm/s),  $\Phi_m$  is Soil matric flux potential (cm<sup>2</sup>/s),  $a^*$  is Macroscopic capillary length parameter (from Table 2),  $a$  is Borehole radius (cm),  $H_1$  is the first head of water established in borehole (cm),  $H_2$  is the second head of water established in borehole (cm) and  $C$  is Shape factor (from Table 2).

One Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$	$K_{fs} = \frac{C_1 \times Q_1}{2\pi H_1^2 + \pi a^2 C_1 + 2\pi \left( \frac{H_1}{a} \right)}$
One Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$	$\Phi_m = \frac{C_1 \times Q_1}{(2\pi H_1^2 + \pi a^2 C_1) a^* + 2\pi H_1}$
Two Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$ $Q_2 = \bar{R}_2 \times 35.22$	$G_1 = \frac{H_2 C_1}{\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $G_2 = \frac{H_1 C_2}{\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $K_{fs} = G_2 Q_2 - G_1 Q_1$ $G_3 = \frac{(2H_1^2 + a^2 C_1) C_1}{2\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$
Two Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$ $Q_2 = \bar{R}_2 \times 2.16$	$G_4 = \frac{(2H_1^2 + a^2 C_1) C_2}{2\pi(2H_1 H_2 (H_2 - H_1) + a^2 (H_1 C_2 - H_2 C_1))}$ $\Phi_m = G_3 Q_1 - G_4 Q_2$

# Attachment D

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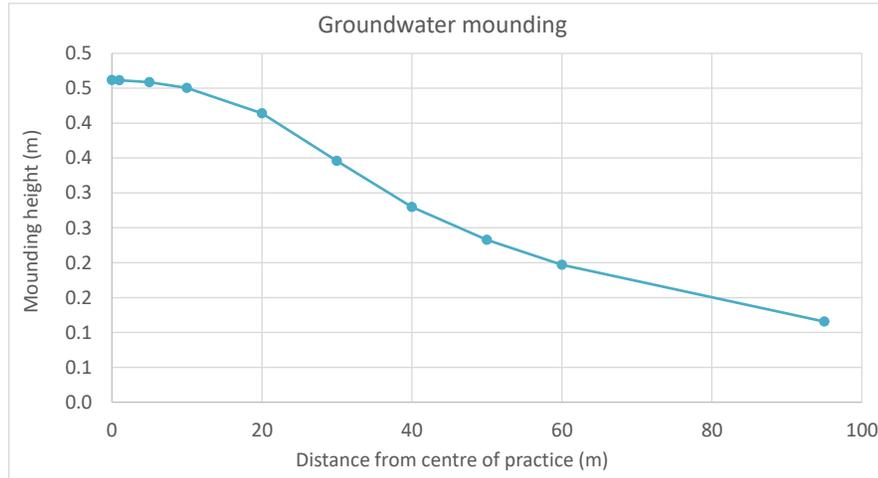
## Mounding Calculation

### Hantush (1967) Mounding Calculation

This spreadsheet will calculate the height of a groundwater mound beneath an stormwater infiltration BMP.  
 More information can be found in the U.S. Geological Survey Scientific Investigations Report 2010-5102  
 "Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins".

[Go to the USGS report](#)

Input Values	
Recharge (infiltration) rate (m/day)	1.632 R
Specific yield, $S_y$ (dimensionless)	0.250 $S_y$
Horizontal hydraulic conductivity, $K_h$ (m/day)	46.656000 K
1/2 length of basin (x direction, in m)	28.5 x
1/2 width of basin (y direction, in m)	11.4 y
Duration of infiltration period (days)	1 t
Initial thickness of saturated zone (m)	37.0 $h_i(0)$



Distance from center of infiltration BMP (m)	Ground-water mounding (m)
0	0.46
1	0.46
5	0.46
10	0.45
20	0.41
30	0.35
40	0.28
50	0.23
60	0.20
95	0.12

**IF YOU CHANGE THE SCALE OF THE DISTANCE MEASUREMENTS (OR ANY OTHER PARAMETER), YOU MUST RECALCULATE!!**