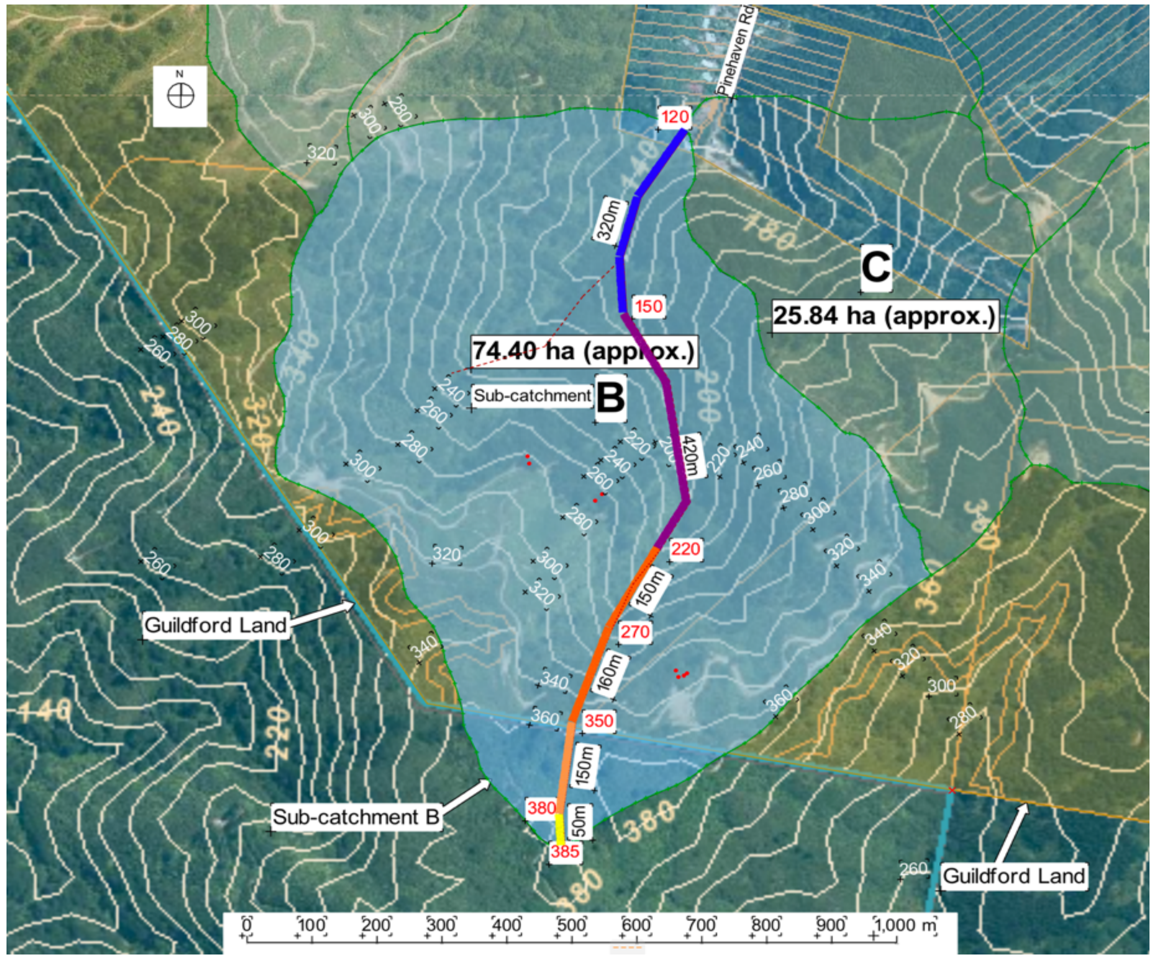
Save Our Hills (SOH): Time of Concentration Investigation - Pinehaven Stream - Sub-catchment B

Sub-catchment B Pinehaven Stream segments		Description	Horizon. (m)	Elevation - Start	Elevation - Finish	Vertical (m)	Angle (Degrees)	Gradient Y	Gradient X	Slope (%)	Hypotenuse Length (m)
Segment 1	Yellow	Overland sheet flow	50	385	380	5	5.7	1	10.0	10.0%	51.0
Segment 2a	Light Orange	Shallow Concentrated Flow	150	380	350	30	11.3	1	5.0	20.0%	153.0
Segment 2b	Dark Orange	Shallow Concentrated Flow	310	350	220	130	22.8	1	2.4	41.9%	336.3
Segment 3	Purple	Small open natural channel	420	220	150	70	9.5	1	6.0	16.7%	425.8
Segment 4	Blue	Larger open natural channel	320	150	120	30	5.4	1	10.7	9.4%	321.4
Segments 1 - 4		Overall hydraulic length	1,250	385	120	265	12.0	1	4.72	21.2%	1,279



Time of Concentration Tc (see Wellington Method opposite):

Tc = T1 + T2 + ... + Tm
m = number of stream segments

Time of Concentration = T c = 14.7 + 1.1 + 1.6 + 3.3+ 3.3 = 24.1 minutes

SCS Lag time = 2/3 x Tc = 16.1 minutes

ALTERNATIVE METHOD:
Bransby Williams equation:
(from Cardno, 2019, Equation 6)
Tc = FL / A^0.1 S^0.2

where Tc is in minutes
F is 92.7
L is length in kilometres (km)
A is area in hectares (ha)
S is slope in metres per kilometre (m/km)

Tc = 92.7 x say 1.25km / (74.4ha)^0.1 x (256m/1.25km)^0.2
Tc = 115.875 ÷ (1.54 2.90)
Tc = 26.0 minutes

Time of Concentration (Tc)
Tc = T1 + T2 + ... + Tm
m = number of stream segments

WELLINGTON METHOD:

Segment 1 - Overland sheet flow
(Wellington Water Ltd - Cardno 2019)
T1 = Time in minutes
n = Horton's coefficient = 0.06 for bush (dense grass - see Cardno worked exxample)
L = Length of overland flow = 50m
S = Slope in % = 10 %
T1 = 107 n L^0.33 / S^0.2

Time of overland sheet flow = T1 = 107 x 0.06 x 50^0.33 / 10^0.2 = 14.7 minute Check: 14.7 minutes

Segment 2a - Shallow concentrated flow
(Wellington Water Ltd - Cardno 2019)
T2a = Time in minutes
L = Length of shallow concentrated flow = 150m
S = Slope = (380 - 350) / 150 = 0.20 m/m
T2a = L / 295 S^0.5

Time of shallow concentrated flow = T2a = 150 / 295 x 0.2^0.5 = 1.1 minutes Check: 1.1 minutes

Segment 2b - Shallow concentrated flow
(Wellington Water Ltd - Cardno 2019)
T2a = Time in minutes
L = Length of shallow concentrated flow = 310m
S = Slope = (350 - 220) / 310 = 0.42 m/m
T2b = L / 295 S^0.5

Time of shallow concentrated flow = T2a = 310 / 295 x 0.42^0.5 = 1.6 minutes Check: 1.6 minutes

Segment 3 - Small open channel flow*
(Wellington Water Ltd - Cardno 2019)
n = Manning's n = 0.09
S = slope of channel = (220 - 150) / 420 = 0.17 m/m
Rh = hydraulic radius = Area / Wetted Perimeter
Velocity of open channel flow = V = 1/n x (Rh^2/3) x (S^1/2)
Area = 1.5m x 0.7m = 1.05m2 (width x depth of channel) 1.05
Wetted perimeter = 0.7 + 1.5 + 0.7 = 2.9m (perimeter of X-section that is wet)
V = 1/0.09 x 0.31^2/3 x 0.17^1/2 = 2.1 m/s 2.1
Rh = 0.9 / 2.9 = 0.31 m 0.31
200.0
2.21 m3/s
At this velocity it takes 420m ÷ 2.1 m/s = 200 seconds = 3.3 minutes to travel the small open channel dist Check: 3.3 minutes
3.3

Segment 4 - Large open channel flow**
(Wellington Water Ltd - Cardno 2019)
n = Manning's n = 0.12
S = slope of channel = (150 - 120) / 320 = 0.094 m/m
Rh = hydraulic radius = Area / Wetted Perimeter
Velocity of open channel flow = V = 1/n x (Rh^2/3) x (S^1/2)
Area = 2.0m x 1.0m = 2.0m2 (width of channel x depth of channel)
Wetted perimeter = 1.0 + 2.0 + 1.0 = 4.0m (perimeter of X-section that is wet)
V = 1/0.12 x 0.5^2/3 x 0.094^1/2 = 1.6 m/s 1.6
Rh = 2.0 / 4.0 = 0.5 m
198.8
3.22 m3/s
At this velocity it takes 320m ÷ 1.6 m/s = 199 seconds = 3.1 minutes to travel the large open channel dist Check: 3.3 minutes
3.3

* Talbot Formula: A = C M^3/4 where
A = waterway area in square ft
M = catchment area in acres = 50% x 74.4ha x 2.47 = acres 91.9 acres
C = constant = 0.6 for rolling to hilly

A = 0.6 x 91.9^3/4
17.8 ft2
1.65 m2 compares ok with waterway area of 1.05m2

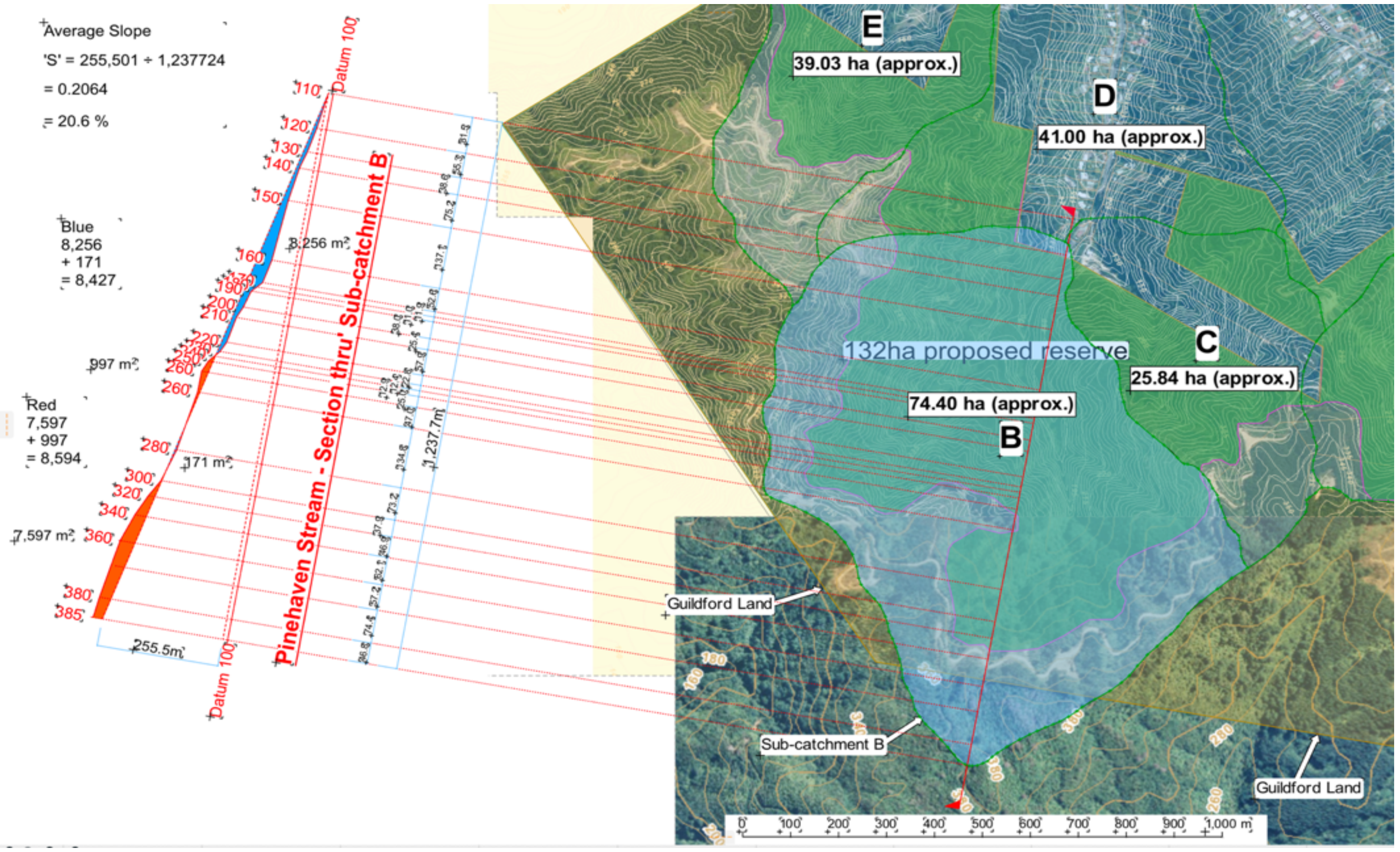
** Talbot Formula: A = C M^3/4 where
A = waterway area in square ft
M = catchment area in acres = = 74ha = 2.47 x 74 = acres 183.8 acres
C = constant = 0.6 for rolling to hilly

A = 0.6 x 183.8^3/4
30.0 ft2
2.78 m2 compares ok with waterway area of 2.0m2

Gradient of Sub-catchment B

Section through Sub-catchment B showing average slope = 20.6% approx.

Aerial View of Sub-catchment B (showing 20m contours)



Equal Area Method					
Elevation (m)	h (m)	x (m)	delta x (m)	ave h (m)	delta A (=h.delta x) m^2
0.0	0.0	0.0			
10.0	10.0	81.5	81.5	5.0	407.5
20.0	20.0	136.8	55.3	15.0	829.5
30.0	30.0	175.4	38.6	25.0	965.0
40.0	40.0	250.6	75.2	35.0	2632.0
50.0	50.0	387.7	137.1	45.0	6169.5
60.0	60.0	440.3	52.6	55.0	2893.0
70.0	70.0	452.2	11.9	65.0	773.5
80.0	80.0	463.2	11.0	75.0	825.0
90.0	90.0	501.2	38.0	85.0	3230.0
100.0	100.0	526.6	25.4	95.0	2413.0
110.0	110.0	584.5	57.9	105.0	6079.5
120.0	120.0	607.3	22.8	115.0	2622.0
130.0	130.0	619.7	12.4	125.0	1550.0
140.0	140.0	632.6	12.9	135.0	1741.5
150.0	150.0	657.6	25.0	145.0	3625.0
150.0	150.0	704.6	47.0	150.0	7050.0
170.0	170.0	839.4	134.8	160.0	21568.0
190.0	190.0	912.6	73.2	180.0	13176.0
210.0	210.0	950.5	37.9	200.0	7580.0
230.0	230.0	997.4	46.9	220.0	10318.0
250.0	250.0	1059.5	62.1	240.0	14904.0
270.0	270.0	1191.1	131.6	260.0	34216.0
275.0	275.0	1237.9	46.8	272.5	12753.0
					158321.0
L	1237.9				
S_c	0.207				

Pinehaven Stream - Sub-catchment B
Segment 2a: Shallow Concentrated Flow (uphill from the road)

Pinehaven Stream - Sub-catchment B
Segment 2a (Contd.): Shallow Concentrated Flow (uphill from the road)

Examples of runoff uphill of the logging road crossing over the road

Pinehaven Stream - Sub-catchment B
Segment 2b: Shallow Concentrated Flow (downhill from the road)

Pinehaven Stream - Sub-catchment B
Segment 2b (Contd.): Shallow Concentrated Flow (downhill from the road)

Pinehaven Stream - Sub-catchment B
Segment 2b (Contd.): Shallow Concentrated Flow (downhill from the road)

Pinehaven Stream - Sub-catchment B
Segment 2b (Contd.): Shallow Concentrated Flow (downhill from the road)

Pinehaven Stream - Sub-catchment B
Segment 2b (Contd.): Shallow Concentrated Flow (downhill from the road)

Pinehaven Stream - Sub-catchment B
Segment 3: Small open channel flow

Pinehaven Stream - Sub-catchment B
Segment 3: Large open channel flow

Pinehaven Stream - Sub-catchment B
Segment 3 (Contd.): Large open channel flow

Pinehaven Stream - Sub-catchment B
Segment 3 (Contd.): Large open channel flow

Pinehaven Stream - Sub-catchment B
Segment 3 (Contd.): Large open channel flow

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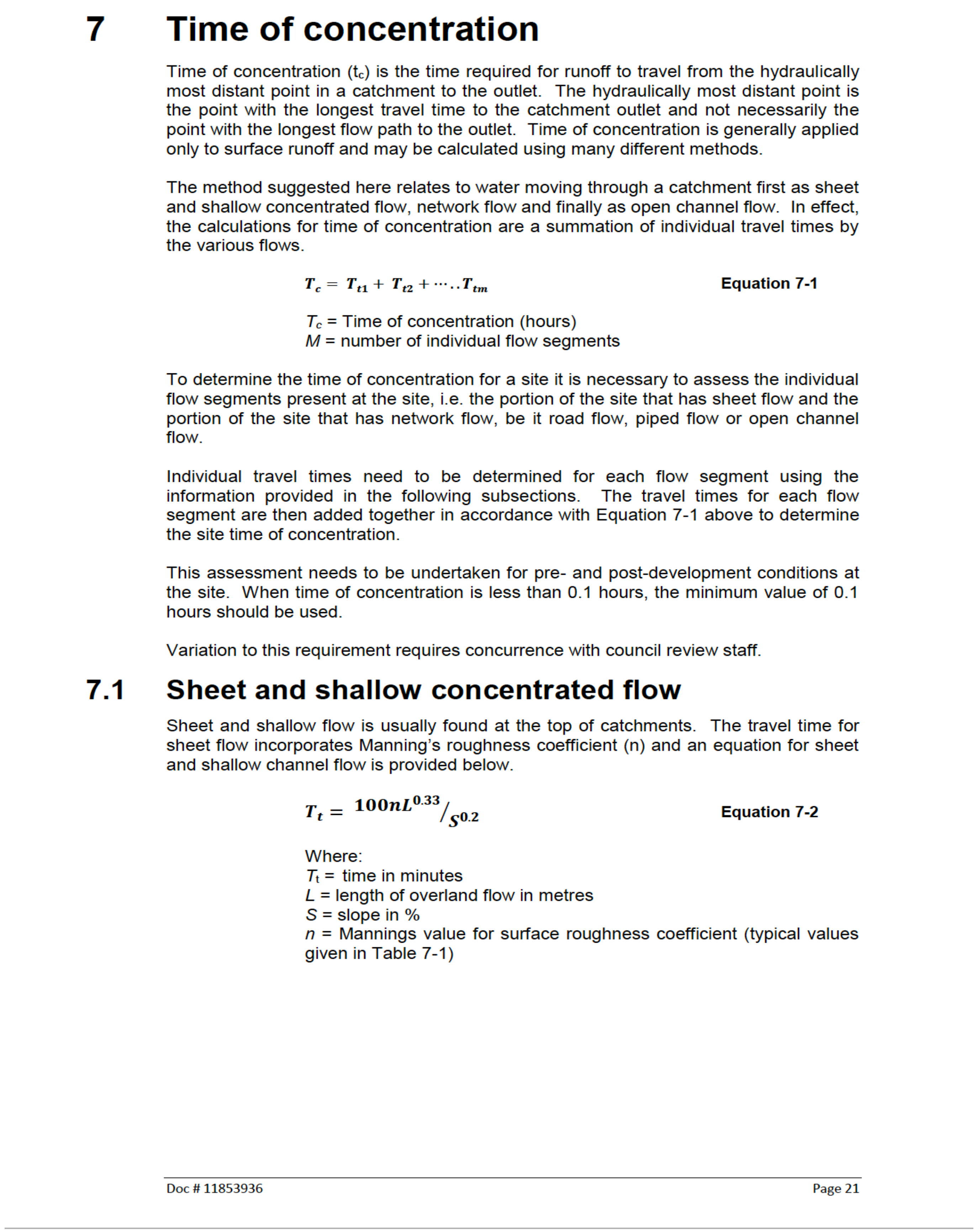

7 Time of concentration

Time of concentration (t_c) is the time required for runoff to travel from the hydraulically most distant point in a catchment to the outlet. The hydraulically most distant point is the point with the longest travel time to the catchment outlet and not necessarily the point with the longest flow path to the outlet. Time of concentration is generally applied only to surface runoff and may be calculated using many different methods.

The method suggested here relates to water moving through a catchment first as sheet and shallow concentrated flow, network flow and finally as open channel flow. In effect, the calculations for time of concentration are a summation of individual travel times by the various flows.

$$T_c = T_{t1} + T_{t2} + \cdots .. T_{tm} \qquad \textbf{Equation 7-1}$$

T_c = Time of concentration (hours)
M = number of individual flow segments

To determine the time of concentration for a site it is necessary to assess the individual flow segments present at the site, i.e. the portion of the site that has sheet flow and the portion of the site that has network flow, be it road flow, piped flow or open channel flow.

Individual travel times need to be determined for each flow segment using the information provided in the following subsections. The travel times for each flow segment are then added together in accordance with Equation 7-1 above to determine the site time of concentration.

This assessment needs to be undertaken for pre- and post-development conditions at the site. When time of concentration is less than 0.1 hours, the minimum value of 0.1 hours should be used.

Variation to this requirement requires concurrence with council review staff.

7.1 Sheet and shallow concentrated flow

Sheet and shallow flow is usually found at the top of catchments. The travel time for sheet flow incorporates Manning's roughness coefficient (n) and an equation for sheet and shallow channel flow is provided below.

$$T_t = {100nL^{0.33}}/{s^{0.2}} \qquad \textbf{Equation 7-2}$$

Where:
T_t = time in minutes
L = length of overland flow in metres
S = slope in %
n = Mannings value for surface roughness coefficient (typical values given in Table 7-1)

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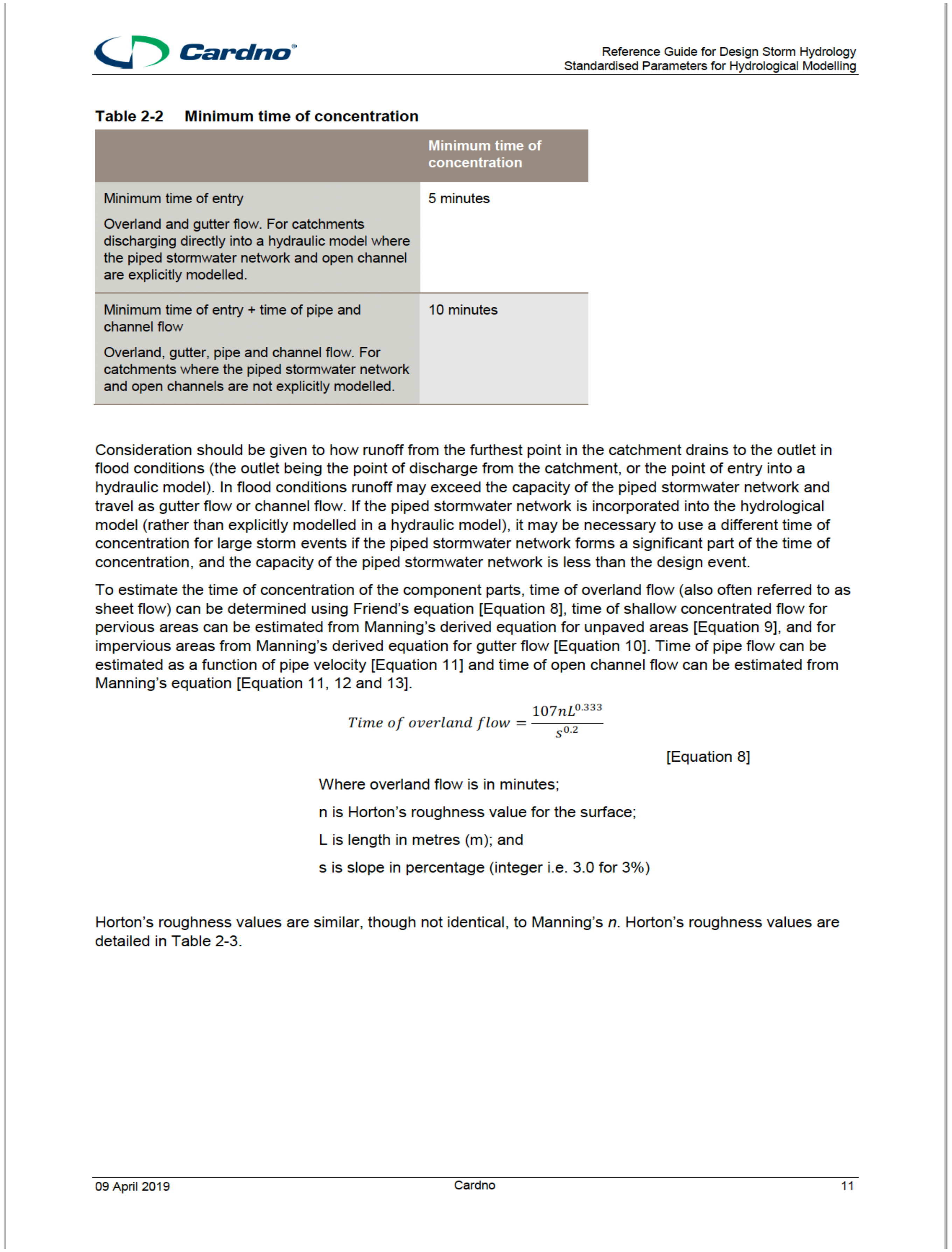

Table 2-2 Minimum time of concentration

	Minimum time of concentration
Minimum time of entry Overland and gutter flow. For catchments discharging directly into a hydraulic model where the piped stormwater network and open channel are explicitly modelled.	5 minutes
Minimum time of entry + time of pipe and channel flow Overland, gutter, pipe and channel flow. For catchments where the piped stormwater network and open channels are not explicitly modelled.	10 minutes

Consideration should be given to how runoff from the furthest point in the catchment drains to the outlet in flood conditions (the outlet being the point of discharge from the catchment, or the point of entry into a hydraulic model). In flood conditions runoff may exceed the capacity of the piped stormwater network and travel as gutter flow or channel flow. If the piped stormwater network is incorporated into the hydrological model (rather than explicitly modelled in a hydraulic model), it may be necessary to use a different time of concentration for large storm events if the piped stormwater network forms a significant part of the time of concentration, and the capacity of the piped stormwater network is less than the design event.

To estimate the time of concentration of the component parts, time of overland flow (also often referred to as sheet flow) can be determined using Friend's equation [Equation 8], time of shallow concentrated flow for pervious areas can be estimated from Manning's derived equation for unpaved areas [Equation 9], and for impervious areas from Manning's derived equation for gutter flow [Equation 10]. Time of pipe flow can be estimated as a function of pipe velocity [Equation 11] and time of open channel flow can be estimated from Manning's equation [Equation 11, 12 and 13].

$$Time\ of\ overland\ flow = \frac{107nL^{0.333}}{s^{0.2}}$$

[Equation 8]

Where overland flow is in minutes;

n is Horton's roughness value for the surface;

L is length in metres (m); and

s is slope in percentage (integer i.e. 3.0 for 3%)

Horton's roughness values are similar, though not identical, to Manning's *n*. Horton's roughness values are detailed in Table 2-3.

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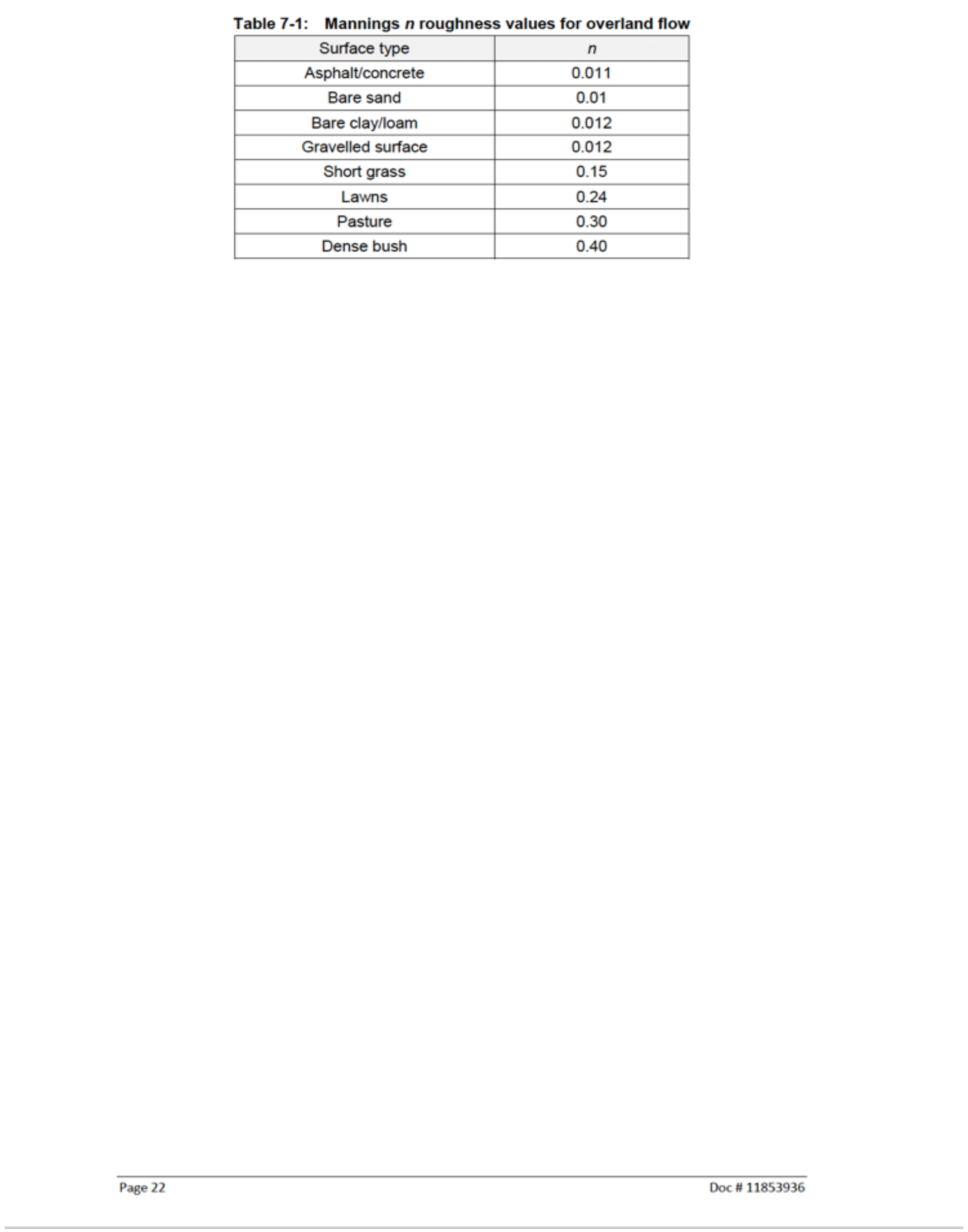

Table 7-1: Mannings *n* roughness values for overland flow

Surface type	*n*
Asphalt/concrete	0.011
Bare sand	0.01
Bare clay/loam	0.012
Gravelled surface	0.012
Short grass	0.15
Lawns	0.24
Pasture	0.30
Dense bush	0.40

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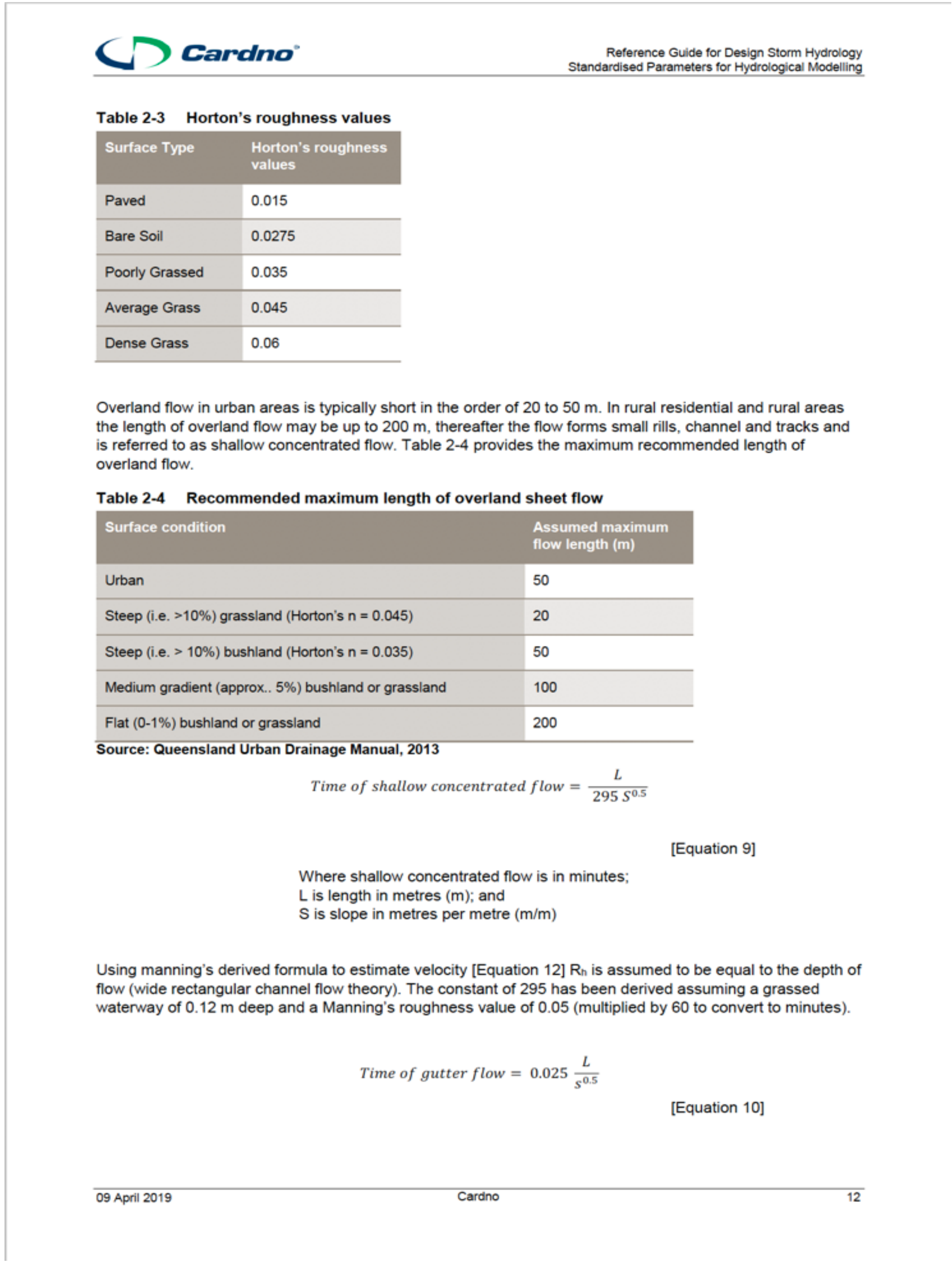


Table 2-3 Horton's roughness values

Surface Type	Horton's roughness values
Paved	0.015
Bare Soil	0.0275
Poorly Grassed	0.035
Average Grass	0.045
Dense Grass	0.06

Overland flow in urban areas is typically short in the order of 20 to 50 m. In rural residential and rural areas the length of overland flow may be up to 200 m, thereafter the flow forms small rills, channel and tracks and is referred to as shallow concentrated flow. Table 2-4 provides the maximum recommended length of overland flow.

Table 2-4 Recommended maximum length of overland sheet flow

Surface condition	Assumed maximum flow length (m)
Urban	50
Steep (i.e. >10%) grassland (Horton's n = 0.045)	20
Steep (i.e. > 10%) bushland (Horton's n = 0.035)	50
Medium gradient (approx.. 5%) bushland or grassland	100
Flat (0-1%) bushland or grassland	200

Source: Queensland Urban Drainage Manual, 2013

$$Time\ of\ shallow\ concentrated\ flow = \frac{L}{295\ S^{0.5}}$$

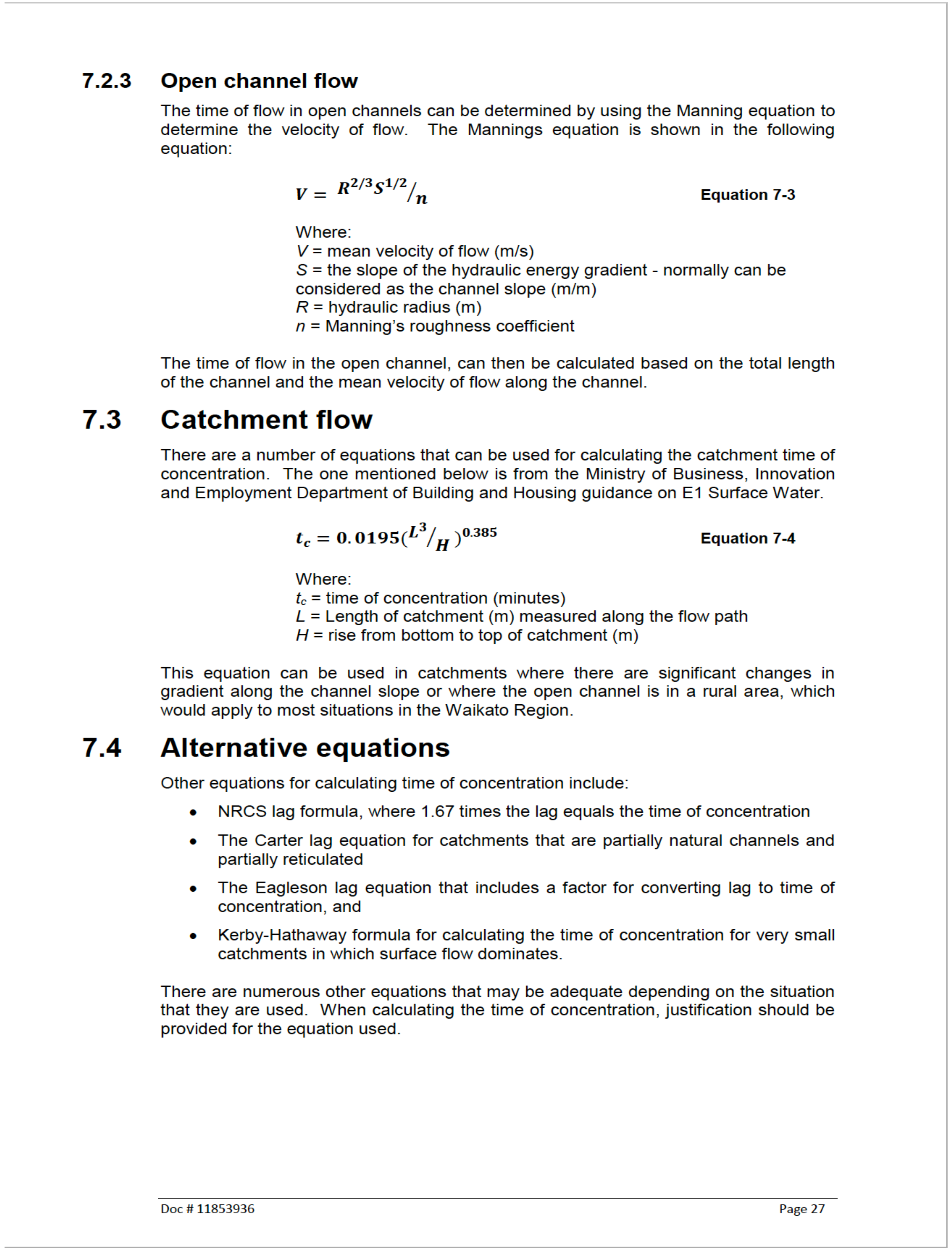
[Equation 9]

Where shallow concentrated flow is in minutes;
L is length in metres (m); and
S is slope in metres per metre (m/m)

Using manning's derived formula to estimate velocity [Equation 12] R_h is assumed to be equal to the depth of flow (wide rectangular channel flow theory). The constant of 295 has been derived assuming a grassed waterway of 0.12 m deep and a Manning's roughness value of 0.05 (multiplied by 60 to convert to minutes).

$$Time\ of\ gutter\ flow = 0.025\ \frac{L}{S^{0.5}}$$

[Equation 10]



7.2.3 Open channel flow

The time of flow in open channels can be determined by using the Manning equation to determine the velocity of flow. The Mannings equation is shown in the following equation:

$$V = {R^{2/3}S^{1/2}}/{n}$$ **Equation 7-3**

Where:
V = mean velocity of flow (m/s)
S = the slope of the hydraulic energy gradient - normally can be considered as the channel slope (m/m)
R = hydraulic radius (m)
n = Manning's roughness coefficient

The time of flow in the open channel, can then be calculated based on the total length of the channel and the mean velocity of flow along the channel.

7.3 Catchment flow

There are a number of equations that can be used for calculating the catchment time of concentration. The one mentioned below is from the Ministry of Business, Innovation and Employment Department of Building and Housing guidance on E1 Surface Water.

$$t_c = 0.0195({L^3}/{H})^{0.385}$$ **Equation 7-4**

Where:
t_c = time of concentration (minutes)
L = Length of catchment (m) measured along the flow path
H = rise from bottom to top of catchment (m)

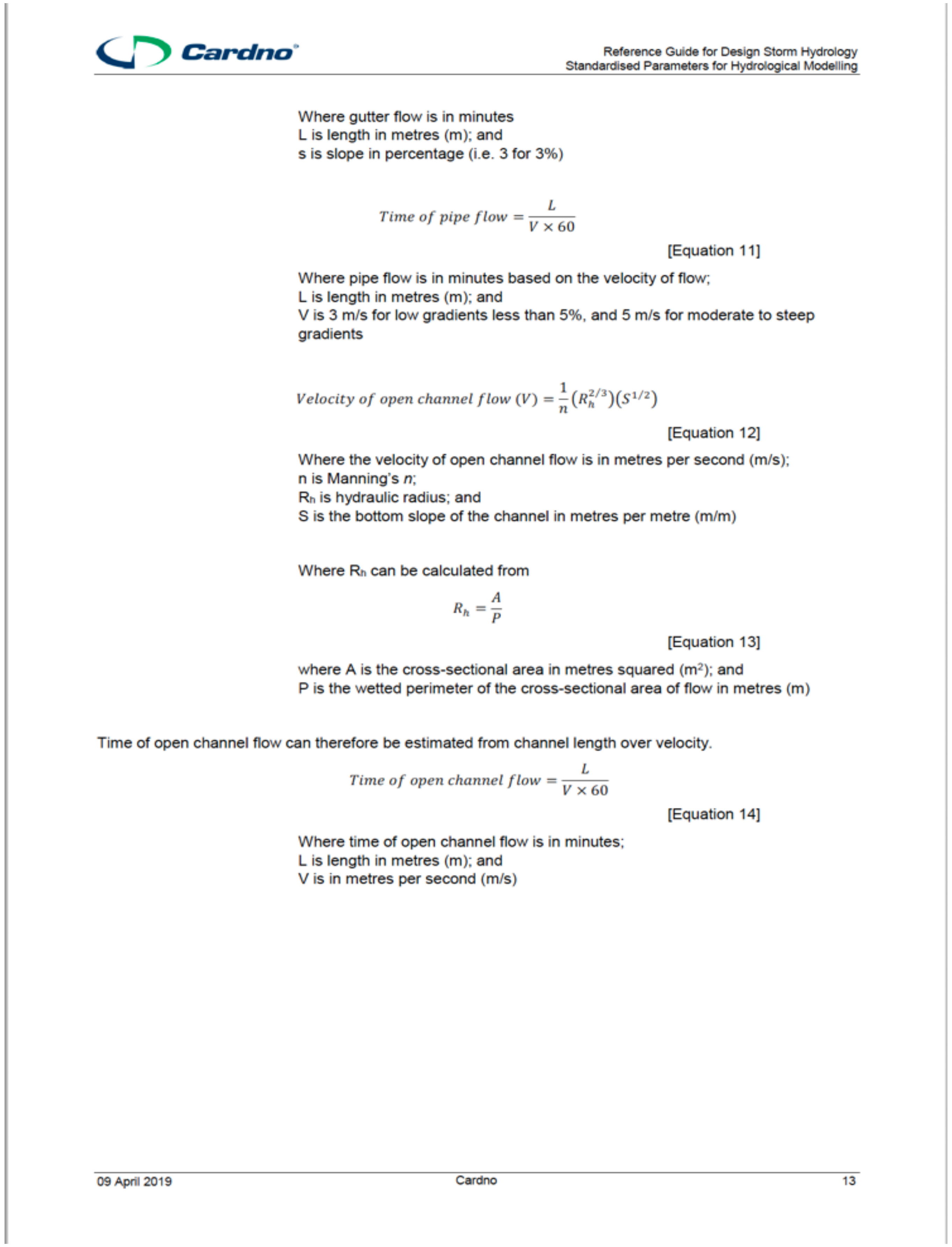
This equation can be used in catchments where there are significant changes in gradient along the channel slope or where the open channel is in a rural area, which would apply to most situations in the Waikato Region.

7.4 Alternative equations

Other equations for calculating time of concentration include:

- NRCS lag formula, where 1.67 times the lag equals the time of concentration
- The Carter lag equation for catchments that are partially natural channels and partially reticulated
- The Eagleson lag equation that includes a factor for converting lag to time of concentration, and
- Kerby-Hathaway formula for calculating the time of concentration for very small catchments in which surface flow dominates.

There are numerous other equations that may be adequate depending on the situation that they are used. When calculating the time of concentration, justification should be provided for the equation used.



Where gutter flow is in minutes
L is length in metres (m); and
s is slope in percentage (i.e. 3 for 3%)

$$Time\ of\ pipe\ flow = \frac{L}{V \times 60}$$

[Equation 11]

Where pipe flow is in minutes based on the velocity of flow;
L is length in metres (m); and
V is 3 m/s for low gradients less than 5%, and 5 m/s for moderate to steep gradients

$$Velocity\ of\ open\ channel\ flow\ (V) = \frac{1}{n}(R_h^{2/3})(S^{1/2})$$

[Equation 12]

Where the velocity of open channel flow is in metres per second (m/s);
n is Manning's *n*;
R_h is hydraulic radius; and
S is the bottom slope of the channel in metres per metre (m/m)

Where R_h can be calculated from

$$R_h = \frac{A}{P}$$

[Equation 13]

where A is the cross-sectional area in metres squared (m^2); and
P is the wetted perimeter of the cross-sectional area of flow in metres (m)

Time of open channel flow can therefore be estimated from channel length over velocity.

$$Time\ of\ open\ channel\ flow = \frac{L}{V \times 60}$$

[Equation 14]

Where time of open channel flow is in minutes;
L is length in metres (m); and
V is in metres per second (m/s)

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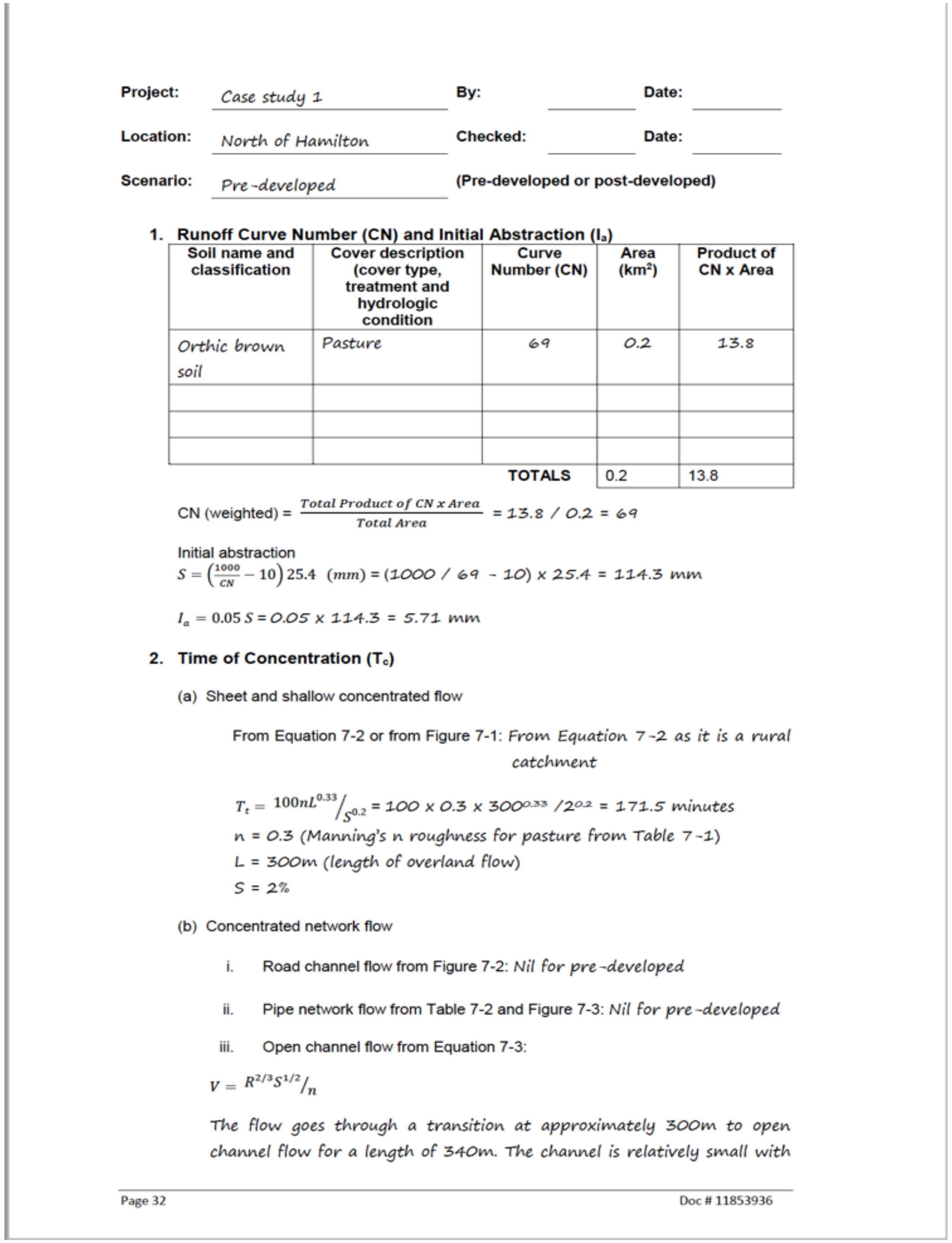

Project: Case study 1 **By:** ____ **Date:** ____

Location: North of Hamilton **Checked:** ____ **Date:** ____

Scenario: Pre-developed **(Pre-developed or post-developed)**

1. Runoff Curve Number (CN) and Initial Abstraction (I_a)

Soil name and classification	Cover description (cover type, treatment and hydrologic condition	Curve Number (CN)	Area (km²)	Product of CN x Area
Orthic brown soil	Pasture	69	0.2	13.8
		TOTALS	0.2	13.8

CN (weighted) = $\frac{Total\ Product\ of\ CN\ x\ Area}{Total\ Area}$ = 13.8 / 0.2 = 69

Initial abstraction

$S = \left(\frac{1000}{CN} - 10\right) 25.4\ (mm)$ = (1000 / 69 - 10) x 25.4 = 114.3 mm

$I_a = 0.05\,S$ = 0.05 x 114.3 = 5.71 mm

2. Time of Concentration (T_c)

(a) Sheet and shallow concentrated flow

From Equation 7-2 or from Figure 7-1: From Equation 7-2 as it is a rural catchment

$T_t = 100nL^{0.33}/S^{0.2}$ = 100 x 0.3 x 300$^{0.33}$ /2$^{0.2}$ = 171.5 minutes

n = 0.3 (Manning's n roughness for pasture from Table 7-1)

L = 300m (length of overland flow)

S = 2%

(b) Concentrated network flow

i. Road channel flow from Figure 7-2: Nil for pre-developed

ii. Pipe network flow from Table 7-2 and Figure 7-3: Nil for pre-developed

iii. Open channel flow from Equation 7-3:

$V = R^{2/3}S^{1/2}/n$

The flow goes through a transition at approximately 300m to open channel flow for a length of 340m. The channel is relatively small with

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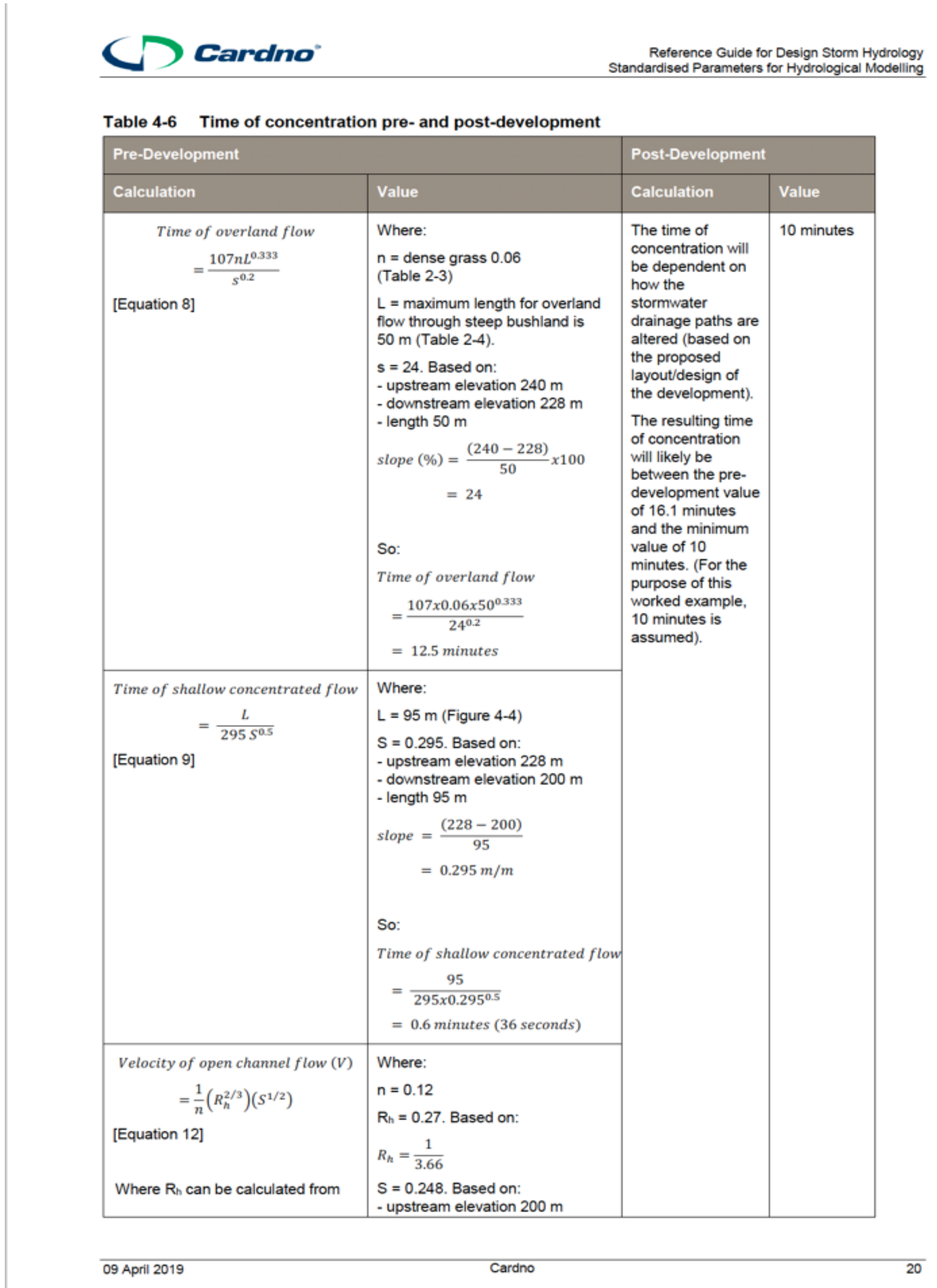

Table 4-6 Time of concentration pre- and post-development

Pre-Development		Post-Development	
Calculation	**Value**	**Calculation**	**Value**
$Time\ of\ overland\ flow = \frac{107nL^{0.333}}{s^{0.2}}$ [Equation 8]	Where: n = dense grass 0.06 (Table 2-3) L = maximum length for overland flow through steep bushland is 50 m (Table 2-4). s = 24. Based on: - upstream elevation 240 m - downstream elevation 228 m - length 50 m $slope\ (\%) = \frac{(240-228)}{50}x100 = 24$ So: $Time\ of\ overland\ flow = \frac{107x0.06x50^{0.333}}{24^{0.2}} = 12.5\ minutes$	The time of concentration will be dependent on how the stormwater drainage paths are altered (based on the proposed layout/design of the development). The resulting time of concentration will likely be between the pre-development value of 16.1 minutes and the minimum value of 10 minutes. (For the purpose of this worked example, 10 minutes is assumed).	10 minutes
$Time\ of\ shallow\ concentrated\ flow = \frac{L}{295\,S^{0.5}}$ [Equation 9]	Where: L = 95 m (Figure 4-4) S = 0.295. Based on: - upstream elevation 228 m - downstream elevation 200 m - length 95 m $slope = \frac{(228-200)}{95} = 0.295\ m/m$ So: $Time\ of\ shallow\ concentrated\ flow = \frac{95}{295x0.295^{0.5}} = 0.6\ minutes\ (36\ seconds)$		
$Velocity\ of\ open\ channel\ flow\ (V) = \frac{1}{n}\left(R_h^{2/3}\right)\left(S^{1/2}\right)$ [Equation 12] Where R_h can be calculated from	Where: n = 0.12 R_h = 0.27. Based on: $R_h = \frac{1}{3.66}$ S = 0.248. Based on: - upstream elevation 200 m		

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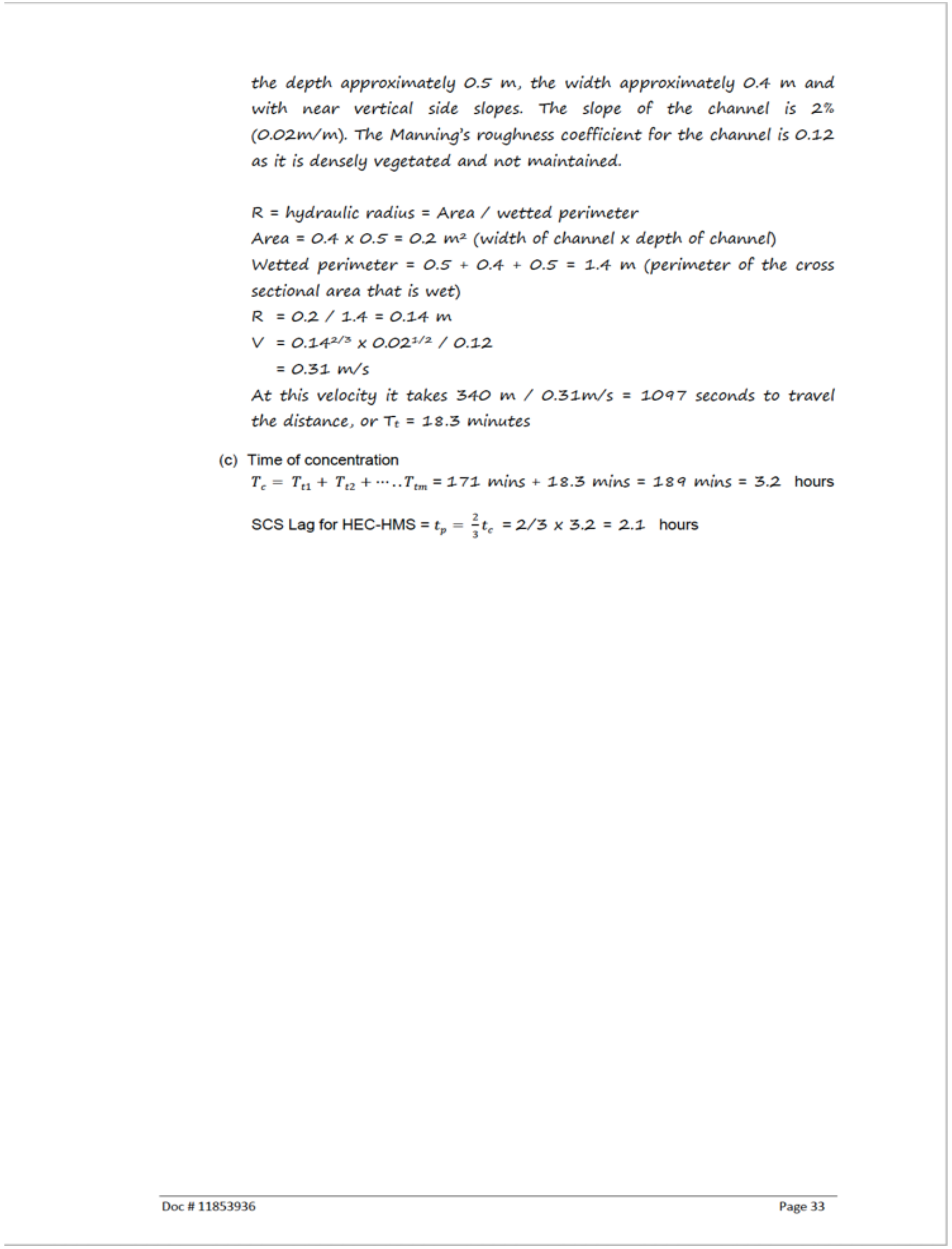

the depth approximately 0.5 m, the width approximately 0.4 m and with near vertical side slopes. The slope of the channel is 2% (0.02m/m). The Manning's roughness coefficient for the channel is 0.12 as it is densely vegetated and not maintained.

R = hydraulic radius = Area / wetted perimeter
Area = 0.4 x 0.5 = 0.2 m^2 (width of channel x depth of channel)
Wetted perimeter = 0.5 + 0.4 + 0.5 = 1.4 m (perimeter of the cross sectional area that is wet)
R = 0.2 / 1.4 = 0.14 m
V = $0.14^{2/3}$ x $0.02^{1/2}$ / 0.12
= 0.31 m/s
At this velocity it takes 340 m / 0.31m/s = 1097 seconds to travel the distance, or T_t = 18.3 minutes

(c) Time of concentration
$T_c = T_{t1} + T_{t2} + \cdots .. T_{tm}$ = 171 mins + 18.3 mins = 189 mins = 3.2 hours

SCS Lag for HEC-HMS = $t_p = \frac{2}{3} t_c$ = 2/3 x 3.2 = 2.1 hours

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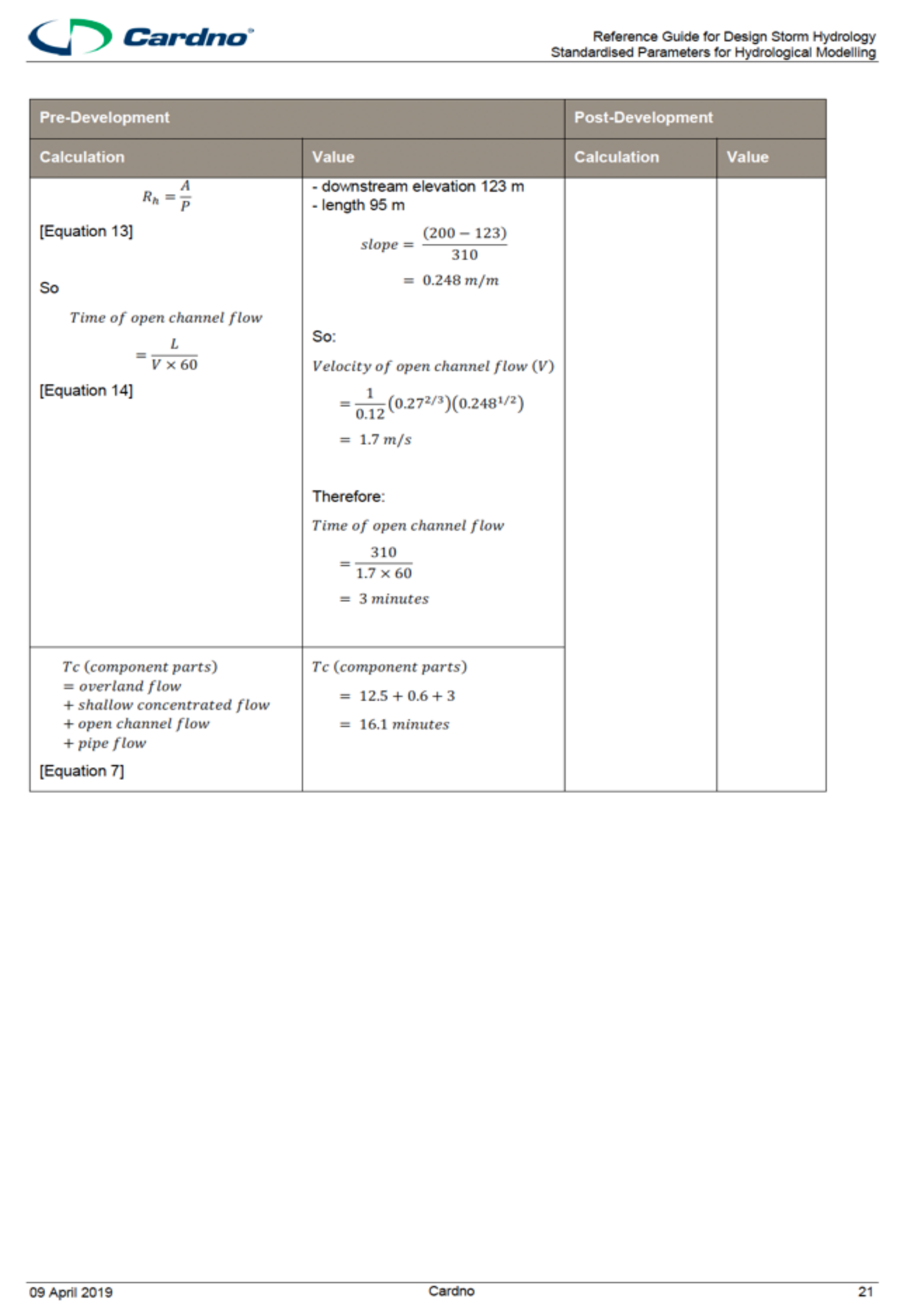
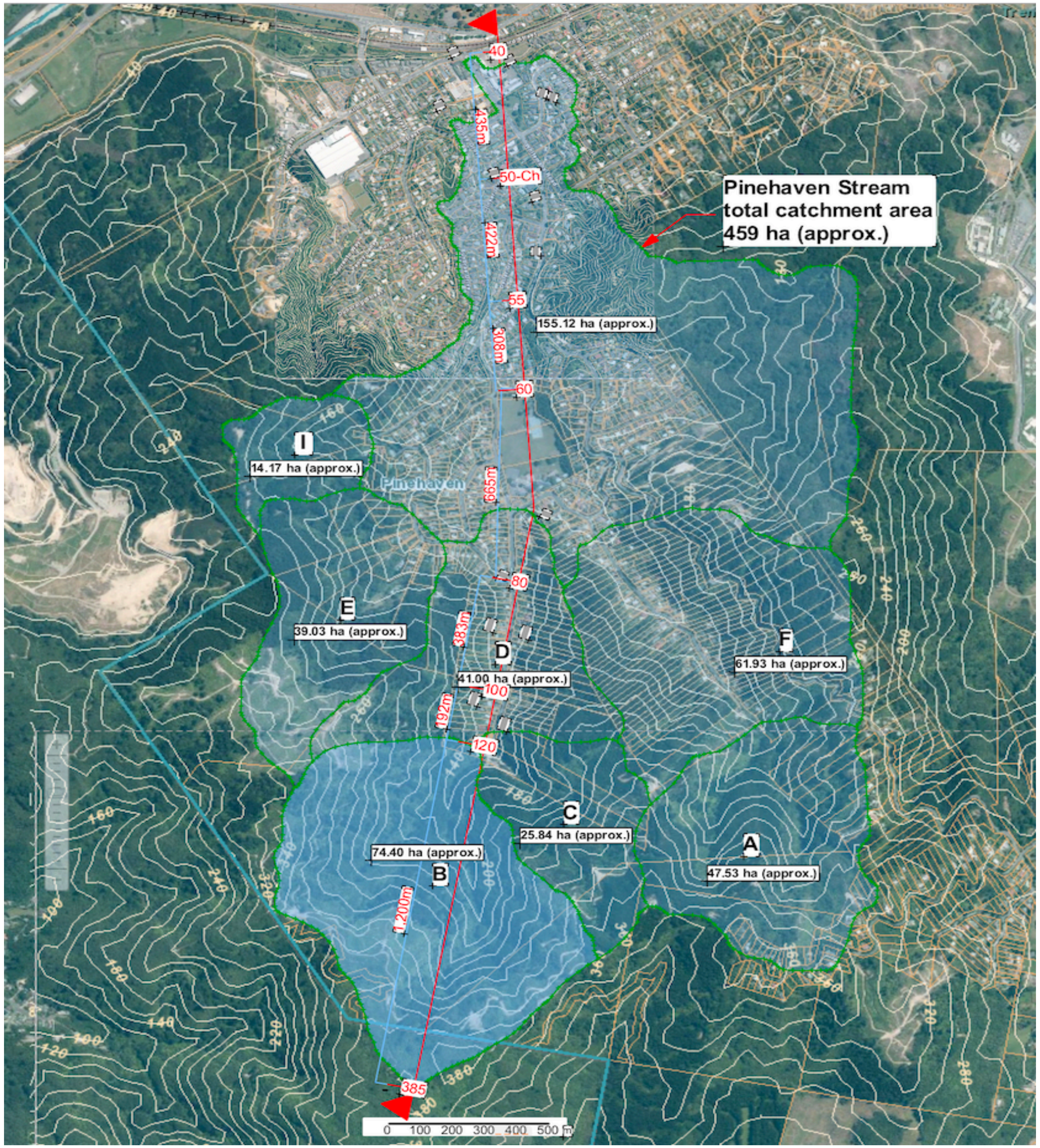


Pre-Development		Post-Development	
Calculation	Value	Calculation	Value
$R_h = \frac{A}{P}$ [Equation 13] So $Time\ of\ open\ channel\ flow = \frac{L}{V \times 60}$ [Equation 14]	- downstream elevation 123 m - length 95 m $slope = \frac{(200 - 123)}{310} = 0.248\ m/m$ So: $Velocity\ of\ open\ channel\ flow\ (V) = \frac{1}{0.12}(0.27^{2/3})(0.248^{1/2}) = 1.7\ m/s$ Therefore: $Time\ of\ open\ channel\ flow = \frac{310}{1.7 \times 60} = 3\ minutes$		
$Tc\ (component\ parts) = overland\ flow + shallow\ concentrated\ flow + open\ channel\ flow + pipe\ flow$ [Equation 7]	$Tc\ (component\ parts) = 12.5 + 0.6 + 3 = 16.1\ minutes$		

Save Our Hills (SOH): Time of Concentration Investigation - Pinehaven Stream - Whole Catchment

Gradient of Pinehaven Stream catchment

Contour Plan of whole catchment



Whole catchment down to confluence at Hulls Creek (i.e. all 15 sub-catchments A - O)

Equal Area Slope = 3.7%

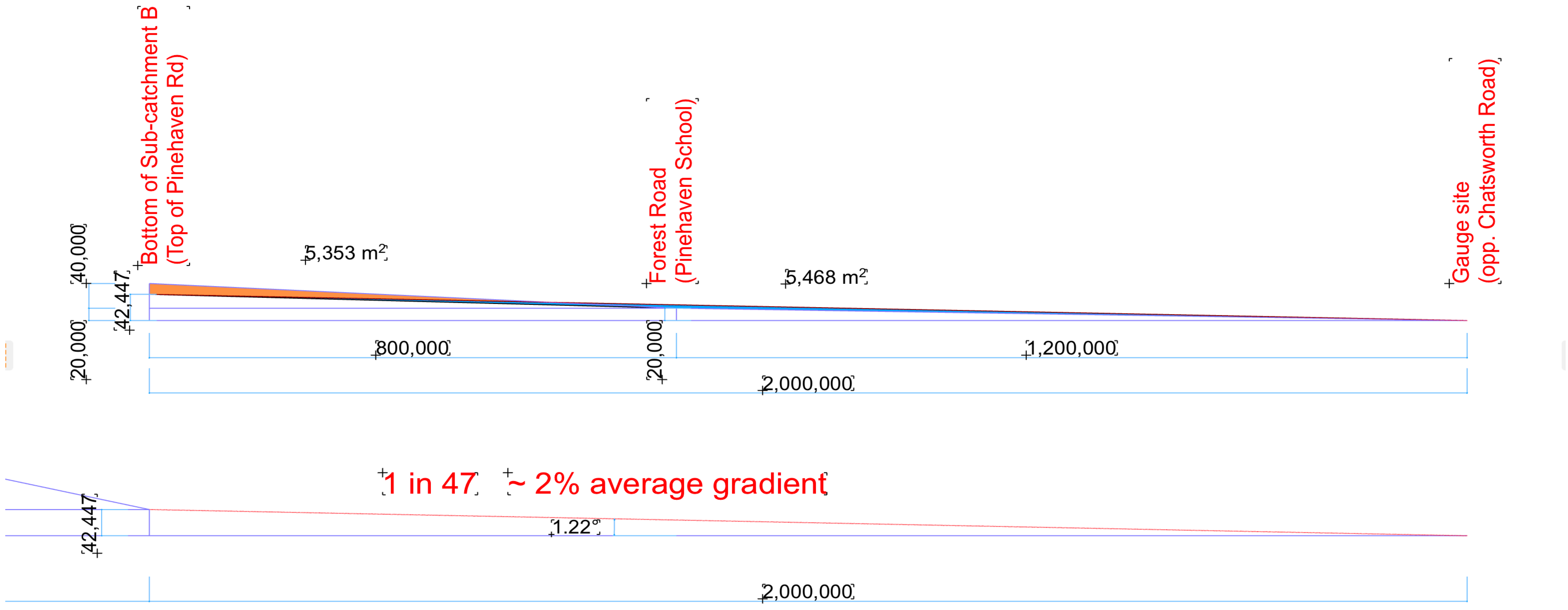
	Equal Area Method					
	Elevation (m)	**h (m)**	**x (m)**	**delta x (m)**	**ave h (m)**	**delta A (=h.delta x) m^2**
Hulls Creek	0.0	0.0	0.0			
opp. Chats. Rd	10.0	10.0	435.0	435.0	5.0	2175.0
	15.0	15.0	857.0	422.0	8.3	3516.7
	20.0	20.0	1165.0	308.0	11.3	3465.0
	40.0	40.0	1830.0	665.0	17.0	11305.0
	60.0	60.0	2213.0	383.0	24.2	9255.8
	80.0	80.0	2448.6	235.6	32.1	7572.9
	90.0	90.0	2503.9	55.3	90.0	4977.0
	100.0	100.0	2542.5	38.6	95.0	3667.0
	110.0	110.0	2617.7	75.2	105.0	7896.0
	120.0	120.0	2754.8	137.1	115.0	15766.5
	130.0	130.0	2807.4	52.6	125.0	6575.0
	140.0	140.0	2819.3	11.9	135.0	1606.5
	150.0	150.0	2830.3	11.0	145.0	1595.0
	160.0	160.0	2868.3	38.0	155.0	5890.0
	170.0	170.0	2893.7	25.4	165.0	4191.0
	180.0	180.0	2951.6	57.9	175.0	10132.5
	190.0	190.0	2974.4	22.8	185.0	4218.0
	200.0	200.0	2986.8	12.4	195.0	2418.0
	210.0	210.0	2999.7	12.9	205.0	2644.5
	220.0	220.0	3024.7	25.0	215.0	5375.0
	220.0	220.0	3071.7	47.0	220.0	10340.0
	240.0	240.0	3206.5	134.8	230.0	31004.0
	260.0	260.0	3279.7	73.2	250.0	18300.0
	280.0	280.0	3317.6	37.9	270.0	10233.0
	300.0	300.0	3364.5	46.9	290.0	13601.0
	320.0	320.0	3426.6	62.1	310.0	19251.0
	340.0	340.0	3558.2	131.6	330.0	43428.0
345	345.0	345.0	3605.0	46.8	342.5	16029.0
						239138.0
	L	3605.0				
	S_c	0.037				

Catchment down to Gauge opposite Chatsworth Rd (i.e. sub-catchment A - N)

Equal Area Slope = 4.5%

	Equal Area Method						
	Elevation (m)	**h (m)**	**x (m)**	**delta x (m)**	**ave h (m)**	**delta A (=h.delta x) m^2**	
opp. Chats.	0.0	0.0	0.0				
	5.0	5.0	422.0	422.0	211.0	89042.0	
	10.0	10.0	730.0	308.0	384.0	118272.0	
	30.0	30.0	1395.0	665.0	636.8	423438.8	
	50.0	50.0	1778.0	383.0	865.0	331295.0	
	70.0	70.0	2013.6	235.6	27.5	6479.0	
	80.0	80.0	2068.9	55.3	80.0	4424.0	
	90.0	90.0	2107.5	38.6	85.0	3281.0	
	100.0	100.0	2182.7	75.2	95.0	7144.0	
	110.0	110.0	2319.8	137.1	105.0	14395.5	
	120.0	120.0	2372.4	52.6	115.0	6049.0	
	130.0	130.0	2384.3	11.9	125.0	1487.5	
	140.0	140.0	2395.3	11.0	135.0	1485.0	
	150.0	150.0	2433.3	38.0	145.0	5510.0	
	160.0	160.0	2458.7	25.4	155.0	3937.0	
	170.0	170.0	2516.6	57.9	165.0	9553.5	
	180.0	180.0	2539.4	22.8	175.0	3990.0	
	190.0	190.0	2551.8	12.4	185.0	2294.0	
	200.0	200.0	2564.7	12.9	195.0	2515.5	
	210.0	210.0	2589.7	25.0	205.0	5125.0	
	210.0	210.0	2636.7	47.0	210.0	9870.0	
	230.0	230.0	2771.5	134.8	220.0	29656.0	
	250.0	250.0	2844.7	73.2	240.0	17568.0	
	270.0	270.0	2882.6	37.9	260.0	9854.0	
	290.0	290.0	2929.5	46.9	280.0	13132.0	
	310.0	310.0	2991.6	62.1	300.0	18630.0	
	330.0	330.0	3123.2	131.6	320.0	42112.0	
335	335.0	335.0	3170.0	46.8	332.5	15561.0	
						227574.0	
	L	3170.0					3170.0
	S_c	0.045					

Gradient of lower catchment



Pinehaven Stream - Lower Catchment (extended to top of Pinehaven Road)

Equal Area Method					
Elevation (m)	**h (m)**	**x (m)**	**delta x (m)**	**ave h (m)**	**delta A (=h.delta x) m^2**
0.0	0.0	0.0			
10.0	10.0	81.5	81.5	5.0	407.5
20.0	20.0	136.8	55.3	15.0	829.5
30.0	30.0	175.4	38.6	25.0	965.0
40.0	40.0	250.6	75.2	35.0	2632.0
50.0	50.0	387.7	137.1	45.0	6169.5
60.0	60.0	440.3	52.6	55.0	2893.0
70.0	70.0	452.2	11.9	65.0	773.5
80.0	80.0	463.2	11.0	75.0	825.0
90.0	90.0	501.2	38.0	85.0	3230.0
100.0	100.0	526.6	25.4	95.0	2413.0
110.0	110.0	584.5	57.9	105.0	6079.5
120.0	120.0	607.3	22.8	115.0	2622.0
130.0	130.0	619.7	12.4	125.0	1550.0
140.0	140.0	632.6	12.9	135.0	1741.5
150.0	150.0	657.6	25.0	145.0	3625.0
150.0	150.0	704.6	47.0	150.0	7050.0
170.0	170.0	839.4	134.8	160.0	21568.0
190.0	190.0	912.6	73.2	180.0	13176.0
210.0	210.0	950.5	37.9	200.0	7580.0
230.0	230.0	997.4	46.9	220.0	10318.0
250.0	250.0	1059.5	62.1	240.0	14904.0
270.0	270.0	1191.1	131.6	260.0	34216.0
275.0	275.0	1237.9	46.8	272.5	12753.0
					158321.0
L	1237.9				
S_c	0.207				