

Soakage and the Building Code

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ABSTRACT

Soakage to ground is often used as a method of managing stormwater runoff generated by development. The New Zealand Building Code compliance document E1 is the only national guideline that provides methods for determining the soil soakage rate and the size of the related system. Several other guidelines exist locally and many engineers do not use the method in E1. Once stormwater is discharged to ground there is often little consideration given to the effects on other properties. This paper explores the variation between the methods and whether the method in E1 complies with the New Zealand Building Code.

1 INTRODUCTION

Effective stormwater management is essential for managing flooding and ponding in the built environment. Soakage to ground is promoted as preferable to assist in groundwater recharge, and in some areas, it also prevents saltwater intrusion.

Based on my experience processing resource and building consents at two councils, many designers did not use the New Zealand Building Code Verification Method E1/VM1 (MBIE, 1992) to determine soakage rates or design soakage systems. The few designers that do use E1/VM1 reported much higher soakage rates and designed substantially smaller systems. Frequently little thought was given to the long-term performance or operation and maintenance of the system. Their design fees are less and their system costs less to construct. The market dictates that they are preferred.

By comparing requirements and soakage test results from E1/VM1 with other guidelines this paper looks at whether soakage systems, in particular, those designed using E1/VM1 can reliably meet the objectives, functional requirements and performance criteria of the New Zealand Building Code.

2 SYSTEM FAILURES

During my first experience at a council, several soakage systems for roads that had been vested to the Council were not functioning well during normal rainfall. The effects of the failures were flooding and erosion. The following patterns were identified in the designs:

- The use of E1/VM1 to determine the soakage rate
- Adopting an average value due to the tail on the soakage curve
- Designing the soakage system using base and side wall areas in combination with using the an averaged E1/VM1 soakage rate
- Testing in summer without consideration to winter groundwater levels
- Testing undertaken in soils that would be excavated during the works

Similar patterns were identified in consents lodged at the second Council that I worked for.

3 REGULATORY REVIEW

3.1 The New Zealand Building Act 2004

The New Zealand Building Act 2004 (BA04) defines building work as works associated with the construction of a building and includes site works (BA04-S7). A stormwater soakage system to service stormwater runoff from the development of a site is therefore building work. All building work must comply with the building code regardless of whether a consent is required for that work (BA04-S17) but there is no requirement to achieve performance criteria that is additional to or more restrictive than the performance criteria described in the building code (BA04-S18). The Building Code is Schedule 1 of the Building Regulations 1992. Clause E1 contains the requirements for surface water. Clause E1 is repeated in Table 1:

Table 1 - Clause E1 of the Building Code

<i>Objective</i>	
<i>E1.1</i>	<i>The objective of this provision is to: (a) safeguard people from injury or illness, and other property from damage, caused by surface water, and (b) protect the outfalls of drainage systems.</i>
<i>Functional requirement</i>	
<i>E1.2</i>	<i>Buildings and sitework shall be constructed in a way that protects people and other property from the adverse effects of surface water.</i>
<i>Performance</i>	
<i>E1.3.1</i>	<i>Except as otherwise required under the Resource Management Act 1991 for the protection of other property, surface water, resulting from an event having a 10% probability of occurring annually and which is collected or concentrated by buildings or sitework, shall be disposed of in a way that avoids the likelihood of damage or nuisance to other property.</i>
<i>E1.3.2</i>	<i>Surface water, resulting from an event having a 2% probability of occurring annually, shall not enter buildings. Performance E1.3.2 shall apply only to housing, communal residential and communal non-residential buildings.</i>
<i>E1.3.3</i>	<i>Drainage systems for the disposal of surface water shall be constructed to: (a) convey surface water to an appropriate outfall using gravity flow where possible, (b) avoid the likelihood of blockages, (c) avoid the likelihood of leakage, penetration by roots, or the entry of ground water where pipes or lined channels are used, (d) provide reasonable access for maintenance and clearing blockages, (e) avoid the likelihood of damage to any outfall, in a manner acceptable to the network utility operator, and (f) avoid the likelihood of damage from superimposed loads or normal ground movements.</i>

An outfall in relation to a surface water disposal system “may include a natural watercourse, kerb and channel, or a soakage system” (MBIE, 1992).

3.2 The Resource Management Act 1991

Clause E1.3.1 of the Building Code allows for a more onerous design storm to be required under the Resource Management Act 1991 (RMA91). RMA91-S76 allows territorial authorities (city and district councils) to include rules in a District Plan to achieve the objectives and policies of the plan, and any rule in a District Plan is thereby given the force and effect of a regulation under RMA91. The section goes on to state:

(2A) Rules may be made under this section, for the protection of other property (as defined in section 7 of the Building Act 2004) from the effects of surface water, which require persons undertaking building work to achieve performance criteria additional to, or more restrictive than, those specified in the building code as defined in section 7 of the Building Act 2004.

(3) In making a rule, the territorial authority shall have regard to the actual or potential effect on the environment of activities including, in particular, any adverse effect.

3.3 Discussion

From the regulatory review, it is apparent that a soakage system associated with a building is building works and must comply with The Building Act 2004 and The Building Code. While the Building Code sets out the minimum requirements that a soakage system must achieve, territorial authorities can include rules in a District Plan that require designs to achieve a higher standard of protection.

4 NATURAL HAZARDS ASSOCIATED WITH SOAKAGE

A Building Consent Authority (BCA) must refuse a building consent if the land on which the building work is to be carried out is subject to or is likely to be subject to one or more natural hazards or the building work is likely to accelerate, worsen, or result in a natural hazard on that land or any other property (BA04-S71-1). Property includes, land, buildings and goods. Other property is any land or buildings, or part of any land or buildings, that are not held under the same allotment or the same ownership, including roads (BA04-S7). BA04-S71 defines five natural hazards, four of which can be affected by the use or lack of use of soakage systems; erosion, subsidence, inundation, and slippage.

4.1 Erosion

If a soakage system fails and/or water does not enter it due to blockages, the resulting runoff can contribute to surface erosion. Soakage can also contribute to subsurface erosion such as piping or tomo development in susceptible soils, such as recent volcanic soils or loess.

4.2 Subsidence

If soakage is not adopted in areas where compressible soils are present, there is potential for lowering of groundwater table(s). This results in an increase in effective stress and can induce or accelerate settlement of the compressible soils. Where peat soils are present, shrinkage due to oxidation may also occur due to changes in the groundwater regime.

4.3 Inundation

There are three types of inundation that can be affected by the performance of a soakage system: flooding, overland flow and ponding. Soakage systems that are under designed may result in ponding within the property but in many instances, there will be overland flow towards other property. If the other property is a road there may or may not be capacity to receive the additional runoff without flooding.

Prior to development, a proportion of the rainfall infiltrates into the ground from the surface, the remainder runs off as sheet flow or is concentrated by topography into overland flow paths that eventually form streams and rivers. On a rural property in a large undeveloped catchment, the change in runoff characteristics as a result of an underperforming soakage system serving a new dwelling is unlikely to significantly alter the drainage characteristics. As development intensifies, the cumulative effects require consideration. In the urban environment if multiple soakage

systems do not perform as designed the runoff volume will be greater. When this is coupled with the reduction in permeable surfaces, there is potential to increase the overland flow volume, depth and velocity. If the flow is impounded, then the depth and extent of ponding or flooding will increase. It is now more common for councils with urban centres to undertake flood hazard modelling for the 1% or 2% Annual Exceedance Probability (AEP) storm. At risk areas, can now be quickly identified by council staff.

The performance criteria of the E1.3.1 (refer **Table 1**) requires design for the storm event having a 10% AEP, except when otherwise required by the Resource Management Act. If the modelling identifies low return period flooding and systems are designed to a lesser standard, then there is potential that flooding is made worse by designing to the requirement in E1.3.1. Many engineers also consider the critical storm duration. E1/VM1 considers only the 60-minute storm. The critical storm duration is often more than 60 minutes and therefore systems designed for the 60-minute storm are more prone to failure. While District Plans can require the higher standard than E1.3.1 there are variations between Councils.

4.4 Slippage

When soakage is used as a primary outfall, both the rainfall that would naturally runoff in the greenfield situation, and the rainfall that would have infiltrated through the soil matrix are collected by the stormwater management system. The rainfall is then injected into the soil profile at a depth. As a result, there is more stormwater going into the ground, in a concentrated location and the natural attenuation is bypassed. If the singular or cumulative effects are sufficient, either a loss of matric suction in partially saturated soils, or an increase in pore water pressure in saturated soils can occur. Both can result in land slippage.

4.5 Discussion

The natural hazards associated with stormwater soakage are not likely to be isolated to the property, as the excess water may affect other property through overland flow and contributing to ponding or existing flood hazards. Changes in groundwater flows because of soakage may also result in slippage, subsidence and erosion on other property.

5 SUITABILITY FOR SOAKAGE

The designer needs to address if the location is suitable for soakage. Landfill sites; flood areas; valley floors where there may be groundwater inflows; access for maintenance; clearance from buildings and services and slope stability all require consideration (NZWERF, 2004). Once the intended location has been assessed, an investigation is necessary to confirm if the subsurface conditions are suitable for soakage. This should consider the depth of the permeable materials, extent and depth of impermeable materials, the winter water table level and likely effects of water table rise, both short term and long term (NZWERF, 2004).

E1/VM1 Section 9.0.1 simply states that the “*suitability of the natural ground to receive and dispose of the water without causing damage or nuisance to neighbouring property shall be demonstrated to the satisfaction of the Territorial Authority*”. E1/VM1 also includes a comment that it does not address the suitability for soakage, however Section 9.0.2 of E1/VM1 contains a prescriptive soakage test. E1/VM1 used the term neighbouring property which is not defined in either BA04 or MBIE, 1992. The Oxford Dictionary defines neighbouring as *next to* or *very near another place*. BA04 and Clause E1 of the Building Code use the term Other Property which is more encompassing and not necessarily limited by proximity.

By not addressing suitability for soakage E1/VM1 is incomplete. It also appears to set a lower standard than required in the Building Code with respect to the protection of other property.

6 SOAKAGE TEST METHODS

Table 2 compares the falling head soakage tests method in E1/VM1 with three other guidelines from the upper North Island. The other guidelines are for Auckland Council (Auckland Council, 2013), Matamata Piako District Council (Aurecon NZ Ltd, 2010) and Cambridge North (Tonkin & Taylor Ltd, 2004).

Table 2 - Soakage Test Methods

	NZBC E1/VM1	Auckland	Matamata Piako	Cambridge North
Test diameter	100-150 mm	100 to 150 mm	100 to 150 mm	100 mm
Depth	Intended depth of the soakhole	Intended depth of the soakhole	Intended depth of the soakhole	≥ intended depth of soakage
Number of tests	Not specified	1 per 50 m ² of soakage device	Varies	Minimum 2 in area of system
Groundwater	If encountered take as depth of the soakhole	Oct-May then water table taken 1 m higher than observed.	0.5 m above winter groundwater and 1 m above summer groundwater	Not addressed
Pre-soak requirement	4 hours unless drains completely in a short time	4 hours winter. 17 hours in summer.	4 hours unless completely drains in < than 5 minutes. If < 5 minutes refill & retest 5 times.	Fill and allow to drain, then repeat.
Completion	Almost empty or 4 hours - use shortest	Water level is 250 mm from base or 4 hours. If quick draining repeat several times	Between 200 and 300 mm from the base	250 mm from base then repeat
Interpretation	The soakage rate in mm/hr is determined from the minimum slope of the curve. If there is a marked decrease the lower rates may be discarded and value closer to the average can be used	Use the minimum slope to determine litres/m ² /min using worksheet provided	Use the average wetted perimeter and volume of water lost at each time step to determine litres/min/m ² . Take the average value and half it for design	Use lower quartile to calculate soakage rate in m/sec using wetted perimeter and volume lost
Comments		Also has a constant head method		
Sizing of system	Use base area only	Use base + half side wall area	Design charts	Not provided

7 COMPARATIVE TESTING

To compare the various methods, several soakage tests were repeated on a Hamilton site in August 2016 and May 2017. The soil profile consisted of 250 mm topsoil overlying stiff clayey silt to 900 mm. Below 900 mm, medium dense to dense sand was present to the base of the 1.9 m deep test hole. In August 2016, the groundwater table was measured at 2.2 m depth. In May, the groundwater was measured in the original test hole at 1.5 m, so a second test hole was augured 2

m away to 1.4 m depth. Wet sieve samples tested by an IANZ accredited laboratory show the sand is primarily a medium sand with less than 15% fines. The test conditions are summarised in **Table 3**. The soakage rate was calculated using the methods in **Table 2** along with Horslev’s method. Constant head calculations were undertaken at the completion of the 4-hour pre-soak. The soakage test data is presented graphically in **Figure 1** and the calculated results are presented in **Table 4**.

Table 3 - Soakage Test Conditions

Test Number	Date	Depth to base / groundwater (m)	Presoak	Time to Drain (min)
1	20 August 2016	1.95 / 2.20	No presoak	26
2	20 August 2016		Immediate refill after Test 1	33
3	20 August 2016		Immediate refill after Test 2	44
4	21 August 2016		4 Hour presoak	174
5	13 May 2017	1.35 / 1.52	No Presoak	145
6	13 May 2017		Immediate refill after Test 5	159
7	14 May 2017		4 Hour presoak	330

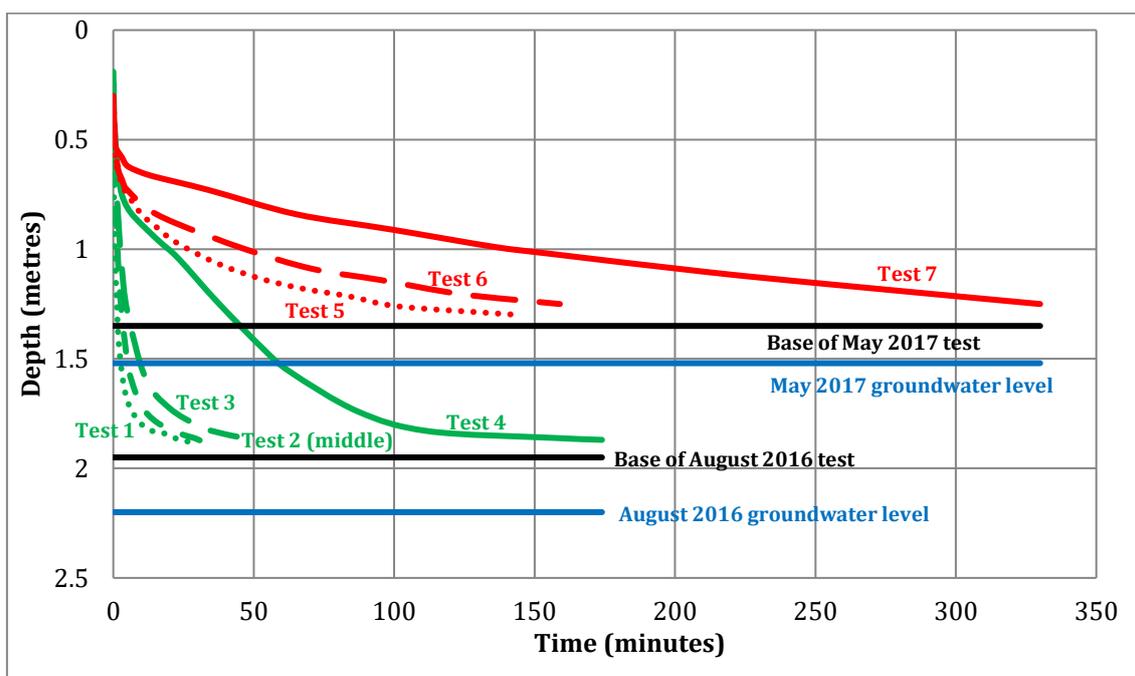


Figure 1 – Soakage test results

E1/VM1 uses mm/hour or distance/time as it is a simple observed drop over time. The other methods all use volume lost/time/surface area. As volume is m³ and area is m² this reduces to m. The time component can be adjusted to suit. Therefore 300 litres/hour/m² is 0.3m³/hour/m² which reduces to 0.3 m/hour or 300 mm/hour. On this basis, the results are comparable.

7.1 Discussion of results

Unsurprisingly the graphical results show decreasing soakage rates with each subsequent test, however the degree of the change with the 4-hour pre-soak was not expected. The volume of water used in the pre-soak was approximately 380 litres in one test and 520 litres in the other test. Considering a 1 hour 50-year storm in Hamilton will generate approximately 490 litres of water

from 10 square metres, the volume of water used in the pre-soak seems disproportionately large to the scale of the test. It is unlikely a full size system would be soaked with 40 to 50 times its volume prior to the design storm occurring. Wetting would be progressive as the hole fills and infiltration occurs during the storm.

Table 4 - Soakage test results – Specified rate in bold

	Test Results in litres/m ² /hour or mm/hour									
	1		2		3		4			
	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.		
NZBC E1/VM1	100	14965	248	14435	164	12435	32	3428		
Auckland	17	372	46	302	29	220	7	62		
Matamata Piako	14	358	39	293	25	215	5	60		
Cambridge North	16	440	43	359	27	265	6	74		
Horslev	19	427	53	346	34	253	8	70		
Constant head								244		
	5		6		7					
	Min.	Avg.	Min.	Avg.	Min.	Avg.				
NZBC E1/VM1	56	4317	77	7110	72	1738				
Auckland	13	126	10	170	5	45				
Matamata Piako	11	122	9	166	5	44				
Cambridge North	12	148	10	203	6	54				
Horslev	15	144	11	195	6	52				
Constant head						338				

The minimum in **Table 4** was the true minimum from the time steps. E1/VM1 does allow the lower values to be discarded and a value closer to the average to be used if there is a marked decrease. For Test 4 the average over the mid-part (0.96m to 1.74m) is approximately 700mm/hour. E1/VM1 doesn't include the side area in the calculation of the soakage rate or the calculation of the soakage system. It also does not include any means of preventing loss through the side walls of the soakage test. The effect of this is shown in **Table 5** where the sidewall surface area in a small-scale test has a much greater proportion of the total soakage area regardless of the water depth. If there is only 0.03 m of water in the test hole, the side wall is the dominant part of the soakage area. For example the average of the tail, (last 5 result increments) on Test 1 is 758mm/hour using E1/VM1. As all soakage tests have a tail, the loose wording in E1 allows un-conservative rates dominated by sidewall soakage to be used.

Table 5 - Surface area ratios of small scale tests and full size soakage tests

Water depth	0.1 m diameter test hole			1.2 m diameter porous soak hole		
	Side wall surface area	Base area	Ratio - Side / Base	Side wall surface area	Base area	Ratio - Side / Base
m	m ²	m ²		m ²	m ²	
0.02	0.006	0.008	0.8	0.08	1.13	0.07
0.03	0.009	0.008	1.2	0.11	1.13	0.1
0.1	0.031	0.008	4	0.38	1.13	0.33
0.2	0.063	0.008	8	0.75	1.13	0.67
0.5	0.157	0.008	20	1.88	1.13	1.67
1	0.314	0.008	40	3.77	1.13	3.33

The averages presented were calculated using all the time steps in the data. This gives a higher weighting to the parts of the test with more data, normally at the commencement of the test, with

greater head. This explains why Test 6 has faster rates than Test 5, even though the curve indicates it should be less. If a single line calculation is undertaken the results are typically much lower, for example using only the first and last data points on Test 6 the MPDC rate is 52 litres/m²/hour. The latter values may also be more representative of steady state saturated conditions. Averages need to be more considered, with outliers removed, and consider the soakage zone. The Auckland Council method appears to be overconservative by requiring the minimum rate of the curve to be used with a prescribed calculation. Several councils require that the test rate is halved in the design (as a factor of safety), while Auckland does not require this, the rate would still be considerably less than the other methods.

The soils in the comparative testing were strongly layered and it is reasonable to assume that the soakage was occurring preferentially through the sand layer. None of the methods used to calculate the soakage rate consider the effects of strongly stratified soils. This may be acceptable as this is also likely to occur in a full-size system, however further research could be done in this area to confirm if scale effects need to be accounted for.

8 CONCLUSIONS

Soakage testing is highly subjective to the method used, the test conditions and the interpretation of the data. As E1/VM1 does not include information on the suitability for soakage, there is potential for soakage systems to cause, accelerate or worsen several types of natural hazards on other property. E1/VM1 did not require the winter water table to be established and testing in summer can result in a reduced storage capacity leading to failure. E1/VM1 does not include any information on the location or the operation and maintenance requirements that the designer needs to address and therefore it does not meet E1.3.3 of the Building Code. Based on the unconservative soakage test rate, failure to address suitability of soakage, groundwater conditions and operation and maintenance requirements, it is concluded that the soakage test and design method in E1/VM1 does not meet the requirements of the Building Code Clause E1. Clause E1 of the Building Code is out of date for modern urban intensification. The level of protection to other property should be reviewed and brought into line with current best practice nationally and internationally. It is recommended that the soakage test and design methods are removed from E1/VM1 and replaced with a New Zealand Standard for On-site Stormwater Management: Soakage and Attenuation. This should be consistently adopted by Councils.

Further research is recommended into the effects of layered soils and the proximity of groundwater to the soakage test, suitable pre-soak times, scale effects, interpretation of the test results and a suitable factor of safety.

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