On-Site Stormwater Management Guideline

Appendices

Appendix A: Comments on comparable guidelines

Organisation and Guideline	Comments
New Zealand	
Auckland Regional Council *TP10*	- sound technically (emphasis on water quality) - includes a lot of background information on the principles of stormwater management - design guideline primarily uses a design storm which has been specifically computed for the Auckland region
Auckland Regional Council *TP124*	- good descriptive background on concepts (with photos) - does not provide a detailed design guideline
Auckland City Council *On-site Stormwater Management Manual*	- applicable to a specific brownfield situation only - technical based format, with design charts and worksheets - strong emphasis on operation and maintenance
Auckland City Council *Soakage Manual*	- as above, but wider-ranging in its application
Christchurch City Council *Waterways, Wetlands and Drainage Guide*	- good description of impacts of development - uses simplified approach to stormwater quality management - large use of soakage, particularly relevant for subsurface conditions in Christchurch
USA/Canada	
City of Portland *Stormwater Management Manual*	- excellent, easy-to-follow layout - good diagrams and numerous photos - comprehensive operation and maintenance schedules
King County (Seattle) *Surface Water Design & Stormwater Pollution Control Manuals*	- very thorough treatment, albeit with unusual technical applications - software needed to perform analyses available by free download
Washington State Dept of Ecology *Stormwater Management Manual*	- very comprehensive (some useful material), but unduly long (5 Volumes)
USEPA *Urban Stormwater Best Management Practices*	- good descriptions etc. on on-site devices - good treatment of costs and benefit
Maryland DOE: *Stormwater Design Manual*	- very thorough treatment, backed by good graphics and worked examples
City of Calgary: *Stormwater Management and Design Manual*	- comprehensive and well researched - format unwieldy
Ontario Ministry of Environment: *Stormwater Management Planning & Design Manual*	- unduly long (400 pages), but short on graphics and worked examples
Other	
Upper Paramatta RCT, Australia: *On-Site Stormwater Detention Handbook*	- narrow focus (on-site detention tanks) - good worked examples and applications
CIRIA, UK: *Sustainable Urban Drainage Systems – Design Manual*	- innovative format; good introductory material - design guidelines generic only
DID, Malaysia: *Stormwater Management Manual*	- very comprehensive in terms of types of OSM devices, but requires analysis/design from first principles (no worked examples)

Appendix B: Collated references

Notes:

1. Internet references are accurate at the time of publication
2. Short references are given in brackets at the end of key documents that are used throughout the text for ease of use, for example (ARC TP10, or CCC, 2003)

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Appendix C: Hydrologic / hydraulic analysis

C1.0 Introduction

Hydrologic/hydraulic analysis will generally be required as part of the design of an on-site device, especially the flow attenuation component. In summary, this will typically involve the following, with coverage on each topic set out in this Appendix:

- preparatory considerations (e.g. methods, technical issues, key parameters, etc): refer Section C2
- peak runoff and hydrograph derivation: refer Section C3.1
- routing computations (ie routing the inflow hydrograph through the device to establish the outflow hydrograph): refer Section C3.2
- hydraulic computations (e.g. to size the likes of pipes, orifices, weirs, etc): refer Section C4

The appendix is written to guide those with a limited familiarity with hydrology and hydraulics; those with no formal training in these areas should consult the references listed in Section 1.2 of the main text for a primer in these disciplines.

C2.0 Preparatory considerations

C2.1 General

In the context of providing guidance on hydrologic/hydraulic topics, the following aspects require consideration, but are addressed only briefly here as they are covered elsewhere in the Guide:

- design storm magnitude (refer Section 3.7), e.g.:
  - 50% AEP (2 year ARI): applies to frequent flooding, often relevant where channel erosion is an issue
  - 10% AEP (10 year ARI): common standard for sizing stormwater reticulation
  - 1% or 2% AEP (100 year or 50 year ARI): the standard upper limits usually considered
- flow attenuation performance standard (refer Section 3.7), e.g.:
  - greenfield
  - as-existing

C2.2 Time of concentration and storm duration

Because an on-site device changes the response characteristics of the catchment in which it is located, an issue arises in respect to selecting the applicable storm duration (D) value to be used in generating the design hydrograph to be used in sizing an on-site device (refer Section C3). The D value should be reflective of the time of concentration (Tc) of the receiving reticulation, but this will vary between the immediate reticulation and the outfall. Building Code Clause E1 – Verification Method E1/VM1: Surface Water, Building Industry Authority, NZ, 2001 (note: referred to hereafter as BIA, 2001) sets out suggested Tc values.
As an example, actual Tc values at points along the receiving stormwater system might be:

Receiving System	Applicable Tc Value
Local street drainage	10 min
Watercourse (ie fed from pipe)	60 min

Main pipe system 30 min

The theoretical critical design case for sizing an individual on-site device, namely the storm requiring the largest storage volume, will generally be quite long, approaching that applicable at the downstream end of the receiving catchment (e.g. 60 minutes, or longer). Further, the higher the Tc/D value, the larger the on-site device orifice diameter. In practice the designer should consider the following methods (refer also Section C2.3):

i. Simplified approach:

Where there are no known major downstream flooding issues and the requirement for implementing an on-site device is more as a matter of applying the principle of mimicking the natural drainage regime, select the Tc value to match that of the immediate receiving system (e.g. typically 5 - 15 minutes)

ii. Rigorous evaluation:

Where downstream flooding is an issue, and/or the local authority requires more in-depth consideration than in (i) above, apply the following approach:

- consider the points in the receiving catchment at which the planned flow attenuation may be critical and identify the corresponding Tc values (e.g. as in the list above)
- for storm durations (D) corresponding to each of the Tc values above, compute device sizings and orifice diameters (ie using the method in Section C3)
- Compare the results, and apply judgement as to which D case is likely to be most important (e.g. if the results show only a small variation, choose the upper bound figures, namely the largest device size and smallest orifice diameter – refer computational example of a rain tank in Section 4.5.10)

C2.3 Rainfall temporal and spatial patterns

In parallel with consideration of the time of concentration issue (refer Section C2.2), the analysis of on-site devices should, in theory at least, be done on a catchment-wide basis. This would then enable assessment as to how each new device will perform, taking into consideration the following:

- catchment and stormwater system characteristics, e.g.:
  - pre-existing on-site devices (and their positions in the catchment)
  - the existing stormwater network (e.g. pipe, watercourse, etc)
- the likely variation in rainfall patterns, e.g.:
  - spatial patterns
  - temporal patterns (e.g. antecedent conditions and/or multi-peak storms may affect the expected performance of the device)

To do this, each proposed new on-site device would need to be plugged-in to an up-to-date catchment model (refer Section C2.4) and simulated. In practice, the degree of effort involved is considerable and not normally justifiable.

As an example of these factors, consider the following case of an on-site device located in the lower part of a catchment:

- say the device is designed to achieve the as existing flow attenuation target with a Tc value of 15 minutes
- in a storm event, the outflow peak will be lower and later than the as existing inflow
- when combined with flows from the upper catchment, the delay-effect may result in the device actually increasing the overall peak flow
- similar but more complex effects may occur with storms that move up or down the catchment

Instead of attempting to quantify these factors, it will generally be adequate to be aware of them and apply appropriate judgement and/or countermeasures (e.g. the problem identified in the example above could be mitigated through the application of a more stringent performance standard, such as greenfield).

C2.4 Computer modelling

The Guide focuses on manual or spreadsheet-oriented analysis methods which will be within easy reach of most users (refer Section C3 for details). However, those with a special interest in the design of on-site devices should consider the option of investing in commercially-available modelling software. Such packages are designed to simulate the performance of on-site devices whereby device sizings can be established.

In summary, such models function broadly as follows:

i. The model is set-up to describe the site to be modelled (e.g. involves the input of site data such as site area, roof area, pervious/impervious areas, soil type, etc)

ii. A rainfall data sequence is input which matches the rainfall at the site; this can be either of the following (albeit noting that the data time step should be quite short, of the order of no longer than 25% of the time of concentration; e.g. 5 minutes where Tc is 20 minutes):
   - a single-event storm (e.g. historical, or synthesised)
   - a long historic pluviographic sequence (as an example the ACC, 2002 work used a 40-year sequence from records at Albert Park, Auckland)

iii. The model is run to replicate the target performance case for the subject site (e.g. greenfield case), to establish the peak site discharge

iv. Data describing the on-site device is input to the model, normally involving <u>trial</u> device sizings (e.g. device area/depth, orifice diameters, etc)

v. The model is run with the rainfall data sequence in ii above

vi. The performance of the device is checked in the model output files, e.g. the peak site discharge is compared to the target performance case (for the pluviographic-based approach, refer to the box below)

vii. If the results in vi do not match the performance target, re-size the device and re-run (ie step v above); continue until a match is achieved and then adopt this as the design sizing

Suggested method for analysing device performance using modelling with long-term pluviographic sequences:

- establish the required design flood performance criteria (e.g. the with-device case to match the greenfield peak discharge in the 10% AEP flood)
- run the model as in iii above, and tabulate the peak discharges in each storm event
- undertake a frequency analysis on these peak discharges to establish the 10% AEP flood (= Qa say)
- run the model for the with device case (ie as in v above) and tabulate the peak discharges in each storm event
- undertake a frequency analysis on these peak discharges to establish the 10% AEP flood (= Qb say)
- re-run model (ie as per vi above) until Qb = Qa

Modelling using the long-term pluviographic sequences is to be preferred over the use of design storms where practicable, because:

- pluviographic-based modelling tests out the performance of a series of rainfall temporal patterns, whereby more confidence can be placed on the ability of the device to meet the target performance
- similarly, it takes out the subjectivity of selecting representative single-event design storms
- a single pluviographic-based model run can give results applicable to a range of flood magnitudes (e.g. where say a 50 year long pluviographic sequence is used, results can be established covering all of the magnitudes normally considered, ie 50% AEP, 10% AEP and 2% AEP - albeit with some uncertainty for the latter, as the pluviographic sequence may not in practice incorporate a representative 50 year event)

As at mid-2004, there are relatively few packages available for modelling on-site devices. A brief description of the known packages is in Table C1[1].

Table C1: Software for modelling on-site devices

Software	Description	Vendor/Available From
HEC-HMS	Hydrological modelling	Freeware from US Army Corps of Engineers www.hec.usace.army.mil
PURRS	Simulates rain tanks	Urban Water Cycle Solutions 70 Howden Street, Carrington, NSW 2294 www.eng.newcastle.edu.au/~cegak/Coombes p.coombes@newcastle.edu.au
MIKE STORM	Able to simulate most types of on-site devices	DHI Water & Environment PO Box 300-705, Albany, NZ www.dhiwae.com nz@dhiwae.com
XP-SWMM and XP-RAFTS	General purpose stormwater model	XP Software Pty Ltd PO Box 3064, Belconnen, ACT, 2166 www.xpsoftware.com.au sales@xpsoftware.com.au

[1] Note, however that the fact that software is listed in Table C1should not be construed as a recommendation as to its suitability for the purpose

C3.0 Runoff estimation, hydrographs and routing

C3.1 Introduction

On-site devices which are to meet quantity-based performance standards are typically sized through the following approach, details of which are given in the following sub-sections:

- compute the applicable peak discharges (refer Section C3.2), e.g.:
  - o for the target performance standard case (e.g. greenfield, as-existing)
  - o inflow to the on-site device, for the post-development case
  - o rest-of-site runoff, for the post-development case (ie to add to the device outflow hydrograph, to establish the post-development with-device outflow)
- derive the corresponding flow hydrographs, for the following post-development cases (refer Section C3.3):
  - o inflow to the on-site device
  - o rest-of-site runoff,
- route the inflow through the on-site device (refer Section C3.4): this involves a trial-and-error approach to compare the target and post-development cases and, once matched, establish the sizings for the:
  - o device (e.g. area, height) and
  - o oultlets (e.g. orifice, weir)

C3.2 Peak discharge computation

C3.2.1 Methods

Aside from the modelling-based approaches (refer Section C2.4) typical peak discharge computation methods used by New Zealand practitioners are listed below. Unless there are reasons to do otherwise, use of method (a), the Rational Method, is recommended (refer notes under 'suitability' below)

(a) Rational method:

i. Form of the empirical relationship:
$Qp = C \times I \times A / 360$
where:
Qp = peak discharge (m^3/s)
C = runoff coefficient (dependent on land use, soils, etc)
I = rainfall intensity (mm/hr), for the specified flood frequency (e.g. 10% AEP) and Tc value
A = site area (ha)

ii. Suitability: recommended for use for catchments under about 50 ha

iii. References:
BIA, 2001
http://agrolink.moa.my/did/river/stormwater/Chapter_14.htm
http://www.itc.nl/ilwis/applications/application11.asp
www.ct.gov/dot/lib/dot/documents/ddrainage/6.9.pdf

iv. Worked examples: refer Section C3.5

(b) TM61 'Method for estimating design peak discharge' (MWD 1980)

i. Form of the empirical relationship:

$Qp = 0.0139 \times C \times R \times S \times A^{0.75}$

where

Qp = peak discharge (m^3/s)
C = catchment coefficient
R = rainfall factor, for the specified flood frequency (e.g. 10% AEP) and Tc value
S = catchment shape factor
A = catchment area (km^2)

ii. Suitability:

- normally used for catchments 10 – 1,000 km^2, but also satisfactory for smaller catchments
- recommended for use only where the user is very familiar with this method (ie otherwise use of method (a), the Rational Method is recommended)

(c) US Soil Conservation Service Method (USCS, 1986)

i. Description:

A relatively more complex method than the Rational or TM61 methods, the USSCS method uses parameters including:

- runoff curve numbers (CN, related to the different land cover types, soil properties and antecedent moisture conditions); from these the catchment storage (S) is computed
- initial abstraction, Ia (or loss)
- the 24 hour rainfall depth (P)

From the above, a runoff index (c*) is computed. The peak flow Q is then computed through reference to a chart relating c* and Tc, where the chart is developed through reference to rainfall and runoff data from representative gauged catchments.

ii) Suitability:

The USSCS method is the basis for Auckland Regional Council's TP108 Guidelines for Stormwater Runoff Modelling in the Auckland Region, which is the standard method in the Auckland region. Consequently, designs for devices located within ARC's area of jurisdiction should use the TP108 method. Noted that TP108 also includes a method to compute hydrographs, either manually, or by use of the HEC-HMS model (refer Table C1).

iii) References:

ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
http://www.alanasmith.com/theory-Calculating-Effective-Rainfall-The-SCS-Method.htm

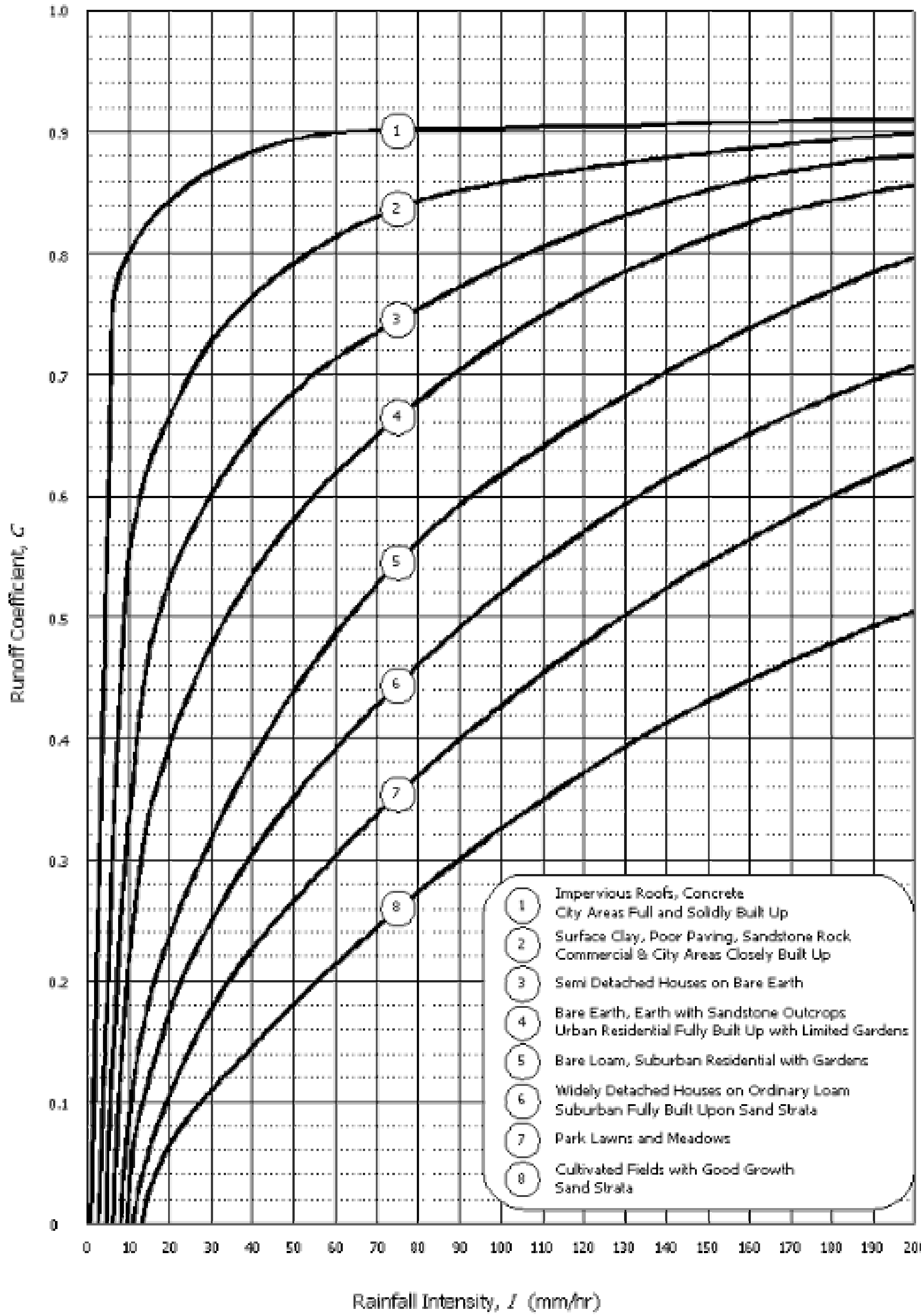
C3.2.2 Application

Notes on compiling the data required to apply the Rational and TM61 methods are:

- location-specific rainfall depth-duration-frequency data: sources of such data include:
    - NZ Meteorological Service (Metservice) publications (e.g. Coulter & Hessell, 1980)
    - NIWA's HIRDS software; URL: www.niwa.cri.nz/ncc/tools/hirds
- time of concentration (Tc): refer Section C2.2
- runoff coefficient C:
    - refer to reference material cited in Section C.2.1, e.g. BIA, 2003 (for convenience, Figure C1 presents a sample of Rational Method C values)
    - where a catchment contains a mix of land-use, the overall C value can be computed by adding the C x sub-area values for each sub-area and dividing the sum of the products by the overall area (refer Section C3.5 for a worked example, namely Case 2)

Figure C1: 'C' Values in rational method – urban catchments

(Source: ARR, 1977)



Runoff Coefficient, C
Rainfall Intensity, I (mm/hr)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
1 Impervious Roofs, Concrete City Areas Full and Solidly Built Up
2 Surface Clay, Poor Paving, Sandstone Rock Commercial & City Areas Closely Built Up
3 Semi Detached Houses on Bare Earth
4 Bare Earth, Earth with Sandstone Outcrops Urban Residential Fully Built Up with Limited Gardens
5 Bare Loam, Suburban Residential with Gardens
6 Widely Detached Houses on Ordinary Loam Suburban Fully Built Upon Sand Strata
7 Park Lawns and Meadows
8 Cultivated Fields with Good Growth Sand Strata

C3.3 Hydrograph derivation

Whereas the Rational or TM61 methods produce <u>peak</u> discharge figures, a hydrograph is needed for use in the routing analysis (note that the USSCS-based ARC TP108 method can produce hydrographs directly and is not covered herein). The hydrographs required will depend on the application, but typically cover:

- inflow to the on-site device (e.g. to tank, off roof), for routing according to the Section C3.4 method
- rest-of-site runoff (ie to be added to the on-site outflow hydrograph to establish the with-device total site outflow); the combined peak is then compared against the performance standard peak (e.g. greenfield)

Two cases need to be considered, addressing the time of concentration (Tc) and storm duration (D) factors discussed in Section C2.2:

i. Storm duration = Tc:
A triangular-shaped hydrograph is produced, with the following characteristics, as illustrated in Figure C2a:

- rising limb: linear rise to reach the peak at time Tc
- falling limb: linear fall back to zero, over a time period 0 - Tc.

ii. Longer storm durations (ie where D is greater than the Tc value for the <u>immediate</u> receiving system):
(ie matching the Tc values further down the receiving system – refer Section 2.2)

- a trapezoidal-shaped hydrograph with a longer peak is produced, as illustrated in Figure C2b, ie:rising limb: linear rise to reach the peak at time Tc
- peak: constant at the peak flow for a time (D -Tc)
- falling limb: linear fall back to zero over a time period Tc

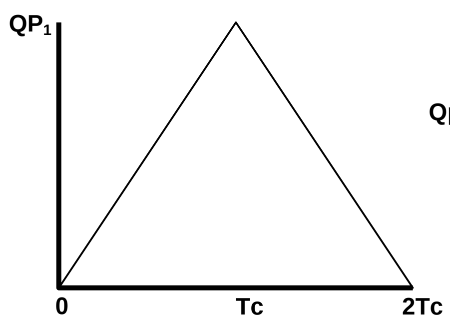


Figure C2a: Hydrograph for storm duration D = Tc (Qp_1 = peak flow for duration D = Tc)

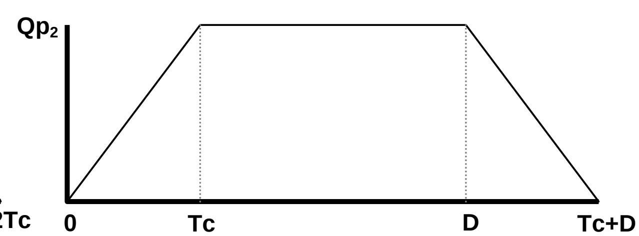


Figure C2b: Hydrograph for storm duration D (Qp_2 = peak flow for storm duration D; Tc = value for the immediate receiving system)

C3.4 On-site device routing computations

Routing involves quantifying the way the storage provided in the on-site device modifies the inflow hydrograph. Typically, a spreadsheet will be used to perform the routing calculations, applying the following general relationships:
Device outflow = function of the applied head on the outlet flow control device (e.g. orifice, weir)
Change in storage = device inflow – device outflow
Site outflow = device outflow + rest-of-site runoff (ie from pervious plus other impervious area)
Table C2 shows a typical spreadsheet used to perform the routing calculation, together with generalised explanations of the cell arithmetic (this arithmetic will vary depending on device type, in particular the type/number/size of the outlet(s), whether there is an infiltration

component, etc). The example is for a detention tank with an orifice outlet at its base – the full spreadsheet is reproduced overleaf.

Table C2: Illustration of spreadsheet-type routing computation

Time (min)	*DEVICE INFLOW*		Device Storage (C, m)	Device WL (E, m)	Device Outflow (F, l/s)	Net Device Storage (G, m³)	SITE RUNOFF CALC	
	Hydrograph (A, l/s) *Note 1*	Volume (B, m³)					Rest of Site (note 3) H (l/s)	Total Site I (l/s)
Go to 2-3 x Tc in about 0.1 x Tc increments	*Design hydrograph (contributing area)*	*= A(l/s) [averaged] x time*	*= volume G at prior time step + inflow B*	*= volume C / device area*	*Refer note 2*	*= volume C – F x time*	*= design hydro-graph for rest of site*	*= device outflow F + rest of site runoff H*
0	0	0	0	0	0	0	0	0
2.5	1.05	0.16	0.16	0.05	0.31	0.11	1.12	1.42
5.0	2.1	0.32	0.43	0.14	0.59	0.34	2.23	2.83
7.5	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…

Notes:
1: For a tank, fed from the roof, this is the roof runoff hydrograph (e.g. as in Section C3.5 – Case 2A below)
2: The device outflow calculation:
- o requires a formula defining the outflow (e.g. orifice flow from tank outlet - refer Table C3 for orifice formula – the flow is a function of the head, ie storage in column C divided by device area – note that it is usual to use the average head over the prior and current time steps)
- o often a more complex formula is needed to also account for device overflow (e.g. out top overflow of tank, once storage height reaches the top level)

3: For a tank, fed from the roof, this is the hydrograph from the pervious plus other site impervious area (e.g. as in Section C3.5 – Case 2B below)

The routing computation spreadsheet is used as follows to size the on-site device, involving applying a trial and error approach (in practice, as in Section C2.2, spreadsheet runs may be required to cover a series of storm durations, to identify the critical case):
- define the device performance target, e.g.: site runoff peak to match the greenfield case in the 10% AEP storm
- derive the peak flows and hydrographs for the following cases:
  - for the target performance standard case, as above
  - inflow to the on-site device, for the post-development case
  - rest-of-site runoff, for the post-development case (ie to add to the device outflow hydrograph, to establish the post-development with-device outflow)
  - select the trial device size characteristics, for example for a detention tank:
  - plan area of tank
  - top outlet pipe diameter and height above tank base
  - outlet orifice diameter and height
- run the spreadsheet and:
  - identify the peak site outflow rate (also, it is useful to check if/when device overflow occurs)
  - compare this to the target peak site outflow (e.g. greenfield, as above)
  - select new trial device sizing parameters (e.g. smaller/larger tank, smaller/larger orifice) and re-run the spreadsheet until the required performance standard is met

C3.5 Worked examples

Note*: The following worked examples illustrate the methods explained in Sections C3.1 – C3.4, note that Cases 1 & 2 derive peak discharges and hydrographs, using the rational method, which are then used in the Case 3 on-site device routing example.*

Case 1: Compute the Peak Discharge Rate - Greenfield Site
(using the Rational Method)

Site Data:
Area (A): 700 m^2 = 0.07 ha
Soil type: Clay

Design Parameters:
Flood frequency (F): 10% AEP
Tc: 15 minutes

Calculation:

i. Rainfall intensity I: consult appropriate rainfall depth-duration (Tc)-frequency (F)curves for the location in question; whence I = 100 mm/hr
ii. C value: From Figure C1, use curve 7 & I = 100 yields C = 0.43
iii. Peak discharge: Q = C x I x A / 360
= 0.43 x 100 x 0.07 / 360
= 0.0084 m^3/s (8.4 l/s)

Case 2: Compute Peak Discharge Rate and Hydrograph - Development Site
(2A) Roof (using the Rational Method):

Site Data:

Roof area:	250 m^2 = 0.025 ha
Other impervious area:	100 m^2
Pervious area:	350 m^2
Total site area:	700 m^2

Design Parameters:
Flood frequency (F): 10% AEP
Tc: 15 minutes

(a) Peak Discharge Calculation:

i. Rainfall intensity I: consult appropriate rainfall depth-duration (Tc) -frequency (F) curves for the location in question; whence I = 100 mm/hr
ii. C value: From Figure C1, use curve 1 & I = 100 yields C = 0.9
iii. Peak roof discharge: Qp = C x I x Aroof / 360
= 0.9 x 100 x 0.025 / 360
= 0.0063 m^3/s (6.3 l/s)

(b) Hydrograph Calculation:

i. Hydrograph base length T = 2 x Tc
ii. Hydrograph is triangular (ie as Figure C2a),, with:
Linear rise to peak 6.3 l/s at time Tc = 15 minutes
Linear fall from peak to zero at time T = 30 minutes

(2B) Rest-of-Site (using the Rational Method):

(a) Peak Discharge Calculation:

i. Rainfall intensity I: as Case 2A
ii. C value: Use sub-area method: from Figure C1, with I = 100:
Pervious area (curve 7): Cp = 0.43
Other impervious area (curve 2): Co = 0.86
Net C = (350 x 0.43 + 100 x 0.86) / 450 = 0.53

iii. Peak discharge: Qp = C x I x A / 360
= 0.53 x 100 x 0.045 / 360
= 0.0067 m^3/s (6.7 l/s)

(b) Hydrograph Calculation:

i. By the approximate method, hydrograph base length T = 2 x Tc

ii. Hydrograph is triangular (ie as Figure C2a), with:
Linear rise to peak 6.7 l/s at time Tc = 15 minutes
Linear fall from peak to zero at time T = 30 minutes

Case 3: On-Site Device Routing Computation

Building on the Case 1 & 2 results, the spreadsheet overleaf illustrates a typical on-site device routing exercise. Details are:

Site data: As Case 2 above

Device target performance: Greenfield (ie as Case 1 above),
Allowable peak discharge 8.4 l/s

Inflow hydrographs:
Roof: as Case 2A
Rest of site: as Case 2B

Device type: Detention tank (ie as described in Section 5.2),
fed from roof and with orifice outlet in base of tank

Trial & error approach: Set tank height (say 1.2 m) and tank area (ie to match sizes available from manufacturers),
Compute trial orifice diameter, as shown on the spreadsheet (ie based on the simplifying assumption that the peak flows from both the tank and rest of site coincide in time),
Then adjust tank area and/or orifice diameter until:
- o total site runoff </= 8.37 l/s target, and
- o tank water level </= full (ie 1.2 m)

[refer also to the note at the bottom of the spreadsheet about tank overflow]

Results: Tank area: 3 m^2 (ie 2.0 m diameter)
Tank height: 1.2 m
Outlet orifice diameter: 30 mm

RAIN TANK - FLOW ROUTING ANALYSIS

(A) SITE DATA:

Soil Type:		Clay					
AREAS:				C value			
Roof area		250	m2	0.9			
Other impervious area		100	m2	0.86			
Pervious area		350	m2	0.43			
Lot area		700	m2				

(B) TANK DETAILS:

Tank area	3.0	m2	(ie	1.9	m dia)	*Trial orifice diameter calculation:*		
Tank height	1.2	m				*Peak orifice flow:*	*1.79*	*l/s*
Orifice dia	0.03	m		d^2=	0.0009	*Max orifice head:*	*1.2*	*m*
Orifice discharge coefficient				0.65		*Trial diameter:*	*0.026*	*m*

(C) HYDROLOGY - BY RATIONAL METHOD:

(refer comparable calculations in Appendix C - Section C3.5)

Tc	15	min	
Storm duration (D)	15	min	
Rainfall intensity (10% AEP)		100	mm/hr
		C value	Peak discharge (l/s)
Peak roof discharge:		0.90	6.25
Peak rest-of-site discharge:		0.53	6.57
Permissible site discharge		0.43	8.36

(D) SIMULATION:

Time step 2.5 min

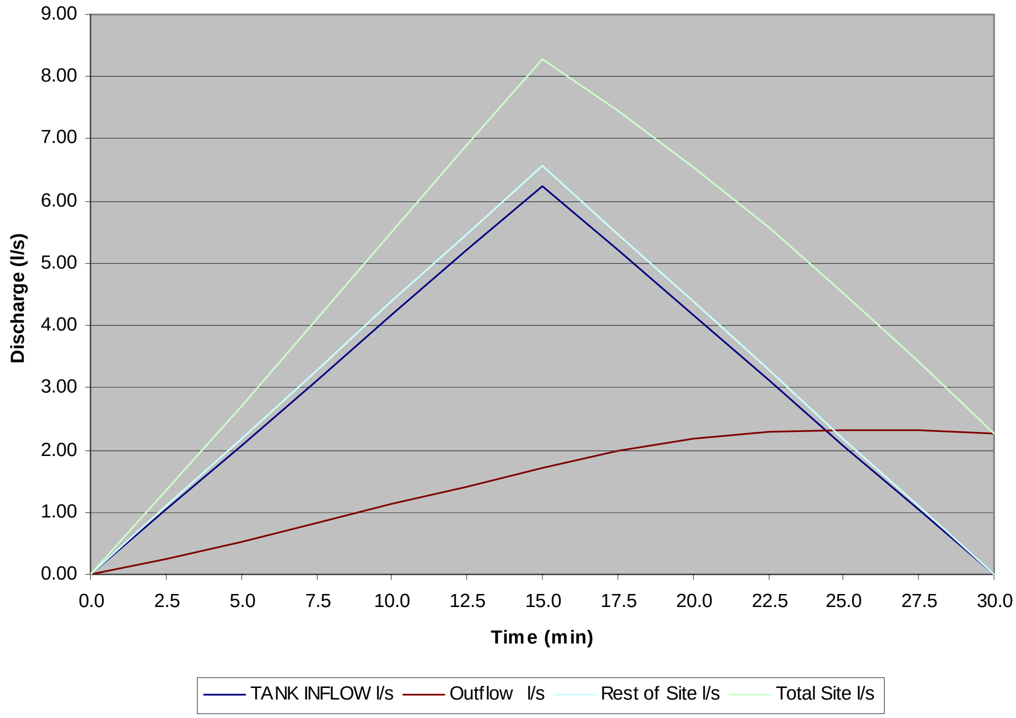
Time	**TANK INFLOW**		Tank Storage	Tank WL	Adjusted Av WL	Tank Outflow	Net Device Storage	**SITE RUNOFF CALC** Rest of Site	Total Site
(mins)	l/s	m3	m3	m	m	l/s	m3	l/s	l/s
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5	1.04	0.08	0.08	0.03	0.01	0.25	0.04	1.09	1.34
5.0	2.08	0.23	0.28	0.09	0.06	0.53	0.20	2.19	2.72
7.5	3.13	0.39	0.59	0.20	0.15	0.82	0.46	3.28	4.11
10.0	4.17	0.55	1.01	0.34	0.27	1.12	0.84	4.38	5.50
12.5	5.21	0.70	1.54	0.52	0.43	1.42	1.33	5.47	6.89
15.0	6.25	0.86	2.19	0.74	0.63	1.72	1.93	6.57	8.29
17.5	5.21	0.86	2.79	0.94	0.84	1.98	2.50	5.47	7.46
20.0	4.17	0.70	3.20	1.08	1.01	2.17	2.87	4.38	6.55
22.5	3.13	0.55	3.42	1.16	1.12	2.28	3.08	3.28	5.57
25.0	2.08	0.39	3.47	1.17	1.16	2.33	3.12	2.19	4.52
27.5	1.04	0.23	3.35	1.13	1.15	2.32	3.01	1.09	3.41
30.0	0.00	0.08	3.08	1.04	1.09	2.25	2.75	0.00	2.25
32.5	0.00	0.00	2.75	0.93	0.98	2.14	2.42	0.00	2.14
35.0	0.00	0.00	2.42	0.82	0.87	2.02	2.12	0.00	2.02

NOTE: If/when tank WL exceeds tank height, site runoff calculation should include tank overflow (ie overflow = inflow - orifice outflow)

RESULT:

Tank area:	3.0	m2
Tank height:	1.2	m
Orifice diameter:	30	mm
Tank capacity (V)	**3.6**	**m3**

Figure C4: Rain tank hydrographs



C4.0 Hydraulic computations

Users of this guideline are referred to the following standard hydraulics references for the various formulae to analyse pipes, orifices, weirs, etc (check that nominated coefficients in formulae apply to the metric/SI units case; especially in material of US-origin where imperial units are prevalent):

(a) Text books:

Building Code Clause E1– Verification Method E1/VM1: Surface Water, Building Industry Authority, NZ, 2001

Handbook of Hydraulics, Brater, King, Lindell & Wei, McGraw Hill, 7th Edition, 1996

Fluid Mechanics, Streeter, McGraw Hill, 8th Edition, 1985

Hydraulics and Hydrology for Stormwater Management, JE Gribbin, Delmar Learning, 1996

Hydraulic Structures, CD Smith, University of Saskatchewan Printing Services, Saskatoon, Canada, 1985

(b) Web Resources:
http://agrolink.moa.my/did/river/stormwater (refer Chapters 12 & 20)

Table C3 presents some of the formulae commonly used in the hydraulic design of on-site devices.

Table C3: Commonly-used hydraulic formulae

FORMULA		Coeff-icient	Typical values of Coefficient
Name	**Formula** (Q = discharge, m^3/s)		
Manning's (pipe flow)	$Q = 1/n \times (d/4)^{0.66} \times S^{0.5} \times A$ where: d = pipe diameter (m) S = friction slope or head loss (m/m) A = pipe cross-sectional area (m^2)	n	Plastic: 0.010 Concrete: 0.012
Manning's open channel flow	$V = r^{2/3} \times s^{1/2} / n$ where: r = hydraulic radius = wetted area /wetted perimeter S = friction slope or head loss (m/m)	n	Refer texts e.g ARC TP 10
Orifice discharge	$Q = 3.47 \times Cd \times d^2 \times h^{0.5}$ where: d = orifice diameter (m) h = head on orifice (m)	Cd	0.6 – 0.7 (square edged)
Weir discharge	$Q = C \times L \times h^{1.5}$ where: L = weir crest length (m) H = head on weir (m)	C	Sharp-crested: 1.8 Broad-crested: 1.7 Circular 1.5 e.g manhole riser pipe inlet (sharp-crested, L = circumference of vertical drop inlet pipe)

C5.0 References

A. Published sources

Auckland Regional Council. (1999). *Guidelines for stormwater runoff modelling in the Auckland Region*. ARC Technical Publication No. 108. (ARC TP108)

Brater, E.F., King, H.W., Lindell J.E., & Wei, C.Y. (1986). *Handbook of hydraulics*. New York: McGraw Hill.

Building Industry Authority. (2003). *Building Code Clause E1– Verification method E1/VM1: Surface water*. (BIA 2003)

Coulter, J.D., & Hessell, J.W.D. (1980). *The frequency of high intensity rainfalls in New Zealand, Part 2 - Point estimates*. Miscellaneous Publication 162, New Zealand, Meteorological Service, Wellington

Gribbin, J. (1996). *Hydraulics and hydrology for stormwater management*. Delmar Learning

Institution of Engineers Australia. (1977). *Australian rainfall and runoff - a guide to flood estimation*. (ARR 1977)

Ministry of Works and Development. (1980). *A method for estimating design peak discharge*. Technical Memorandum No 61, Planning and Technical Services, Water and Soil Division.

Smith, C.D. (1985). *Hydraulic structures*. Saskatoon: University of Saskatchewan Printing Services.

Streeter, V.L. (1985). *Fluid mechanics*. Tokyo: McGraw Hill.

US Soil Conservation Service. (1986). *Urban hydrology for small watersheds*. US Department of Agriculture, Soil Conservation Service Technical Release No. 55. (SCS 1986). From http://www.mi.nrcs.usda.gov/technical/engineering/neh.html

B. Web-based resources

(a) Hydrology/Hydraulics & General Treatise on Stormwater Management: http://agrolink.moa.my/did/river/stormwater

(b) Rational method
http://agrolink.moa.my/did/river/stormwater/Chapter_14.htm
http://www.itc.nl/ilwis/applications/application11.asp
www.ct.gov/dot/lib/dot/documents/ddrainage/6.9.pdf

(c) USCS method
ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
http://www.alanasmith.com/theory-Calculating-Effective-Rainfall-The-SCS-Method.htm

(d) NIWA's HIRDS NZ Rainfall Rainfall Depth-Duration-Frequency Software: www.niwa.cri.nz/ncc/tools/hirds

Appendix D: Operation and maintenance

D1.0 Introduction

In order to meet water quantity and/or quality targets, the long-term effective operation of on-site devices depends not only on sound design and construction, but also on applying routine operation and maintenance practices. The importance of applying these 'O&M' practices, which are typically not especially onerous in terms of either effort or frequency, cannot be overstressed. Further, the costs are modest – and are typically less than neglecting O&M, leaving the device to fall into disrepair and require a major overhaul.

It will generally be the responsibility of the on-site device owner to carry out appropriate O&M, unless the local authority agrees to take-over responsibility. Ideally, requirements should be scheduled in the appropriate consent. O&M practices will typically involve:

- frequently:
  - check for and rectify any problems evident during/after heavy rain
  - regularly check state of repair of the OSM device and rectify any problems
- periodically (e.g. once or twice a year): inspect pipes, remove sediment, repair any defects

O&M requirements are specific to each on-site device, but will typically involve a monitoring and inspection programme covering the following topics:

- general maintenance (e.g. removing growths, repairing leaks, clearing blockages)
- soils in stormwater planters, rain gardens, roof gardens
- vegetation management
- sediment management/pollutant control
- access and safety

D2.0 Alternative models for delivery of O&M

Given the importance of sound O&M, a key issue is then how to educate and motivate the owner to undertake O&M, or whether to apply some form of obligatory O&M regimen. Any requirements for the latter option must lie within the powers of the controlling local authority, be it under the Local Government Act and/or a bylaw. Research shows that various models can be used to facilitate O&M:

- traditional voluntary regime:
  - guidance is given to the on-site device owner
  - random inspections are made to check compliance (whereas this is common overseas, it is not legally allowed in New Zealand, unless the controlling authority has reasonable cause to believe that the device is posing a problem to others)
- legal obligation on owner: under a bylaw provision, owners can be required to have their device serviced at designated intervals, with certification as to the servicing submitted to the controlling authority (e.g. as applied by Auckland City Council – ACC 2002)
- contracted-out: in installing an on-site device, the owner agrees to contract-out O&M to the controlling authority (in Orlando, Florida, a high-tech approach is applied, involving equipping the serviceperson with a notebook computer that has the site and device details; on completing the service, details are logged-in and downloaded to the controlling authority's database)

Whereas the legal obligation on owner model is more likely to ensure sound O&M, in most cases the traditional voluntary regime will apply. In this case, the following measures will assist with compliance:

- raise public awareness in stormwater generally and on-site devices in particular, e.g. through:
  - media coverage
  - website coverage, e.g. refer to North Shore City Council's website, URL: http://www.northshorecity.govt.nz/WaterInfo/stormwater/storm.htm
  - brochures (e.g. refer to Auckland City Council's *Rain and the City*)
  - demonstration projects incorporating on-site devices (e.g. Auckland City's Wesley Community Centre)
- provide owners with details of how their device works and what is required in respect to operation and maintenance (e.g. as set out in ACC 2002)

Where the implementation of a device requires a resource consent, such a consent may include conditions in respect to O&M (note that under Auckland City Council's legal obligation on owner O&M regime, an O&M Plan must be submitted at the consent application stage, using the standard forms in ACC 2002). Similarly, on-site devices should ideally be recorded on LIM's and PIM's, so that incoming owners are aware of their presence and with it the O&M imperatives.

D3.0 Operation and maintenance practices

D3.1 General

The following inventories indicate the general O&M practices that should ideally be applied to on-site devices:

(a) Monitoring and Inspection:

Devices should be regularly inspected, with inspection records kept to:

- determine where special maintenance conditions exist
- determine optimal frequencies for future inspection and maintenance
- establish scheduled and unscheduled maintenance provisions
- assure device operation and aesthetics

Specific requirements:

- the owner should be responsible for conducting inspections (or having then done on his/her behalf) with the device as-built plans in hand, generally at the following intervals (noting that this may vary, depending on site-specific conditions):
  - quarterly basis for the first 2 years
  - minimum of semi-annually thereafter
- the owner should keep inspection records to track the progressive development of the OSM device(s) over time, covering:
  - general condition of vegetation area(s), predominant plant species, distribution, and success rate (where applicable)
  - sediment condition and depth in forebay (or other pre-treatment structure), treatment facility, bench planting zones, and other sediment removal components
  - water elevations/observations (sheen, smell, etc.)
  - condition of the inlet, outlet, and overflow structures/devices, etc
  - unscheduled maintenance needs
  - components that do not meet performance criteria and require immediate maintenance and subsequent remedial actions
  - common problem areas, solutions, and general observations
  - aesthetic conditions

(b) Soils in stormwater planters and rain gardens:

The following guidelines apply:

- test the ph of planting bed soils in areas where vegetation has died:
  - if the ph is below 5.2, apply limestone
  - if the ph is above 7.0, add iron sulfate plus sulfur to reduce the ph
- use core aeration of unvegetated areas if the surface of the bed becomes clogged with fine sediments over time: redesign plantings to correct problems, and re-establish soil coverage

(c) Vegetation management
Vegetated stormwater facilities may require a number of control practices, especially during their 2-year establishment period. Corresponding required practices cover:

- maintain plantings for a period of 2 years after date of the building consent final inspection
- during the establishment period, remove undesired vegetation with minimal (or preferably no) use of toxic herbicides and pesticides at least three times in year 1, and once or twice in the summer of year 2; replace plants that die during this period within 3 months
- at the end of the second year, healthy plant establishment shall be achieved for at least 90% of the vegetation
- selectively irrigate if necessary during the establishment period, during times of drought, or until the vegetation becomes established: it is preferred that the facility be designed to sustain its function without a permanent irrigation system
- replenish mulch at least annually, noting also that mulching shall be done to retain topsoil, heat, and moisture, and to inhibit weed growth
- schedule maintenance outside sensitive wildlife and vegetation seasons
- minimise plant disturbance during maintenance activities
- insofar as practicable, avoid the use of fertilisers, herbicides, or pesticides for vegetation maintenance
- use replacement plants that conform with the initial planting plan

(d) Sediment management/pollutant control:
Sediment and other pollutants that degrade water quality will accumulate in on-site devices and require removal to ensure proper operational performance. Corresponding guidelines cover:

- remove sediment when accumulations reach 100 mm in depth, or 50% of the designed sediment storage depth, or if sediment accumulation inhibits facility operation
- dispose of the sediment in a safe manner, noting that sediment from trafficked and other high use areas may be contaminated
- if sediment and/or other pollutants are accumulating more rapidly than assumed when the O&M Plan was formulated, investigate and rectify the cause

(e) Access and safety
O&M programmes must provide for safe and efficient access to a facility. The following are general requirements; specific conditions may require site-specific modifications:

- secure easements necessary to provide facility and maintenance access (if applicable)
- use only suitably trained personnel to access confined spaces
- uaintain ingress/egress routes to design standards, in a manner that allows efficient maintenance of the facility
- ensure that fencing is in good repair

D3.2 Device-specific operation and maintenance guidelines

O&M guidelines are presented for each specific on-site device covered by this Guide in Section 4. These have been compiled through reference to various published guidelines including ARC TP10, ACC (2002) and CoP (2002). An example of an O&M checklist for a grass swale is in Table D1.

Table D1 O&M checklist - grass swale

Frequency			**Action**
As required	**Quarterly**	**Annually**	
	✓	✓	**General** Remove any debris accumulations and waste vegetation
		✓	**Inlets and outlets** Remove sediment
✓	✓	✓	**Grass** Mow (with catcher) to maintain the grass length at 50 – 150 mm
	✓	✓	**Grass** • remove nuisance weeds • fertilise or treat to maintain vigorous growth, as required • fill any erosion holes and re-seed
	✓	✓	**Pipework:** Check for debris/blockages/leaks & rectify

Routine O&M should be backed by inspection and record keeping by the device owner/operator, to track the progressive development and operation of the device over time [refer Section D3.1(a)]. As an example, for the grass swale, inspections cover and document the following:

- general condition of vegetation area(s), predominant plant species, distribution, and success rate (where applicable)
- condition and depth of erosion
- condition and depth of sediment accumulations
- water elevations/observations (sheen, smell, etc.)
- condition of the inlet, outlet, and overflow structures/devices, etc
- unscheduled maintenance needs
- components that do not meet performance criteria and require immediate maintenance
- common problem areas, solutions, and general observations
- aesthetic conditions

References

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