

Table C.2 Modified Cowan method for determining channel roughness

$$\text{Manning's } n = (n_b + n_1 + n_2 + n_3 + n_4) m$$

Channel condition		n and m values	Description
Channel material (n _b)	Earth Bed rock Sand-fine gravel Coarse gravel	0.020 0.025 0.024* 0.026	Clay-based channels. Channels cut into bed rock. Sandy creeks. Gravel-based creeks (otherwise use Eqn C.1).
Degree of irregularity (n ₁)	Smooth Minor Moderate Severe	0.0 0.001–0.005 0.006–0.010 0.011–0.020*	Smooth channel. Excavated channels in good condition. Channels with considerable bed roughness and some bank erosion. Natural' channels: pools and riffles, exposed tree roots, boulders, and/or irregular banks.
Variation in channel cross section (n ₂)	Uniform Gradual Severe	0.0 0.001–0.005* 0.010–0.015	Near-uniform channel section. Large and small cross sections alternate occasionally (eg. typical NCD n ₂ = 0.003). Large and small cross sections alternate frequently (eg. a significant pool-riffle system).
Effect of obstructions (n ₃) excluding vegetation	Negligible Minor Appreciable Severe	0.0–0.004 0.005–0.015* 0.020–0.030 0.040–0.050	A few scattered obstructions (boulders, trees, logs) that occupy less than 5% of the channel. Obstructions occupy 5–15% of the channel and the obstructions are generally isolated. Obstructions occupy 15–50% of the channel. Obstructions occupy more than 50% of the channel (eg. severe debris collection).
Amount of vegetation (n ₄) Consideration should be given to the obstruction caused by vegetation relative to channel width and depth	Small Medium Large Very Large	0.002–0.010 0.010–0.025* 0.025–0.050 0.050–0.100	Grasses and/or weeds with the flow at least three times the height of the vegetation. Grass and/or weeds with the flow one to two times the height of the vegetation; or reeds or tree seedlings growing with the flow two to three time the vegetation height; or minor bed vegetation with medium bank vegetation. Grasses and/or weeds with flow depth equal to vegetation height; or weedy beds with thick bank vegetation; or moderate shrub growth across the bed and banks. Grass and/or weeds more than twice the height of flow depth; or dense, strong reed growth; or significant shrub growth within the channel; or significant inflexible vegetation within channel.
Degree of channel meandering (m)	Minor Appreciable Severe	1.00 1.15* 1.30	Channel sinuosity is 1.0 to 1.2 Channel sinuosity is 1.2 to 1.5 Channel sinuosity is greater than 1.5 or; m = 0.57 + 0.43 (Sinuosity), but > 1.30

(*) Typical NCD channel roughness n = (0.024 + 0.003 + 0.012 + 0.005 + 0.015) 1.15 = 0.068

Table C.3 Manning's n for a watercourse floodplain

Minimum	Normal	Maximum	Description
A. Pasture, no brush			
0.025	0.030	0.030	Short grass – use design charts for grass
0.035	0.035	0.050	High grass – use design charts for grass
B. Cultivated areas			
0.020	0.030	0.030	No crop
0.040	0.040	0.050	Mature crop
C. Brush			
0.035	0.040	0.070	Scattered brush, heavy weeds
0.050	0.060	0.100	Light brush and trees
0.070	0.080	0.160	Medium to dense brush
D. Trees (also refer to Table C.5)			
0.080	0.100	0.110	Heavy stand of timber, a few fallen trees, little undergrowth, tree branches above flood level.
0.100	0.120	0.150	As above, but with tree branches below flood level.
0.120	0.160	0.200	Dense tree cover

Table C.4 Modified Cowan method for floodplain roughness

$$\text{Manning's } n = (n_b + n_1 + n_2 + n_3 + n_4) m$$

Floodplain condition		n and m values	Description
Floodplain material (n_b)	Earth	0.020*	Clay-based soil.
	Bed rock	0.025	Smooth, flat rock floodplains.
	Sand	0.024	Sandy soils.
	Gravel	0.026	Gravel-based soils (otherwise use Eqn C.1)
Degree of irregularity (n_1)	Smooth	0.0	Smooth, flat, floodplains.
	Minor	0.001–0.005	Slightly irregular shape. A few rises and dips.
	Moderate	0.006–0.010*	Regular rises and dips.
	Severe	0.011–0.020	Very irregular floodplains. Pasture furrows perpendicular to the flow.
Variation in floodplain cross section (n_2)		0	Not applicable.
Effect of obstructions (n_3) excluding vegetation	Negligible	0.0–0.004	A few scattered obstructions (debris, stumps, logs, boulders) occupying less than 5% of the floodplain flow area.
	Minor	0.005–0.015*	Obstructions occupy 5–15% of the flow area.
	Appreciable	0.020–0.030	Obstructions occupy 15–50% of the flow area.
Amount of vegetation (n_4) Consideration should be given to the obstruction caused by vegetation relative to the depth of flow.	Small	0.002–0.010	Grasses and/or weeds with the flow at least twice the height of the vegetation.
	Medium	0.010–0.025	Grass and/or weeds with the flow one to two times the height of the vegetation; or tree seedlings growing with the flow two to three times the vegetation height.
	Large	0.025–0.050	Grasses and/or weeds with flow depth equal to vegetation height, or irregular shrub growth across the floodplain.
	Very large	0.050–0.100*	Grass and/or weeds more than twice the height of flow depth; or significant shrub growth, woody weeds, or other inflexible vegetation growing across the floodplain.
	Extreme	0.100–0.200	Dense bushy shrub growth, or heavy stands of trees with understorey vegetation and a few fallen trees, or a heavy stand of trees with branches below flood level.
Floodplain meander (m)		1	Not applicable.

(*) Example calculation: $n = (0.020 + 0.008 + 0.0 + 0.012 + 0.090) 1.0 = 0.130$

Table C.5 Floodplain revegetation density guidelines for various Manning's n roughness values

Manning's n	Description
0.03	Short grass with the water depth >> grass height.
0.04	Short grass with water depth >> grass height on a slightly irregular earth surface. Trees at 10 metre spacing, area is easy to mow.
0.05	Long grass on an irregular (bumpy) surface with few trees. Irregular ground could make grass cutting difficult. Alternatively, trees at 8 metre spacing on an even, well-grassed surface, no shrubs, no low branches.
0.06	Long grass, trees at 6 metre spacing, few shrubs. The vegetation is easy to walk through. Area not mowed, but regular maintenance is required to remove weeds and debris.
0.07	Trees at 5 metre spacing, no low branches, few shrubs, walking may be difficult in some areas.
0.08	Trees at 4 metre spacing, some low branches, few shrubs, few restrictions to walking.
0.09	Trees at 3 metre spacing, weeds and long grasses may exist in some locations. Walking becomes difficult due to fallen branches and woody debris.
0.10	Trees at 2 metre spacing, low branches, regular shrubs, no vines. Canopy cover possibly shades weeds and it is difficult to walk through.
0.12	Trees at 1.5 metre spacing with some low branches, a few shrubs. Slow to walk through.
0.15	Trees and shrubs at 1 metre spacing, some vines, low branches, fallen trees, difficult and slow to walk through. Alternatively, a continuous coverage of woody weeds with sparse leaves and no vines.
0.20	Trees and shrubs at 1 metre spacing plus thick vine cover at flood level and fallen trees. Very difficult to walk through. Alternatively, a continuous coverage of healthy shrubs and woody weeds from ground level to above flood level.

Photo C1

Straight, excavated, tidal channel.

Bed: $n = 0.02$

Banks: $n = 0.06$

Bankfull: $n = 0.024$



Photo C2

Slight meandering, regular cross section, well maintained grass channel.

Bankfull: $n = 0.028$



Photo C3

Mown grass channel, regular cross section, slight meander.

Bankfull: $n = 0.028$ (clean)

$n = 0.030$ (some shrubs)



APPENDIX C

Photo C4

Regular cross section, slight meandering, mown overbanks.

Bankfull: $n = 0.04$

Overbank grass: $n = 0.03$ (shallow flow depth assumed)



Photo C5

Mown grass banks, unmaintained wetland plants on bed, regular cross section, very slight meander.

Bed: Manning's n is variable depending on flow depth.

Bankfull components:

bed $n = 0.035$

bank $n = 0.030$

resulting in a bankfull $n = 0.035$



Photo C6

Canopy trees in early stages of growth, straight, regular channel.

Bankfull: $n = 0.04$

Overbank: $n = 0.15$



Photo C7

Rock size approx. 300 mm, this results in a Manning's $n = 0.034$ assuming deep water flow.

Bed: $n = 0.04$



Photo C8

Deep channel, irregular cross section, meandering channel.

Bankfull: $n = 0.045$



Photo C9

Near straight channel, full canopy cover with few weeds, pool-riffle system, shallow pools with boulders.

Bed: $n = 0.045$

Bank: $n = 0.09$



APPENDIX C

Photo C10

Pool-riffle bed system, meandering channel, thick shrub growth on banks, deep pools.

Bed: $n = 0.04$

Left bank: $n = 0.06$

Right bank: $n = 0.20$

Bankfull: $n = 0.06$



Photo C11

Channel vegetation in early growth stage, gradual bends, regular cross section, deep water, pool-riffle system.

Bankfull (existing): $n = 0.04$

Long-term (full vegetation) bed: $n = 0.05$

banks: $n = 0.15$



Photo C12

Irregular, meandering, constructed channel with boulders.

Bankfull: $n = 0.05$

Bank vegetation: $n = 0.15$



Photo C13

Irregular channel with meanders and woody debris (logs).

Bankfull: $n = 0.05$

Overbank: $n = 0.10$



Photo C14

Bed is a combination of thick, flexible vegetation and open rock pools and riffles. banks have sparse trees and woody shrubs. Irregular channel shape with slight meandering.

Bed: $n = 0.06$

Bank: $n = 0.12$

Bankfull: $n = 0.07$



Photo C15

Weedy channel passing through a long grass floodplain. Irregular channel cross section with some meanders.

Bankfull: $n = 0.08$ (assuming low velocity and shallow depth that will not flatten reeds)

Overbank: $n = 0.03$ to 0.10

(depends on flow depth and velocity)



APPENDIX C

Photo C16

Irregular mountain creek with flexible understorey plants, few vines or woody shrubs.

Bankfull: $n = 0.10$ to 0.12



Photo C17

Overbank vegetation at approximately 8 metre spacing with no shrubs.

Overbank: $n = 0.05$



Photo C18

Overbank vegetation consists of tall truck trees, no low branches or shrubs. Tree spacing of approx. 8 metres.

Overbank: $n = 0.05$



Photo C19

Irregular channel with meanders.

Channel: $n = 0.04$ to 0.05 depending on channel irregularity and debris content.

Overbank area consists of single truck trees with no low branches or shrubs.

LHS (5 m spacing): $n = 0.055$

RHS (6-7 m spacing): $n = 0.05$



Photo C20

Trees at approx. 5 metre spacing, no low branches.

Overbank: $n = 0.055$



Photo C21

Irregular natural channel and wetland system with many weeds.

Overbank: $n = 0.06$



Natural Channel Design Guidelines

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