

Guidelines for water table mounding tests

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Ian Ralston P.L.Eng and Michael Payne PEng PGeo

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A. Introduction

A- 1 GENERAL INTRODUCTION AND VERTICAL SEPARATION

Unsaturated vertical separation (VS) below an onsite sewerage dispersal system is a primary factor for effective soil-based treatment.

To maintain unsaturated vertical separation below the dispersal system, the onsite sewerage system designer should account for the water table rise below the dispersal area during operation. The vertical separation remaining, after the water table rises, is termed “retained vertical separation” (retained VS). See Figure A- 1, below, for explanation of terms.

Designers of onsite systems manage retained vertical separation through contour loading rate standards. Designers use linear loading rate (LLR) tables to establish a minimum system contour length that will maintain vertical separation.

Alternately, by measuring the soil’s hydraulic conductivity, the designer can use a Darcy’s Law calculation or simple modeling to select a design contour length. Designers of stormwater infiltration systems use a similar approach. Commonly, designers use small-scale tests to measure soil hydraulic conductivity.

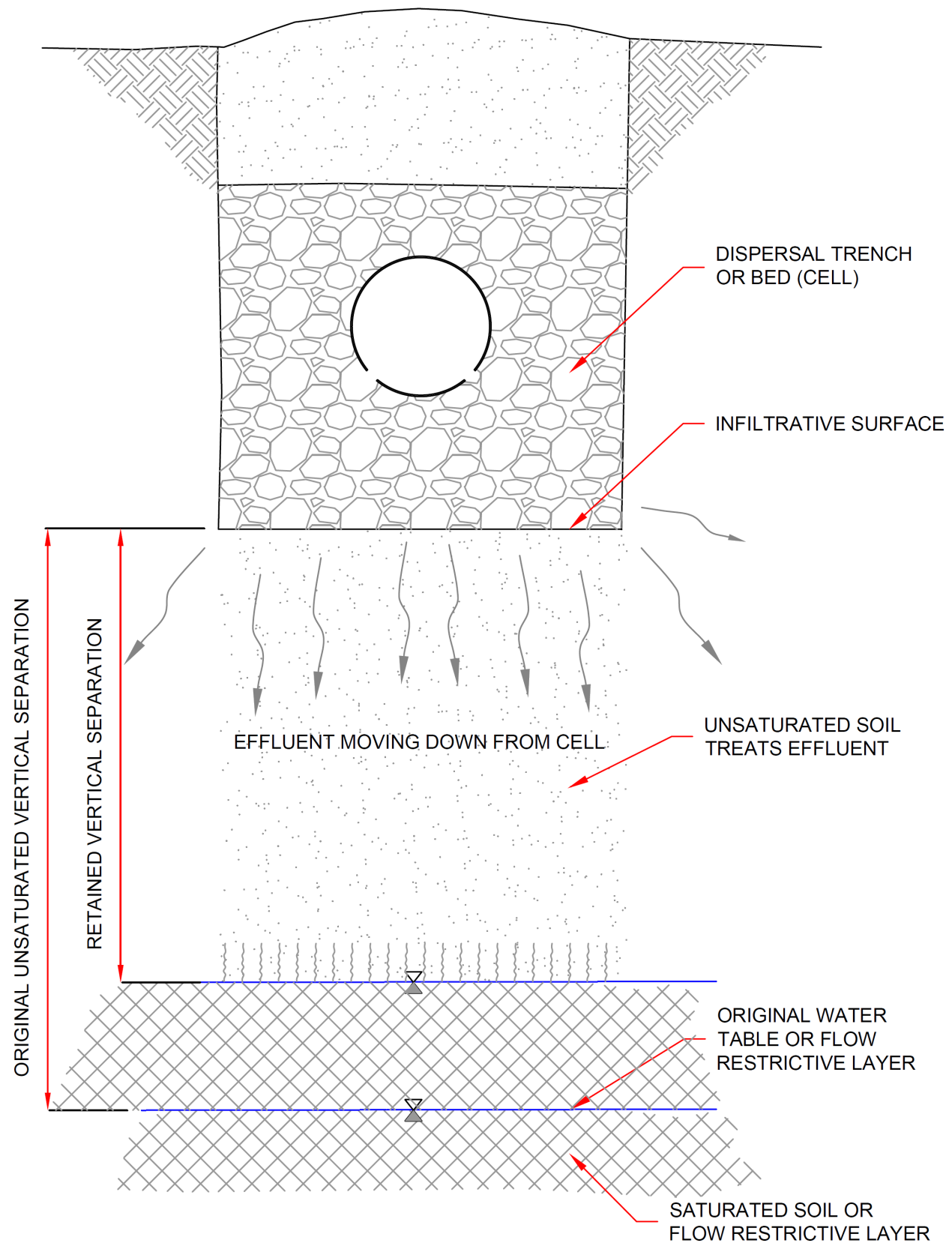
We have observed that large scale testing of a site’s natural discharge capacity, also termed hillslope scale hydraulic conductivity, often reveals a higher discharge capacity than expected.

We have found that large scale tests to be a reliable method for estimating and validating retained vertical separation. Large scale tests will often validate a shorter system contour length for the same retained vertical separation in comparison to the minimum LLR standards in design manuals or required contour length based on calculations using small scale hydraulic conductivity testing. For discussion, refer to Payne and Ralston (2024).

During large scale tests we can directly check the risk of downslope breakout of percolate. Testing may be combined with basin flooding tests to provide information on clean water infiltration capacity.

This guideline presents is for professionals testing water table mounding for small and medium sized onsite sewerage systems or stormwater infiltration systems. Under current guidelines in British Columbia, a professional engineer or geoscientist must either conduct or supervise the test.

Figure A- 1. Vertical separation and retained vertical separation



A- 2 TEST CONTEXT

A- 2.1 General description of testing

A large-scale test consists of applying clean water, to the soil or to sand media fill overlying soil. Apply water evenly along the proposed dispersal contour length (or part of that length) at a measured rate, use observation standpipes (monitoring wells) to measure the shallow groundwater table.

It is best to test during when water table is close to the typical seasonal high water table (SHWT). If this is not practical, design the test to account for effects of normal rainfall or snow melt. Refer to the BC Sewerage System Standard Practice Manual (SPM) for a definition of SHWT.

Time required for testing is typically one to three weeks. Allow time for the induced water table mound to stabilize. After the water table stabilizes, it is good practice to continue testing at a reduced flow rate to confirm the water table mound recedes.

A- 2.2 Planning

Planning starts with finding a reliable water supply with adequate capacity.

Where an existing dispersal system is available, it may be practical to use that system for testing. This is often practical if the system is in operating condition and can accept and distribute applied water evenly along the contour length at the necessary application rate.

Designers can adapt the protocol to answer other questions. Examples include: measuring clean water infiltration rate, assessing drainage design and drainage discharge rates, assessing risk of breakout, and measuring travel time. This guideline does not advise on these uses.

B. Test protocol

This standard test procedure outlines the simplest practical approach. This procedure is for a test with a single flow rate into a test trench that is the same length as the proposed dispersal system.

Refer to the Section C for background information on the test, optional additional steps, and how to vary the procedure for unusual circumstances. See Figure B- 1 and Figure B- 2, below, for terms.

B- 1 PREPARE FOR THE TEST

1. Evaluate the site and soils. Sketch a conceptual design and section for the proposed system. Include in the conceptual design the peak-day design flow rate (in BC this is the daily design flow, "DDF"), the planned height above or depth below grade to infiltrative surface, and the planned system contour length. *Note that this information is for planning the test, the test results may lead to a different design.*
2. Establish a target for the minimum retained vertical separation.
3. Select the clean water application flow rate for the test. The simplest approach is to use the peak-day design flow rate.
4. Confirm a reliable water supply.
5. Specify the length, base elevation, depth and width of the trench for applying water. *The base of the trench should be at about the same level as the proposed depth or height of the system infiltrative surface. See Section C- 2.4 for further discussion.*
6. Select a distribution method. Specify the equipment, including flow meter, flow control and a distribution system. *Specify the distribution system to result in less than 20% variation in application rate per metre along the trench.*
7. Sketch a diagram with monitoring standpipes. Include at least one standpipe up-gradient from the center of the trench at 3 to 20 m from the trench and at least two standpipes located down gradient at 1 to 3 m from the trench. Show the down gradient standpipes at 1/3 total trench length from each end (*see Figure B- 1, Figure B- 2 and Section C- 3*).
8. Draw up a data collection sheet. Include daily applied flow rate and daily water table depth below ground surface at each standpipe (*see the attached example*).
9. Ideally, plan the test to coincide with the seasonal high water table (SHWT). If this is not feasible, then compensate for this by pre-soaking and adding compensating water flow. *See Section C- 4 for pre-soaking and compensation.*

B- 2 SET UP THE TEST

1. Install the test trench in the proposed system location, with base of trench level, following the land contour. For systems in BC, follow SPM trench standards.
2. Install and label the monitoring standpipes. Record the depth to restrictive horizon if present.
3. Install the flow control and distribution equipment.
4. Record the depths or elevations of the trench base, bottoms and tops of standpipes, ground level at trench and standpipes. *Express elevations relative to a bench mark.*
5. Before starting the test, check that any water table has stabilized in the standpipes. Record the depth of the water table in the standpipes.

B- 3 RUN THE TEST

1. Start the test, by turning on the water. Check for even distribution in the trench. During the test continue to check the distribution and check for water overtopping the trench.
2. Pre-soak at a higher water flow rate to raise the water table if necessary. *See Section C- 4.*
3. Daily, record the applied water volume and the depth to water table in standpipes.
4. During the test, adjust the flow control to maintain the planned daily rate.
5. If the water table rises in the up-gradient standpipe, add another up-gradient standpipe located further from the trench. If levels in the down-gradient standpipes show large variation (>30%), install a third standpipe.
6. Continue measuring the applied flow rate and water table depth until the water table depth at the down gradient standpipes stabilizes. *See Section C- 6 for guidance.*
7. Record any evidence of breakout at down gradient locations.
8. Reduce the water flow rate by 50%. Continue testing for a few days to confirm that the water table mound recedes after the water application rate is reduced.

B- 4 ANALYZE THE DATA

1. Use the water level data to calculate the retained vertical separation, based on the planned depth or height to infiltrative surface. Calculate the slope of the original water table or flow restrictive layer. Optionally, calculate the apparent hillslope scale hydraulic conductivity if that is helpful.
2. If the retained vertical separation meets your target with a full-scale test, then the test has validated (confirmed) the proposed system contour is long enough.
3. In other cases, refer to Sections C- 6 and C- 7.2.2 for options and calculations.
4. When designing the sewerage system, include one or more standpipes to allow for ongoing monitoring of the depth of the water table below the dispersal system.

Figure B- 1. Water table mounding test layout

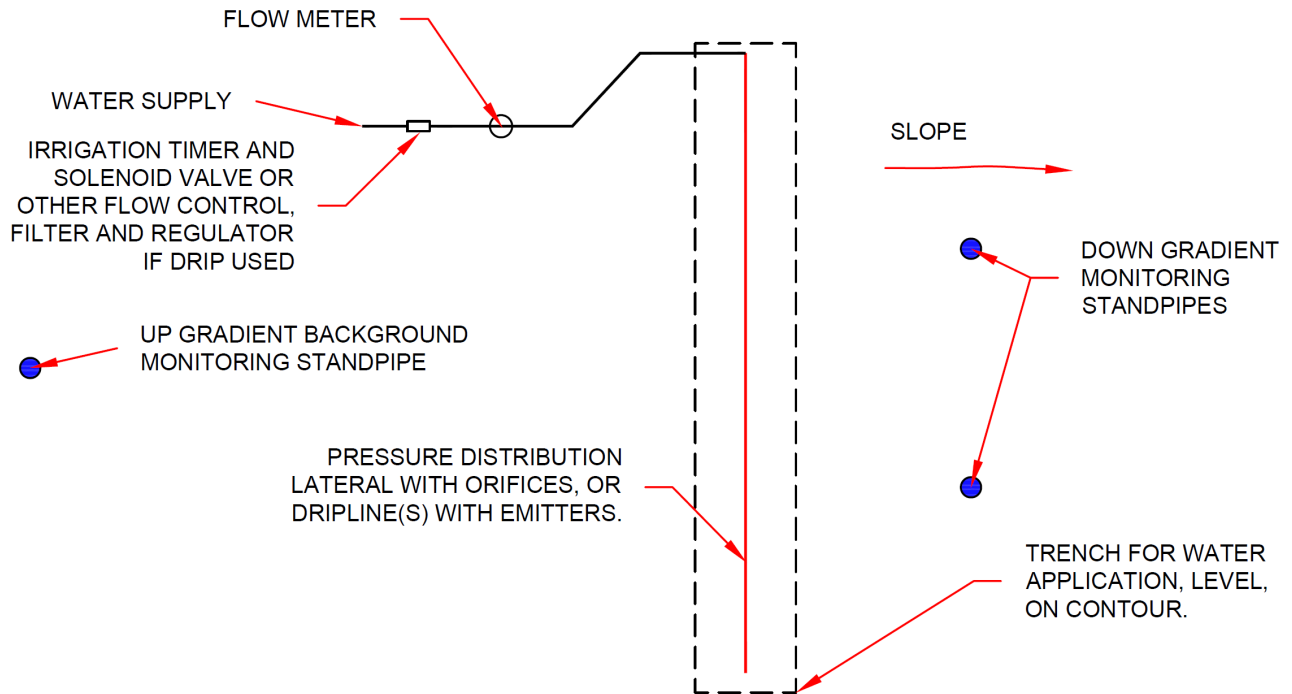
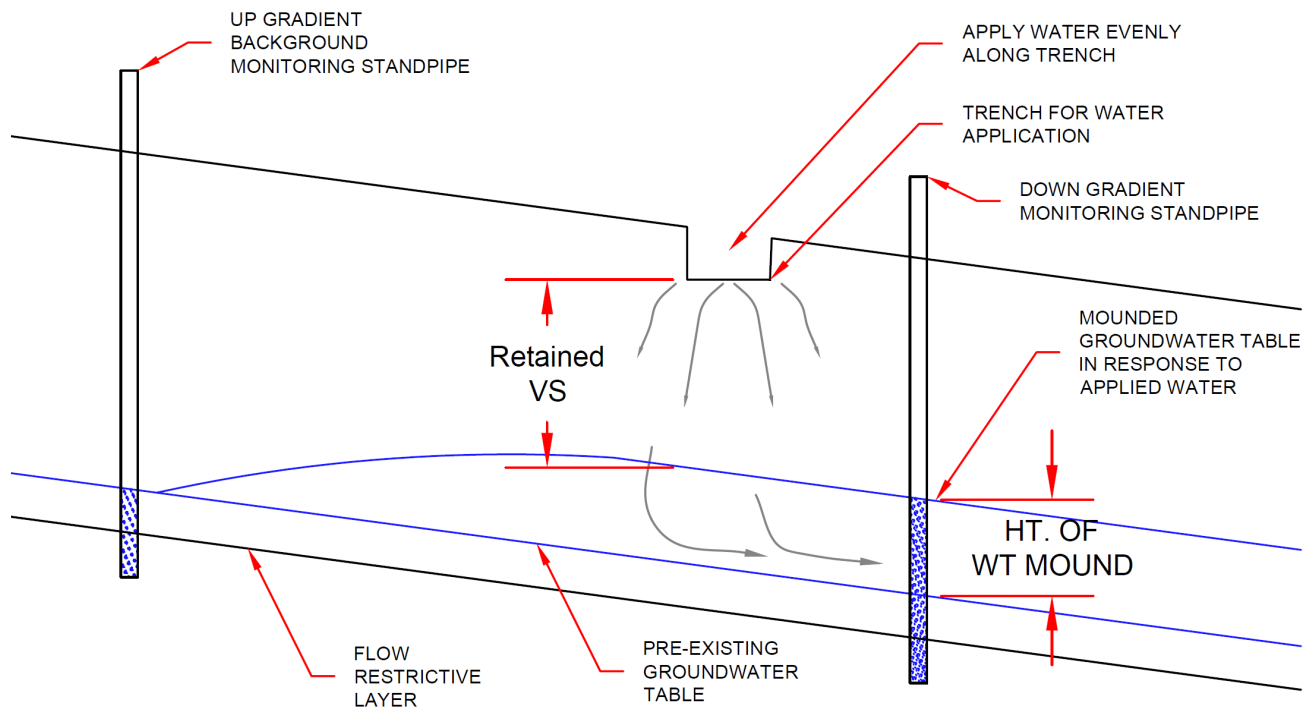


Figure B- 2. Water table mounding test schematic section



C. Test guidance

The following sections discuss test methods, test options and unusual circumstances. These guidelines do not cover all situations. Designers should write their own rationale for variations on the basic test method.

C- 1 SITE EVALUATION AND DISPERSAL SYSTEM CONCEPTUAL DESIGN

C- 1.1 Preliminary site and soil evaluation

Run the test after site and soil evaluation, so that key information is on hand for the proposed dispersal area alignment and immediate receiving area. In the Site Evaluation Report, include at least the following:

- Available contour length for dispersal.
- Water table gradient and direction(s) of flow, existing and as affected by proposed site works (e.g., proposed drains, cut banks and down gradient water courses).
- Soil profile (test pit logs) and soil permeability test results.
- Current measured or estimated seasonal high water table depth below grade.
- Characteristics of underlying restrictive layer or non-soil unsaturated (vadose) zone (e.g., fractured rock, gravel).
- Proposed sewage system design flow rates.

C- 1.2 Preliminary system selection and performance objectives

Prior to the test, record the following information in the conceptual design:

- Sewerage system design flow rates, including peak-day (DDF) and average daily discharge flow (ADF) rates.
- Conceptual layout of the proposed dispersal system to inform choice of alignment for the test.
- Minimum required retained unsaturated vertical separation as a target to help to inform decisions during testing (see below).
- Where seasonal water table is close to ground surface, or usable soils are very shallow; the proposed sand media depth above grade in dispersal and, if necessary, receiving area.

When establishing the target minimum retained vertical separation, the goal is to retain sufficient vertical separation after mounding of the water table so that the soil can adequately reduce pathogens and other contaminants before percolate reaches the water table.

In British Columbia, refer to the BC SPM for minimum vertical separations. For a custom design, select a minimum retained vertical separation, and record your rationale.

C- 1.3 Pre-installing sand media

Some sites have very shallow usable soils or no native soils or a very shallow seasonal water table. On these challenging sites, one option is to pre-install all or part of a proposed sand mound (and any drainage layers) in the dispersal prior to testing. Run the test by applying water to the sand media.

In some cases, the designer might install the entire dispersal system before the test. The test then becomes a full-scale validation of the installed system. Keep in mind that it is impossible to predict the test results. If the system fails the test, then this causes more problems.

C- 1.4 Pre-installing drainage

If the design includes up-slope or down-slope drains, then one option is to pre install the drainage system before the test. The monitoring standpipes can first measure the effect of these drains and then, second, measure the effect of the mounding test. The post-drainage seasonal water table level is the seasonal water table for test purposes.

On poorly drained sites it often helps to have down slope or down gradient drains, sometimes termed "relief drains". Foundation perimeter drains and ditches can also serve as relief drains. For a water table mounding test, it is good practice to install these drains before running the test. If this is not practical, another option is to install temporary drainage trenches in the planned location of the permanent drains. Trenches allow you to observe water flow in soil layers in the receiving area.

C- 2 WATER APPLICATION

C- 2.1 Full-scale versus scale testing

The protocol recommends testing at full-scale, that is applying water over the same contour length and in the same location as the planned effluent dispersal system.

A full-scale test, with water applied at the estimated design flow rate for the planned sewerage system, provides direct validation of a specific retained vertical separation and associated LLR.

Scale testing is an option to consider if it is not practical to use the full contour length. For example, there may be an existing system in place, or the water supply could be limited. Risks attached to this approach include the following:

- Soil and other conditions might be different between the test alignment and the final system alignment.
- Heterogeneity of soil, with layered soils resulting in risk of extrapolating calculated hillslope scale hydraulic conductivity to a water table rise different from that tested.
- Drainage of water away from the edges or ends of the trench is relatively more significant with short trenches versus long trenches.

C- 2.2 Choice of water application rate

The designer of the test can consider different flow rates, both single rates and variable rates.

An example of variable applied flow rate during a test is as follows:

- At 4 times peak-day design flow rate for an initial period to hasten water table mounding,
- At estimated peak-day design flow rate (DDF) for a period as for the standard test until the water table stabilizes,
- At the estimated average daily flow rate, for a few days, to observe the water table mound recovering and to measure a longer-term mound height.

Designers can start with higher than the design flow rate, also called pre-soaking. Section C- 4 discusses how to run the test when the water table is below the normal SHWT level.

If the water table does not rise, the designer can increase the flow rate to see what flow rate, if any, causes the water table to rise.

Conversely, if the water table rise is too fast, the designer can reduce the flow rate to one that leads to a stable and acceptable water table mound.

C- 2.3 Water supply

A garden hose with dedicated hose bib is often used for water supply. Clearly labeling the hose and bib is important to reduce the risk of someone turning it off. Removing the handle may also help.

If there is no hose bib connection, then other options include using an elevated tank system or a pump in a tank or water body.

Use clean water. Avoid water with a high level of sodium or other deleterious substances. Consider filtering surface water to reduce the risk of clogging flow meters and other distribution system components.

C- 2.4 Applying water to the soil or sand media

Use a recording flow meter (mechanical or datalogging) to record the applied water flow rate daily. If the water table rise is slow it may be practical to measure every 2 to 3 days. Ensure the flow meter is capable of measuring the expected flow rates, and that it is installed following manufacturer guidelines.

Try to keep the flow rate close to the selected flow rate, or slightly higher. Day-to-day variations of less than 30% will not ruin the test results. However, the overall daily average flow rate, at the end of the test, should be equal to or larger than the selected rate.

A common method is to dig a small, level, trench along the planned alignment of the effluent dispersal system. The trench size should be adequate to avoid overflow. It is good practice to add water at a soil hydraulic loading rate less than 100 times the allowable septic tank effluent hydraulic loading rate (HLR) for the soil, use this maximum loading rate to calculate the minimum width for the trench.

For example, for a septic tank effluent (Type 1) peak-day HLR of 15 L/day/sqm do not apply water at greater than 1500 L/day/sqm. So, for a peak-day design flow rate of 1600 L/day a minimum infiltrative surface area is 1600 divided by 1500 equals 1.07 sqm. Therefore, for an 8 m long trench the minimum trench width would be 1.07 divided by 8 equals 0.13 m. This example shows that, in many cases a practical trench width will be wider than the minimum.

The trench base must be level. For sites with very difficult access, a series of small basins may be dug by hand along the contour with each receiving flow from a drip emitter or pressure distribution orifice.

The trench should be deep enough to keep ponded water below the LFH horizon. Trench depth or elevation should be similar to the proposed infiltrative surface depth (or height above grade in the case of a sand mound). One option is to use one of the proposed trenches or part of a proposed seepage bed width. For a raised system, the base of the trench should be at the proposed infiltrative surface height, to contain water in the trench either dig the trench into placed sand media or raise sand media around the trench.

Two common options for even water distribution to the trench are: (1) low pressure pipe distribution or (2) drip dispersal tubing or tape with pressure compensating emitters. The pipe or drip laterals should extend the whole length of the trench. When setting up the test keep the following in mind:

- Pressure Distribution
 - Avoid flow rates exceeding the capacity of the water supply.
 - If the water supply is limited, then consider a larger spacing between orifices, smaller diameter orifices, and a lower distal pressure.
 - Orifice shields can be helpful.
 - Consider an irrigation controller with solenoid valve to dose the pipe lateral(s). This controller can then be used to adjust the flow rate. Another option is to use a timed dosing control panel controlling pumping from a tank.
 - Another method of flow adjustment is a Dole valve.
 - When testing in an existing dispersal system, then that system's control panel or float switches can control the discharge pump. With demand dosing one or more Dole valves can control water flow to the pump tank.
 - Laterals may lie in the trench or be on pipe stands. Pipe stands may improve leveling of the pipe and reduce risk of debris entering orifices on pipe depressurization.

- Drip Distribution
 - Use agricultural drip tubing or tape with built in pressure compensating emitters. 30 or 60 cm emitter spacings are commonly available with emitter flow rates of 0.5 to 1.2 usgph.
 - Include a 150-micron filter ahead of the flow meter and drip tubing.
 - A pressure regulator is normally necessary.
 - One option is to use of several drip laterals, supplied by a manifold with a valve for each lateral. This allows a field technician to adjust flow without using a timer. Alternatively, standard irrigation timer and solenoid valve may be used as described above.
 - Cap the distal ends of the drip laterals or provide a cleanout ball valve.
 - Consider an air vacuum valve at the manifold to reduce risk of emitters aspirating fines on depressurization.
 - Drip lines may lie in the trench or suspend from a wire on posts or other method.
 - If basins are used instead of a continues trench, one option is to install individual pressure compensating drip emitters inserted in PE pipe lateral(s).

Where soils are sensitive to sorting, consider protecting the trench base with a layer of pea gravel. A gravel layer can also help if there is risk of sand and silt flowing into orifices or emitters when the pressure drops in the laterals.

In hot dry weather, consider measures to reduce evaporation from the trench. One option is to cover the trench with plastic to reduce evaporation.

Divert surface water flows and seepage away from the trench.

C- 3 WATER TABLE MONITORING

For water table monitoring, use lengths of 25 to 100 mm (1" to 4") PVC pipe, side slotted or perforated. Install the pipes vertically from the surface to a level below the restrictive layer, water table or seasonal water table.

Install the pipes by hand or in an auger hole or test pit. If the soil is likely to flow into the pipe or form a plug around the pipe, use slotted pipe and backfill around the slotted portion with pea gravel. Leave the pipe sticking up from the ground with a loose cap. Record the standpipe depth, the depth from ground surface to restrictive layer, depth of estimated seasonal water table and any existing water table in the standpipes.

Before installing pipe in an auger hole, check for smearing and over compaction. When backfilling, take care to reduce the risk of preferential flow of surface water down the outside of the pipe and leave a berm around the pipe to divert water flow.

To measure the depth to water in the standpipe, use a measuring tape and flashlight or an electrical water level meter. Measure distances down from the top of pipe. Another option is to use automated level loggers.

In general, place the up-gradient standpipe at least 6 m from the trench to keep the standpipe separated from the water table mound effect. A hydrogeologist might set the up-gradient standpipe at a different distance based on a good understanding of the up-slope extent of the water table mounding effect.

Sometimes it is not practical to install an up-slope standpipe as the background monitoring standpipe. Another option is to install one or more background monitoring standpipes on the side slope, along the contour. As a guideline, install the standpipe at least 6 m from the test trench.

Where the water table gradient is hard to estimate, or the slope is less than 2%, use more than the minimum of three standpipes. Place the standpipes around the system and then use the measured levels to estimate the direction of shallow groundwater flow. If the groundwater flow direction is important to know, then an elevation survey can help.

Sometimes it helps to add standpipes during the test. This can improve background monitoring or help evaluate unexpected mounding results.

For a site with a deep water table, it may be difficult to reach the water table by excavation. On larger projects, designers have used a drill or power auger to install monitoring wells, but this is not commonly feasible for small onsite sewerage systems.

It may be practical to re-use the testing standpipes for long term monitoring of water table depth for the installed system.

C- 4 ADJUSTING FOR WEATHER CONDITIONS

The best time to test is during the period of seasonal high water table, but this is not always practical. For sites where snow melt is the cause of seasonal water tables, it may not be practical to run a test in an undisturbed snow-covered location.

If a test must be completed outside this time, it may be important to adjust for the impact of surface water flow, shallow groundwater flow, and precipitation—potentially including snow melt.

On some sites, it may be important to adjust for seasonal evapotranspiration. This should consider the time of testing and planned changes such as the impact of tree clearing.

To adjust flow rates, the designer can use a simple water balance model to estimate input (melt water, precipitation, run on, incoming shallow groundwater flow) and output (evapotranspiration, runoff, outgoing shallow groundwater flow). When estimating precipitation input, use local rainfall data or local model data to estimate normal wet season input. Estimate peak day or week input by correcting recorded rainfall to effective rainfall (rainfall that results in recharge of shallow groundwater).

Modeling can estimate a range of flow rates for planning a test. However, in our experience, the estimates are often inaccurate.

To adjust using compensating flow, during the test take the following approach:

- Start the test by pre-soaking.

- Continue to apply water to raise the water table up to the seasonal water table level.
- Then, maintain this level until stable for at least two days, adjusting the flow rate to result in a stable water table at the seasonal water table level at a stable compensating flow rate.
- Then, continue the test following the standard procedure. Apply the selected test flow rate **plus** the adjusted compensating flow.

For the pre-soaking, consider applying water at a higher rate for more rapid wetting and raising of the water table. A flow rate of 10 times the selected test application flow rate may be suitable for short term pre soaking, check trench infiltration capacity per Section C- 2.4.

Testing in freezing conditions may be difficult. One option is to use an existing dispersal system or another sub-surface application method.

If heavy rainfall occurs during the test, record the date and estimate of daily rainfall. It is normal for the water table to rise temporarily above normal seasonal high water table in response to heavy rainfall or sudden snow melt. For further information, see the BC SPM definition of seasonal high water table. If this occurs, continue the test after the water table at the up-gradient monitoring standpipe(s) stabilizes at normal SHWT levels.

C- 5 DATA COLLECTION

Typically, a field technician will visit the site daily and report to the designer. This allows the designer to adjust the test to deal with unexpected results. Daily visits also allow the technician and designer to spot and correct data inconsistencies or errors.

For remote sites a data logging flow meter and level loggers can help. However, it is still important for someone to check the test once every few days.

Use a standard form or a shared spreadsheet to record all test data. Notes should include time of year and current state of seasonal water table, flow adjustments and observation of breakout. Where heavy rainfall occurs during the test, record the rainfall amount from an on-site rain gauge or from a nearby weather station. Include restrictive horizon slope or pre-existing and induced groundwater slopes.

See Section C- 7.2 for an example table, also available from COTRA in spreadsheet format.

C- 6 COMMON ADJUSTMENTS DURING TESTING

Questions, problems and solutions include the following:

- **Question:** When is the water table “stable”?
- **Solutions:**
 - This is when the water table has risen and does not rise further over a period of at least two days.
 - Alternatively, if the water table does not rise at all, then see the comments below.
- **Problem:** Water table does not register in the standpipes, or does not rise.
- **Solutions:**
 - Increase the clean water application flow rate. It is common to raise the flow rate as high as 4 times the planned application rate.
 - If the water table does not rise, even at this higher flow rate, continue the test for at least one week at the increased rate in an effort to measure a response.
 - If the water table does rise after increasing the flow rate, then continue the test at the increased rate until the water table stabilizes. A good practice is to then reduce the flow rate to the original rate and record the change in depth.
- **Problem:** Water table rises too high, approaching the trench base or soil surface, or above the objective retained vertical separation.
- **Solutions:**
 - If testing at peak-day design flow (DDF), reduce the applied flow rate to the average daily flow rate (ADF).
 - If heavy rainfall is affecting the test, then extend the test following Section C- 4.
 - If surface water or shallow groundwater flow from up gradient raises the water table, then install interception drains and or swales and re start the test.
 - Consider re-designing the planned sewerage system with a shallower required vertical separation (for example, by using micro timed dosing), a longer contour length, increase vertical separation by adding sand media, or install relief drainage.
- **Problem:** Water table rises in the background (up-gradient) monitoring standpipe.
- **Solution:**
 - Install one or more additional standpipes up-gradient or end (side) gradient to the test trench and further away from the test trench.
- **Problem:** Background water table changes during the test, rising above normal seasonal water table level.
- **Solution:**

- Adjust the measured mound height to account for the measured change in the background (up-gradient) standpipe. Check that the background water table recedes to normal seasonal water table level over time. (See BC SPM definition of seasonal high water table for guidance.)
- **Problem:** Background water table falls during the test, falling below the normal seasonal water table level.
- **Solution:**
 - If lower water table persists once the test reaches stable state, adjust by increasing applied flow rate with addition of a compensating flow per Section C- 4 and re-establishing stable state.
 - Another option, when analyzing the data, is to take the measured fall in the up-gradient standpipe and add that to the measured stable water table height recorded during the test.

C- 7 DATA ANALYSIS

Use the test results to validate a design linear loading rate based on an objective for minimum retained vertical separation.

In addition, designers may use the test results with Darcy's Law calculations to support other conclusions. This may include one or more of the following:

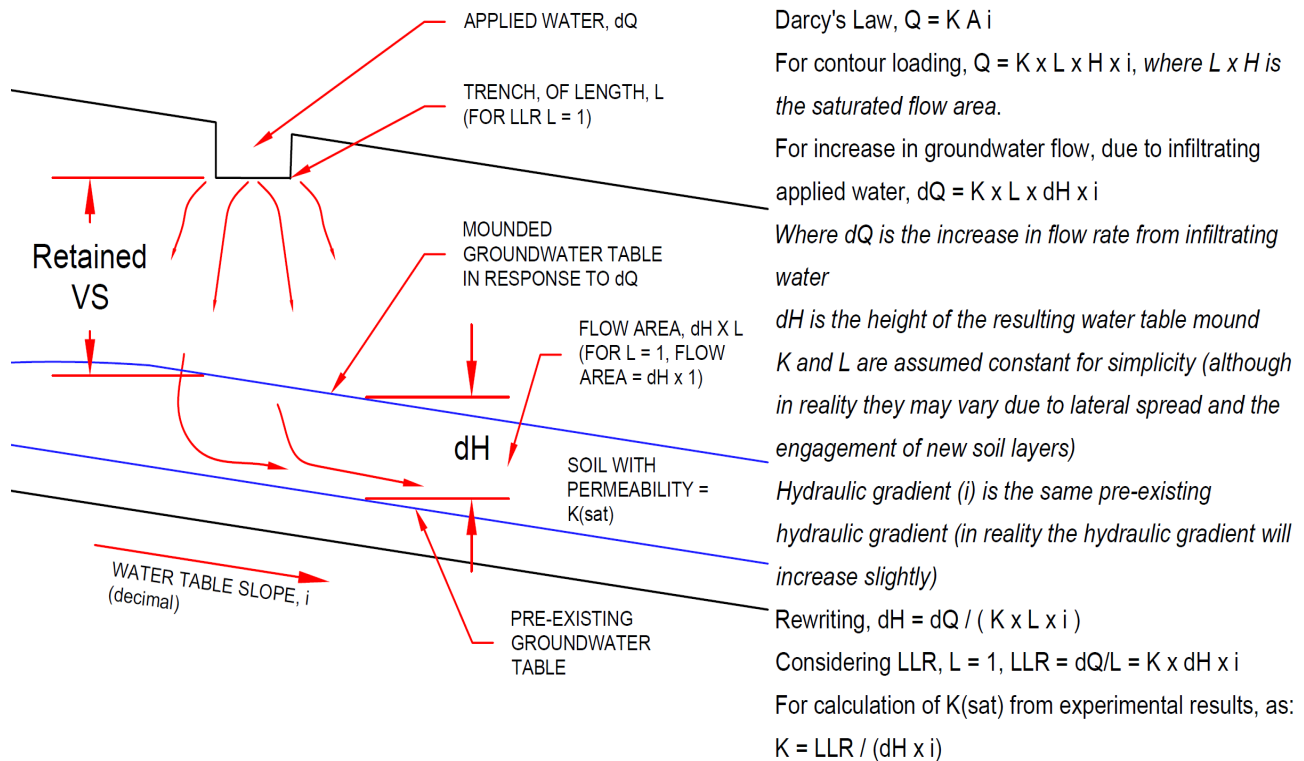
- Calculate the effective or apparent hillslope scale hydraulic conductivity.
- Estimate the probable contribution of vertical seepage or flow in non-soil vadose zone layers to water flow away from the site.
- Extrapolate the results to select a design contour length for a longer system, or one with a larger discharge rate than the test (also called scale testing).
- Evaluate the effectiveness of drainage systems.
- Estimate seasonal inflows of shallow groundwater from up gradient.
- Adjustments discussed in Section C- 6.

C- 7.1 Darcy's Law calculations

C- 7.1.1 DARCY'S LAW

The following diagram summarizes the application of Darcy's Law to the water table mounding test.

Figure C- 1. Water table mounding test and Darcy's Law



C- 7.1.2 HILLSLOPE SCALE HYDRAULIC CONDUCTIVITY AND VALIDATED LINEAR LOADING RATE

As shown in Figure C-1, estimate the apparent or effective hillslope scale hydraulic conductivity as follows:

$K_{sat} = LLR / (dH \times i)$ where dH is the stable rise of the water table in response to the test water flow rate, dQ is the test flow rate and LLR is equal to dQ / L .

Keep in mind the following:

- During a variable rate test, this calculation can lead to different values of K_{sat} for each step of the test. This depends on the height of the stable water table mound at each step, and on which soil layers transmit water as the mound rises. After a variable rate test, it is helpful to calculate the overall average K_{sat} based on the overall average flow rate. This is the most relevant calculation if the groundwater flow responds slowly to changes in the rate of flow to the test trench.

- If most of the flow is vertically down rather than sideways, then the calculated Ksat will be very high. This flow path is different from Figure C-1. As a result, this version of the Darcy equation does not apply. Therefore, the calculated Ksat is not a measure of the Ksat for the soil in the sideways flow path. However, functionally, the test still measures the retained vertical separation and validates a workable linear loading rate for that site.
- Be careful about extrapolating results to other locations on the property, including along the same contour, because soil conditions do vary. When extrapolating results, consider the soil characteristics (texture, structure, and consistence) and soil depth in the area in question, together with the receiving area.
- For a short test trench, or a short operating dispersal system, side slope flows (parallel to the contours) tend to reduce the height of the water table mound compared with the situation in Figure C-1. This phenomenon is sometimes called “edge effects”. This flow system (flow regime) does not match Figure C-1 and, as a result, the equations above do not apply. Darcy’s Law still applies, but the flow is 2-dimensional instead of 1-dimensional. This may also be a risk with tests that use very high water application flow rates, including tests performed in the dry season, with SHWT compensation requiring significant local raising of the water table prior to testing.
- See Payne and Ralston (2024) for further discussion of scale and edge effects.

C- 7.2 Example test results

The table, in Figure C- 2, below, shows the results of a full-scale test using real world values, followed by example calculations.

See the COTRA website for a blank data sheet in spreadsheet format.

Figure C- 2. Record of an example water table mounding test

WATER TABLE MOUNDING TEST - Example with field notes											
Client:	Page Turner										
Project:	123 Literary Road, District of Fiction					Date:	2016-02-24 [wet season]				
File:	NWS-15-2					By:	A. Writer				
Paperback Consulting Company											
Preliminary system design:											
Daily design flow rate (DDF):	2,300 Lpd					Seasonal high water table (SHWT):	70 cm				
Soil infiltration depth:	0 cm (Sand Mound)					Sand infiltration depth (height):	60 cm (above grade)				
Total vertical separation before water table mounding:						130 cm					
Max. LLR allowed by the SPM:	75 Lpd/m					Min. contour length from SPM:	30.7 m				
Test Setup:											
Location of discharge:		4 metres downslope from existing septic field. Land slope is 12%.									
Test trench dimensions:		Length:	14 m	Width:	0.5 m	Area:	7 sq.m.	Depth:	0.4 m		
DOSING PLAN		Water source:	Domestic			Transport method (hose, pipe, truck):			Garden hose		
Flow rate (range):		14 litres per minute			Hose needed:	Yes		Pipe needed:	Yes		
Dose frequency:		6/day	Dose volume:	390 litres	LLR:	167 Lpd/m	(LLR as tested) Note (4)				
Locations of Observation Wells: 2 down-slope wells and 1 up-slope (background) wells											
Depth and Elevation of Observation Standpipes:											
MW #	Length	Stickup	Depth	Top elev	WL @ start of test		Dist from discharge	BGS = below ground surface			
	cm	cm	cm BGS	cm	Depth	Elev		Note			
1	200	120	80	NA	> 80		2.5 m	Soil texture is Sandy Loam, structure is Granular, Strong			
2	210	143	67	NA	> 67		2.5 m				
3	200	140	60	NA	> 60		5 m	Upslope standpipe. Shallow bedrock.			
Water level reference point: Ground surface											
Flow Rate and Rise of Water Table in Observation Wells:											
Date	Time of day	Time	Time	Flow	Total	Average	Depth to water in standpipes BGS (cm)				Remarks
		elapsed mins	elapsed days	meter litres	flow litres	flow Lpd	1	2	3	4	
2016-02-24	9:36	0	0.00	903,224	0		> 80	> 67	> 60		
2016-02-24	10:06	30	0.02	903,614	390		> 80	> 67	> 60		
2016-02-25	9:53	1,457	1.01	905,914	2,690	2,659	47	28	> 60		
2016-02-26	10:31	2,935	2.04	908,164	4,940	2,424	32	28	> 60		
2016-02-27	10:10	4,354	3.02	910,514	7,290	2,411					
2016-02-28	10:21	5,805	4.03	912,764	9,540	2,367	31	30	> 60		
2016-02-29	11:07	7,291	5.06	915,089	11,865	2,343	31	29	> 60		Notes (1, 5)
Totals (and WL rise):		7,291	5.06		11,865		(49 cm)	(38 cm)	(NA)		
Retained VS (cm)							31	29	NA		Min. 29 cm Note (3)
Averages:						2,343					Note (2)
NOTES:											
(1) System design flow rate (peak day) is 2,300 Lpd and target minimum retained VS is 25 cm in native soil for sand mound per SPM Table II-17											
(2) Average test flow rate of 2340 Lpd caused the water table to rise an average of 44 cm (range 38-49 cm).											
(3) For the proposed Sand Mound, the validated retained native soil vertical separation (after mounding) is 29 cm (range 29-31 cm). The validated total VS is 29 cm in native soil plus 60 cm sand media, equals 89 cm. Meets SPM sand mound standards.											
(4) Maximum allowable LLR following SPM LLR tables is 75 Lpd/m, based on 70 cm usable soil depth before water table rise											
(5) The water table is stable or falling so we can stop the test here.											

C- 7.2.2 CALCULATIONS

In the example in Figure C- 2, the test flow rate is average 2340 L/day and the trench length is 14 m long on contour. The results directly validate a retained vertical separation of 29 to 31 cm (average 30 cm) below ground surface at an average linear loading rate of 2340 divided by 14 equals 167 L/day/m or 0.17 cum/day/m.

The designer estimated a system peak-day design flow rate of 2300 L/day based on local standards (termed DDF in BC). Keep in mind this peak-day design flow rate includes a peaking factor. Under BC's SPM, all planned new residential sewage systems have a peaking factor of 2.0 unless a design engineer documents a different peaking. Using BC standards, the estimated average flow rate is 1150 L/day. Since the applied flow rate was approximately 2 x higher than expected system average flow rate, this results in an implied safety factor and the validated retained vertical separation (VS) of 29 to 31 cm (30 cm average) in native soil and the overall retained vertical separation of 89 cm is conservative.

For the planned sewage system, the linear loading rate for the 14 m system length at average flow would be 1150 divided by 14 equals 82 L/day/m or 0.082 cum/day/m.

Using the average ground surface slope (12%) and the average water table rise (0.44 m), calculate the hillslope scale hydraulic conductivity as follows:

$$K_{sat} = LLR / (dH \times i) \quad K_{sat} = 0.17 / (0.44 \times 0.12) = 3.2 \text{ m/day, or } 3200 \text{ mm/day}$$

Using this K_{sat} , we can estimate the average water table rise resulting from the average daily flow rate (ADF). This is an estimate or approximation because different soil layers often have different permeabilities. We can estimate the operating system water table rise as follows, using average values:

$$dH = LLR / (K_{sat} \times i) \quad dH = 0.082 / (3.2 \times 0.12) = 0.21 \text{ m or } 21 \text{ cm.}$$

Then, if we subtract this from the minimum soil depth near the trench alignment (from MW-2 67 cm), this gives us an estimated retained vertical separation (VS) of 46 cm. This is our best estimate of the average seasonal retained vertical separation under an operating system at this location.

Using similar calculations, we can extrapolate the test results to a proposed system with a greater design flow rate and greater contour length, using the test as a pilot scale test. As discussed, designers should be cautious about extrapolating test results. We can extrapolate test results using the validated LLR, or we can use Darcy's Law for a particular target retained vertical separation.

For example, we can calculate an allowable contour length for a larger average flow rate of 3000 L/day, and a target retained vertical separation at average flow rate resulting in maximum allowable water table rise of 50 cm. Remember to use averages for these calculations.

$$\text{Allowable LLR} = K_{sat} \times dH \times i$$

$$\text{Allowable average flow LLR} = 3.2 \text{ m/day} \times 0.5 \text{ m} \times 0.12 \text{ m/m} = 0.192 \text{ cum/day/m or } 192 \text{ L/day/m}$$

$$\text{The resulting minimum allowable contour length} = ADF / LLR = 3000 / 192 = 15.6 \text{ m}$$

C- 7.3 Risk management

When running a water table mounding test at the peak-day flow rate (the DDF in BC), then this results in an implied safety factor.

A designer may use a model to estimate pathogen attenuation and apply an explicit safety factor to establish the target minimum retained vertical separation. Often, this results in a target equal to or greater than the vertical separation specified in local standards.

To reiterate, be cautious when extrapolating test results and when using scale testing. One way to manage the risk of extrapolating is to apply a safety factor to your final calculated result. Considering the example above, a designer could apply a safety factor of 1.5 and say that the minimum allowable contour length is $15.6 \times 1.5 = 23.4$ metres. For scale testing, be cautious and consider the risks from extending the system into untested locations.

Testing at more than one flow rate can validate more than one retained vertical separation. This improves estimates of retained vertical separation at various design flows for the test contour length.

When comparing test results and analysis to recommended LLR values from design manuals and standards, consider the linked design flow rate and retained vertical separation basis used by the particular table and standard.

We recommend monitoring water table depth during system operation. The system maintenance plan should include required actions if the water table rises too high, thus reducing the vertical separation.

Consider specifying timed dosing. This will provide improved control of discharge flow rate during system operation.

D. References

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