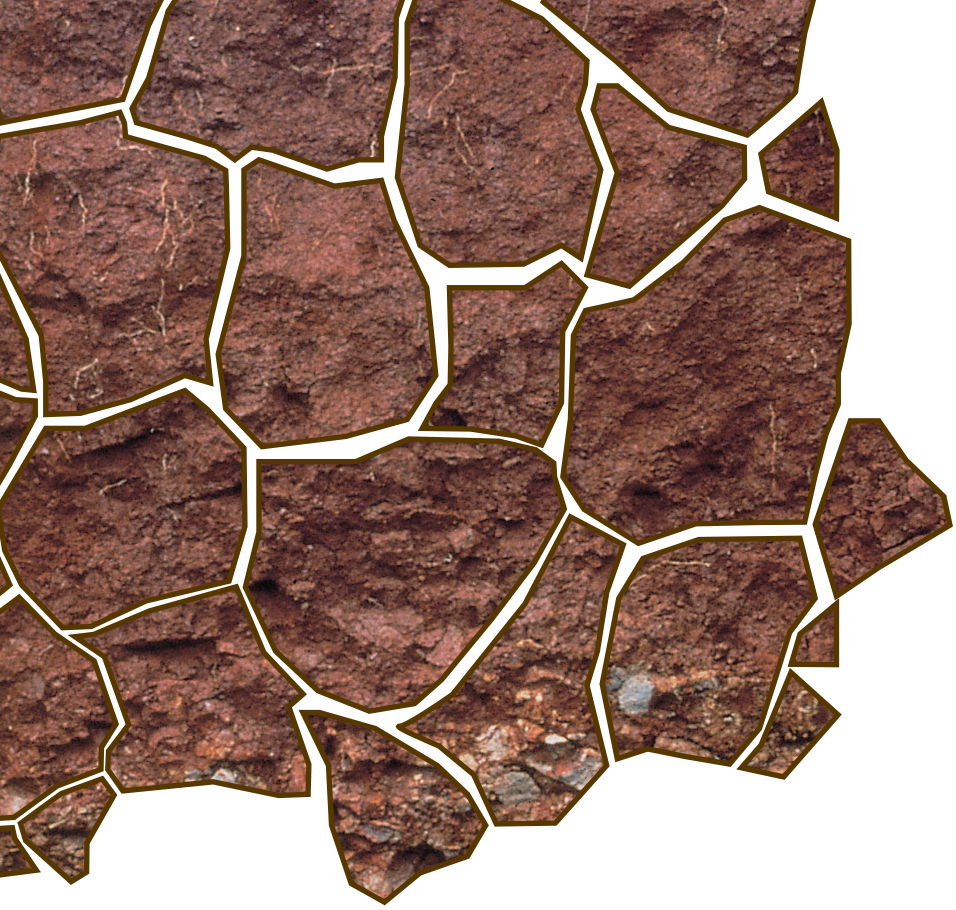


Appendices

Contents

Appendix 1: Air photo interpretation

Equation A1.1

D/d = f/H

Where

d = distance between two points on a photograph

D = the distance between the same two points on the ground

f = the focal length of the camera lens

H = the height above sea level of the aeroplane minus the height above sea level of the land surface.

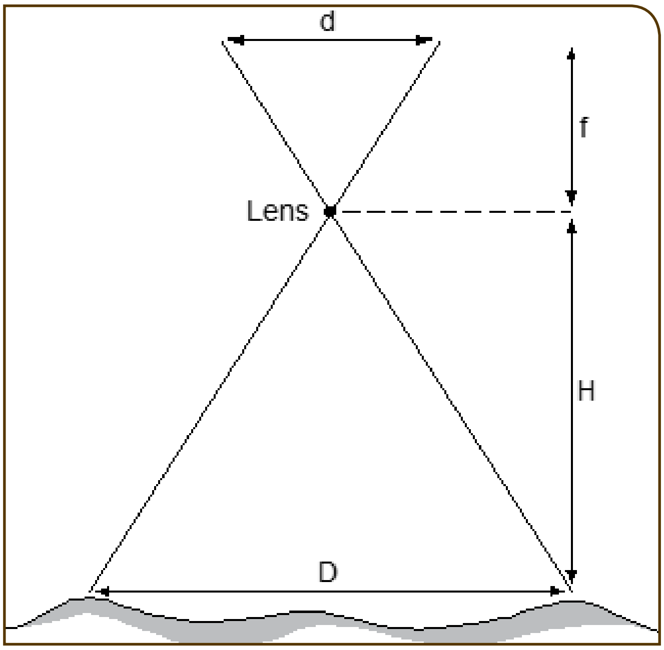
A stereoscope enables the images of overlapping parts of a stereoscopic pair of photos to be optically fused into a single three-dimensional image. When interpreting aerial photographs, it is useful to use clear overlay sheets to record information from the photographs using different coloured marking pens.

An approximate scale is usually noted in the frame of aerial photographs. A perfectly vertical photograph of flat, level land will have a reasonably constant scale over the whole photo. However, there will be some variation in the scale depending on the height of the land at any point and the distance of the point from the centre of the photograph.

For aerial photography, scale can be determined using Equation A1.1.

The measurements used to calculate the respective ratios in Equation A1.1 must be in the same units. Figure A1.1 shows a sketch of the distances referred to in Equation A1.1. The distance D can be obtained by field measurement or from a cadastral map or survey plan.

Figure A1.1: Relationship between lengths appropriate to the calculation of an aerial photograph



Equation A1.2

If 'f' and 'H' are known then the scale can be expressed as 1: H/f

Example:

f (of camera lens) = 152.7 mm (0.1527 m)
H = 5250 (flying height) less 510 m (GL) = 4740m.

Then photoscale is
1: H/f = 4740/0.1527 = 31 041

(i.e. 1 mm on the photo is equal to 31 m on the ground)

Equation A1.3

If neither 'f' or 'H' are known then the scale can be expressed as 1: D/d

Example:

d (photograph) = 505.1 mm = 0.5051m
D =1567.5mm (on 1:10 000 map) = 15 675m

Then photoscale is 1: D/d = 15675/0.5051 = 31 033

(i.e. 1 mm on the photo is equal to 31 m on the ground)

The following information can be interpreted from aerial photography (or satellite imagery depending on the scale) and later verified by field inspection:

1. Land-related factors
   - land use
   - soils
   - topography and land slopes
   - infrastructure
     - roads
     - railways
     - air strips
     - buildings
     - stockyards
   - areas of degradation

— erosion patterns
— saline areas
— scalded areas
— landslips.

2. Water-related factors
   — catchment boundaries (ridges)
   — rilling and gullying
   — drainage lines
   — wetlands
   — flood-prone areas
   — dams and possible dam sites.
3. Vegetation-related factors
   — vegetation, types, condition and extent
   — weed infestation.

These visible features can indicate important aspects of land use. Examples include:

- A radial pattern of converging cattle tracks usually indicates the presence of a stock watering point.
- Tracks converging to a point on a fence line usually indicate the presence of a gate.
- Fence locations are often made obvious by the variations in land use between paddocks. Paddock appearances in cultivated areas will vary according to crop type, stubble management, ploughing patterns and contour bank location. In grazing lands, different grazing pressures will often be apparent. Fence lines can also be observed if they have strips of vegetation along them.
- Orchards may have a distinctive 'checkerboard' appearance.
- Railway lines can be distinguished from roads by the greater length of straights, long uniform curves and the presence of stations or sidings. In hilly country, there may be tunnels.
- Outcrops of rocks may be suspected if irregular margins are observed around cultivated land or if 'islands' of uncultivated land occur within cultivated areas.
- Different vegetation types may be indicated by factors such as height, density, tone and location in the landscape. Patches of vegetation with similar characteristics can be defined on the photos and sample areas identified by ground traversing, for example:
  — Most eucalypts grow in fairly open communities, are of light tones and have fairly open canopies of foliage. This may be indicated by their shadows.
  — Brigalow, belah and wilga trees grow together in dense and extensive communities and melon holes may be evident.
  — Some acacias such as wattles, bendee and lancewood are usually found on steep and stony scarps, or on the tops of mesas. They grow in dense communities and have a very dark tone.
  — Rainforests usually occur on the eastern slopes of coastal ranges and on south-facing aspects and are unmistakable because of the large size and density of canopies.
  — False sandalwood and bull-oak usually grow on very dispersible soils with a high content of sodium salts which makes such soils vulnerable to gully erosion.
- Erosion
  — Rill erosion is often visible in an aerial photo.
  — Gully erosion is relatively easy to identify, especially in cleared country. Tree canopy may conceal gullies in forested lands.
  — Areas that have lost significant quantities of topsoil can usually be identified by the presence of soils with a lighter colour.

Appendix 2: Land capability and land suitability classifications

A number of systems of classifying land have been used in Queensland. Since soil conservation planners may come across any of these systems when checking existing soil conservation plans and other resource information, they have been included here for reference purposes.

The following systems for classifying land are described:

- the eight-class land capability classification for agricultural purposes
- the seven-class land zoning system used in the Area of Erosion Hazard Program in the 1970s and 1980s
- the five-class land suitability system for agricultural land evaluation, for assessing the suitability of a land for growing a specified crop
- the four-class land suitability system for the assessment of good quality agricultural land.

A recommended reference on this topic is *Guidelines for Agricultural Land Evaluation in Queensland* (Department of Primary Industries (2015 in press). This report includes a good coverage of the philosophies relating to land capability and land suitability. In general, the term 'land capability' refers to the capability of land to support a broad range of land uses. The term 'land suitability' is used to describe the suitability of land for a specified purpose such as a specific crop.

It is difficult to make generalisations about the value of different Queensland soils. As an example, the black Vertosols (cracking clays) on the floodplains of the Darling Downs are very suitable for cereal cropping because of their high fertility and moisture holding capacity. However these soils are generally unsuitable for growing trees for forestry and in their natural state were grasslands with no trees. Many Sodosols (shallow and sodic, duplex soils) are unsuitable for cropping because of limitations such as low fertility and moisture holding capacity as well as sodicity. However, these soils are capable of supporting native woodlands and forests with very large trees such as eucalypts.

A2.1 The eight-class land capability classification for agricultural purposes

This system identifies eight classes of land for different agricultural uses as listed in A2.1. The level of management needed, in particular that for soil conservation, increases from Class 1 to 4. Note that classes 3 and 4 state the need for a period under pasture to provide extra protection from erosion but a pasture rotation would be desirable for all classes in order to increase soil organic matter levels and the overall health of the soil. The three classes that are suitable only for pastoral or forestry uses (Class 5 to 7) also have different limitations and require different levels of conservation management. Class 8 land is not suitable for any form of agriculture.

The eight-class system is arranged broadly into three divisions:

Division A: Agricultural land —arable classes I–IV

Division B: Agricultural land —pastoral classes V–VII

Division C: Non-agricultural land—class VIII.

Class IV land is within Division A, but its limitations make it capable for mainly pastoral uses with only infrequent cropping uses.

Table A2.1 describes the eight-class land capability classification, and Table A2.2 details the level of limitation within each class where applicable.

Table A2.1: Land classes for the eight class land capability classification (Rosser et al. 1974)

Land class	Limitations
Land suitable for cropping and grazing	
1	Land suited to a wide range of agricultural crops and is highly productive. It presents no limitations to the use of machinery or choice of implements. Wind and water erosion hazard is low
2	Land with some limitation to the choice of crops and/or slight restrictions to productivity. Land with some impediment to the use of cultivation machinery which limits the choice of implement or restricts the conditions for successful operation. Land which under cultivation requires simple conservation practices to reduce soil loss to an acceptable level. (Simple practices include contour working, strip cropping and stubble mulching)
3	Land with moderate limitations to the choice of crops and/or moderate restrictions to productivity. Land with moderate impediments to the use of cultivation machinery which limits the choice of implement or restricts the conditions for successful operation. Land, which under cultivation, requires intensive conservation practices to reduce soil loss to an acceptable level. Such practices include the retention of high levels of stubble cover, the use of crops that provide high levels of surface cover, pasture rotations and the use of contour banks and waterways for runoff management
4	Land on which the choice of crops is severely restricted and/or conditions are such that productivity under cropping is severely limited. Land with severe impediments to the use of cultivation machinery which limits the choice of implement or severely restricts the conditions for successful operation. Land which cannot be used safely for permanent cultivation; if cropped, a pasture phase must be the major component in the cropping programme to limit soil loss to an acceptable level
Land suitable for grazing	
5	Land which has limitations that, unless removed, make cultivation impractical and/or uneconomic. Such limitations include rocks or stones, gilgai (melon hole) microrelief, wetness or waterlogging or subject to regular flooding
6	Land which is not suitable for cultivation but is well suited to pastoral use and on which pasture improvement involving the use of machinery is practicable
7	Land which is not suitable for cultivation but on which pastoral use is possible only with careful management; pasture improvement involving the use of machinery is not practicable
Land not suitable for any agricultural purpose	
8	Land with limitations that would preclude its use for any form of agriculture

Table A2.2: Factors for determining classes in the land capability classification (Clarke & Wylie, 1997)

Limiting or controlling factors	Degree of limitation or special measures	Level	Sub-class
Factors limiting choice of crops or crop productivity			
Climatic limitation other than rainfall (c)	Affects crop choice or restricts production potential	• Slight • Moderate • Severe • Cropping not possible	c2 c3 c4 c6
Moisture availability for crop growth (m)	• Occasional • Regular limitation • Frequent • Moisture availability too unreliable for cropping	• 7–8 crops possible/10 years • 5–7 crops possible/10 years • <5 crops possible/10 years	m2 m3 m4 m6
Effective soil depth (d)	Exerts influence on the 'm' factor	• >60 cm • 45–60 cm • 25–45 cm • <25 cm	d2 d3 d4 d6
Soil physical factors affecting crop growth (p)	Crusting, subsurface compaction, etc.	• Slight restriction • Moderate restriction • Severe restriction	p2 p3 p4
Soil nutrient fertility (n)	Nutrient requirement	• Replacement of removed N and/or P only • N/P/micro-nutrients need supplementing • Deficiencies preclude regular cropping	n2 n3 n4
Soil salinity or sodicity (s)	Affects crops through: • loss of soil water availability • loss of structure • toxicity	• Slight effect on crops • Moderate effect on crops • Severe effect on crops • Tolerant pasture/herbage species only • Salt pan	s2 s3 s4 s6/7 s8
Factors limiting the use of agricultural machinery or accessibility			
Topography (t)	Severe relief or gullies preclude cultivation	• Occasional cropping possible. • Slopes 15–20% or severe relief prevent cultivation • Slopes 20–45% or extreme gullying, accessible for grazing • Slopes or topography too severe for grazing animals	t4 t6 t7 t8
Soil workability (k)	Soil properties restrict machinery and reduce production potential, e.g. stiff clay, columnar structure, compaction, narrow moisture range for working	• Slight restriction • Moderate restriction • Severe restriction	k2 k3 k4
Rockiness or stoniness (r)	Affects use of tillage machinery	• Restriction progressively increasing • Use of all machinery for cropping impractical	r2–4 r5
Surface micro-relief, gilgai and gullying (g)	Affects use of tillage machinery	• Restriction progressively increasing • Use of all machinery for cropping impractical	w2–4 w5
Wetness (w)	Delays implement use and reduces production potential	• Delay and reduction progressively increasing • Permanently wet; cultivation impractical	w2–4 w5

Limiting or controlling factors	Degree of limitation or special measures	Level	Sub-class
Factors controlling land deterioration			
Susceptibility to water erosion (e)	Degrades soil and water on-site and downstream	• Cropping possible but with increasing intensity of erosion control measures • Cropping precluded and continuous pasture required • Grazing precluded	e2–4 e6–7 e8
Susceptibility to flooding (f)	• Occasional overflow flooding • Regular overflow flooding • Severe overflow flooding; permanent cultivation not possible • Flood frequency and/or severity precludes any cropping	• Occasional overflow flooding • Regular overflow flooding • Permanent cultivation not possible • Cropping precluded	f2 f3 f4 f5
Susceptibility to wind erosion (a)	• Erosion risk requires increasing level of control measures for cropping • Erosion risk precludes cropping; restricted grazing only	• Increasing level of control measures required for cropping • Cropping precluded	a2–4 a6–8

A2.2 Land zoning under past legislative programs

Soil conservation plans prepared under the Areas of Soil Erosion Hazard Program in the 1970s and 1980s identified land zones based on the degree of erosion hazard and limitation. These zones formed the basis for establishing land use and management practices that would reduce soil erosion to acceptable levels.

The Erosion Hazard Zoning system was generally applicable to arable land and it allowed for only two primary limitations relative to specific soil types: that is, land slope and soil depth. Susceptibility to flooding in the alluvial areas of the Darling Downs was an additional limitation taken into account.

Table A2.3 provides a synopsis of the descriptions that applied to each zone. Some of the terms used in the 1970s have been modified to match the terminology used in these Guidelines; for example, 'standard' spaced contour banks are now referred to as 'single' spaced.

Table A2.3: Land zoning system used for the Areas of Soil Erosion Hazard program in the 1970s and 1980s

Zone	Land slope and depth	Land management requirements
0	0 to 1%	Land with no significant hazard or limitation under normally accepted farming methods. Generally no soil conservation measures are required. However some situations may require: protection from local catchment runoff by runoff control structures; conservation tillage practices to minimise soil surface sealing and soil structure deterioration that is likely to result in unacceptable soil loss.
1	1 to 3%	Land of low erosion hazard and limitation. Cultivated land requires: contour banks at single spacing if erosion-inducing cropping systems are used; contour banks at double spacing if cropping systems achieving high levels of cover are used; pasture land should be managed to provide adequate levels of cover to reduce erosion to acceptable levels.
1f	0 to 1%	Low, sloping land with varying degrees of erosive flooding hazard. No specific requirements are detailed but they would include strip cropping with rotations and stubble management practices appropriate to the risk of erosive flooding.
2	3 to 5%, depth >45 cm	Land of moderate erosion hazard and limitation. Limitations are as for zone 1 (as land slopes would normally be steeper, contour banks would be more closely spaced); and require adoption of conservation tillage practices.

Zone	Land slope and depth	Land management requirements
3	3 to 5%, depth <45 cm 5 to 8%, depth >45 cm	Land of high erosion hazard and limitation. Limitations are as for zones 1 and 2 (steep slopes would require more closely spaced contour banks) and will require adoption of conservation tillage practices, and use of a pasture phase in a crop rotation system.
4a	8 to 12%, depth >45 cm	Land of severe erosion hazard and limitation. Although this land is arable, it is considered to be unsuitable for long-term cropping. While significant areas of such land were cultivated in the 1970s, most of this land has been returned to pastures because it is generally uneconomic to use these areas for cropping.
4b	Not applicable	Land that has limitations other than, or in addition to, erosion hazard that make it unsuitable for agriculture e.g. stoniness, salinity, waterlogging.

A2.3 Land suitability classes

The publication *Guidelines for Agricultural Land Evaluation in Queensland* (Department of Primary Industries (2015 in press) describes five land suitability classes that have been defined for use in Queensland, with land suitability for agricultural uses decreasing progressively from Class 1 to Class 5 (Table A2.4). Land is classified on the basis of its suitability for the growing specific crops.

Detailed descriptions of these limiting factors, along with a number of subsets, are provided in *Guidelines for Agricultural Land Evaluation in Queensland* (Department of Primary Industries (2015 in press).

The following attributes are some of those considered in determining the appropriate land suitability.

- climate
- soil moisture availability
- effective soil depth
- soil physical factors
- soil nutrient fertility
- soil salinity or sodicity
- topography
- soil workability
- rockiness
- surface microrelief (gilgai or gullying)
- wetness
- water erosion limitation
- susceptibility to flooding
- susceptibility to wind erosion.

Table A2.4: Five land suitability classes for a specified land use, e.g. growth of a specific crop type

Suitability class	Description
Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Suitable land with minor limitations that either constrain production, or require more than the simple management practices of class 1 land to maintain economic production.
Class 3	Suitable land with moderate limitations that either further constrain production, or require more than those management practices of class 2 land to maintain economic production.
Class 4	Marginal land that due to severe limitations is currently unsuitable. The long-term significance of these limitations on the proposed land use is unknown, or is not quantified. The potential use of this land is dependent upon undertaking additional studies to determine whether the effects of the limitation(s) can be reduced to achieve sustained economic production.
Class 5	Unsuitable land with extreme limitations that preclude its use.

The five land suitability classes are summarised below and described in detail in Table A2.4.

Class 1	Suitable land with negligible limitations
Class 2	Suitable land with minor limitations
Class 3	Suitable land with moderate limitations
Class 4	Unsuitable land with severe limitations
Class 5	Unsuitable land with extreme limitations

Table A2.4: Land suitability classes (Extracted from *Guidelines for Agricultural Land Evaluation in Queensland*, 2015 in press)

Class	Suitability	Limitations	Description
1	Suitable	Negligible	Highly productive land requiring only simple management practices to maintain economic production.
2	Suitable	Minor	Land with limitations that either constrain production, or require more than the simple management practices of class 1 land to maintain economic production.
3	Suitable	Moderate	Land with limitations that either further constrain production, or require more than those management practices of class 2 land to maintain economic production.
4	Unsuitable	Severe	Currently unsuitable land. The limitations are so severe that the sustainable use of the land in the proposed manner is precluded. In some circumstances, the limitations may be surmountable in time with changes to knowledge, economics or technology.
5	Unsuitable	Extreme	Land with extreme limitations that preclude any possibility of successful sustained use of the land in the proposed manner.

A2.4 Agricultural land classes

Based on the assessment of the suitability of land for agriculture, four agricultural land classes have been identified for use in statutory land planning. These agricultural land classes were initially described in the *Guidelines for Agricultural Land Evaluation in Queensland* (Department of Primary Industries 1990) and have been further refined (as per table A2.5) and described in the report of the Queensland Agricultural land Audit Method (State of Queensland 2013).

Table A2.5: Land classes to assess the suitability of land for agriculture

Class	Description
A	**Crop land**—Land that is suitable for a wide range of current and potential crops with nil-to-moderate limitations to production.
B	**Limited crop land**—Land that is suitable for a narrow range of current and potential crops. Land that is marginal for current and potential crops due to severe limitations but is highly suitable for pastures. Land may be suitable for cropping with engineering and/or agronomic improvements.
C	**Pasture land**—Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment.
D	**Non-agricultural land**—Land not suitable for agricultural uses due to extreme limitations. This may be: undisturbed land with significant conservation and/or catchment values; land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop, poor drainage, salinity or acidic drainage; or land that is an urbanised area.

In some regions of Queensland, the classes have been subdivided to suit local needs (e.g. Class A is subdivided into A1 and A2 depending on whether suitable techniques are currently available to address limitations; and Class C is subdivided into C1, C2, and C3 depending on the degree to which it is suitable for sown pastures or only for native pastures).

Table A2.5: Definition of agricultural land classes (extracted from *Guidelines for Agricultural Land Evaluation in Queensland*, 2015 in press)

Class	Description
A	**Crop land**—Land that is suitable for a wide range[1] of current and potential crops with nil-to-moderate limitations to production.
A1	Suitable for a wide range of current and potential broadacre and horticultural[2] crops.
A2	Suitable for a wide range of current and potential horticultural crops only.
B	**Limited crop land**—Land that is suitable for a narrow range[3] of current and potential crops. Land that is marginal for current and potential crops due to severe limitations but is highly suitable for pastures. Land may be suitable for cropping with engineering and/or agronomic improvements.
C	**Pasture land**—Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment.
C1	Suitable for grazing sown pastures requiring ground disturbance for establishment; or native pastures on higher fertility soils.
C2	Suitable for grazing native pastures, with or without the introduction of pasture species, and with lower-fertility soils than C1.
C3	Suitable for light grazing of native pastures in accessible areas, and includes steep land more suited to forestry or catchment protection.
D	**Non-agricultural land**[4]—Land not suitable for agricultural uses due to extreme limitations. This may be: undisturbed land with significant conservation and/or catchment values; land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop, poor drainage, salinity or acidic drainage; or land that is an urbanised area.
A/C, A/D B/C, C/D	Land that is a complex of class A, B, C or D land where it is not possible to delineate the land class at the map scale. The dominant class is the first code in the sequence and is assumed to be >50% of the area, but <70%[5].

1. A wide range of crops is four or more crop types of local commercial significance. In areas with existing major infrastructure that supports a cropping industry (e.g. cotton gin, cane mill); the land may be suitable for fewer than four crops.
2. Horticulture includes intensively grown small crops (e.g. vegetables) as well as tree crops (e.g. grown for nuts, seeds or fruit). Silviculture (plantation forestry) is not included.
3. A narrow range of crops is three or fewer crop types (broadacre or horticulture) of local commercial significance. Silviculture (plantation forestry) may be included. Crops with similar agronomic requirements (e.g. maize and corn, peaches and nectarines) are not generally regarded as different crop types. Different management regimes (including irrigation strategies) for the same crop do not increase the number of crops.
4. Non-agricultural land includes land that cannot be placed in any of the other land classes and also includes land such as urban areas and stream channels.
5. In cases where two or more land classes are equally dominant and none are greater than 50%, judgement will be used to identify the most appropriate agricultural land class/es for the unit.

Appendix 3 Design aids for soil conservation works and measures

Figure A3.1: Pro forma for soil conservation specifications

No…. of ………..sheets

Landholder:			
Date:	Farm Code:	Plan Number:	Local authority:
Contact details:			
Property description:			
Designed by:			

Waterway specifications

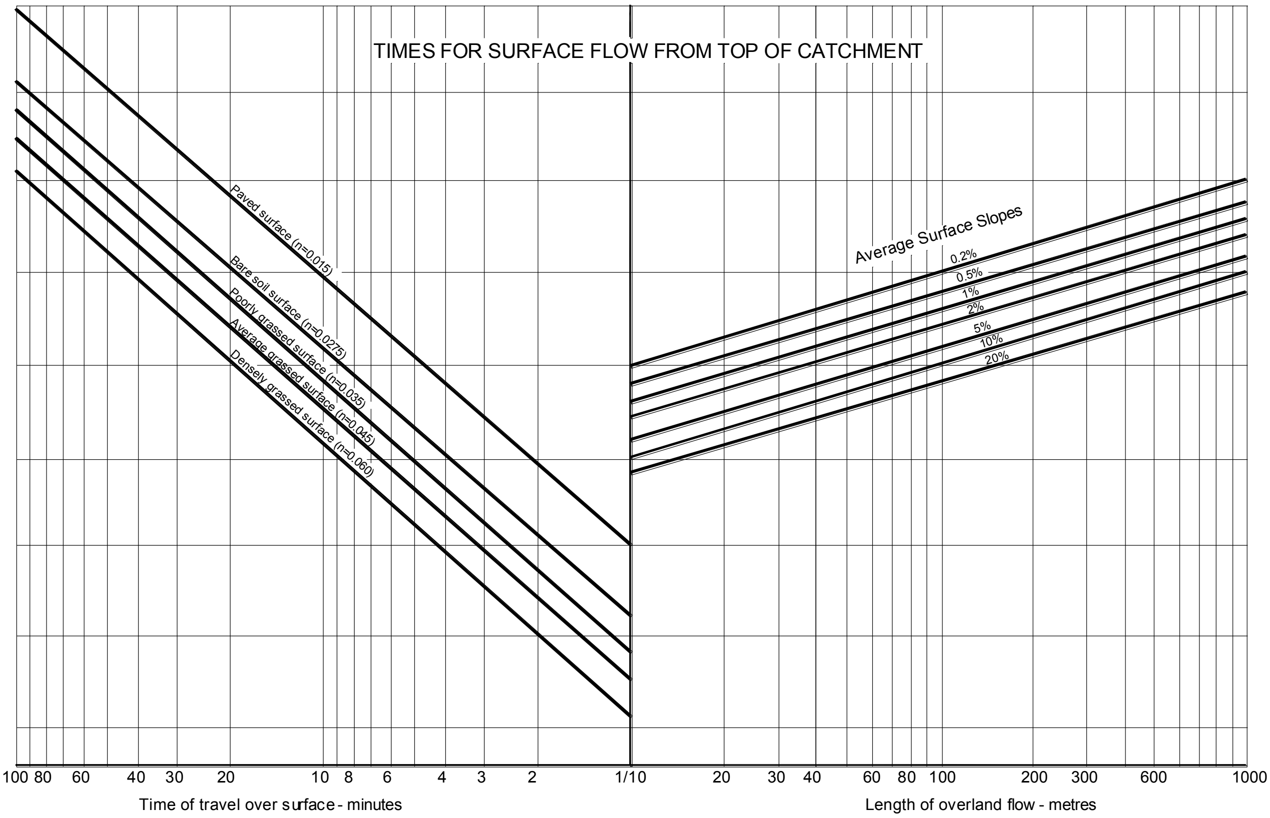
Design point on plan	Type of cross-section (Note A)	Bank height m		Design flow depth m	Width m		Bank batters (V:H)		Comments
		Unsettled	Settled		Bottom	Top	Inside	Outside	

Contour and diversion bank specifications

Location on plan	Type of cross-section (Note B)	Bank height (settled) m	Cross-sectional area (settled) m^2	Bank batters (V:H)		Comments
				Upslope	Downslope	

Notes A: See Chapter 9, Waterways for types of cross sections
B: See Chapter 7, Contour banks and Chapter 8, Diversion banks

Figure A3.2: Travel time for overland flow



Formula $t = \frac{107\, n \sqrt[3]{L}}{\sqrt[5]{s}}$

where
- t = time of travel over surface in minutes
- n = Norton's values for the surface
- L = Lenght of flow in metres
- s = slope of surface in %

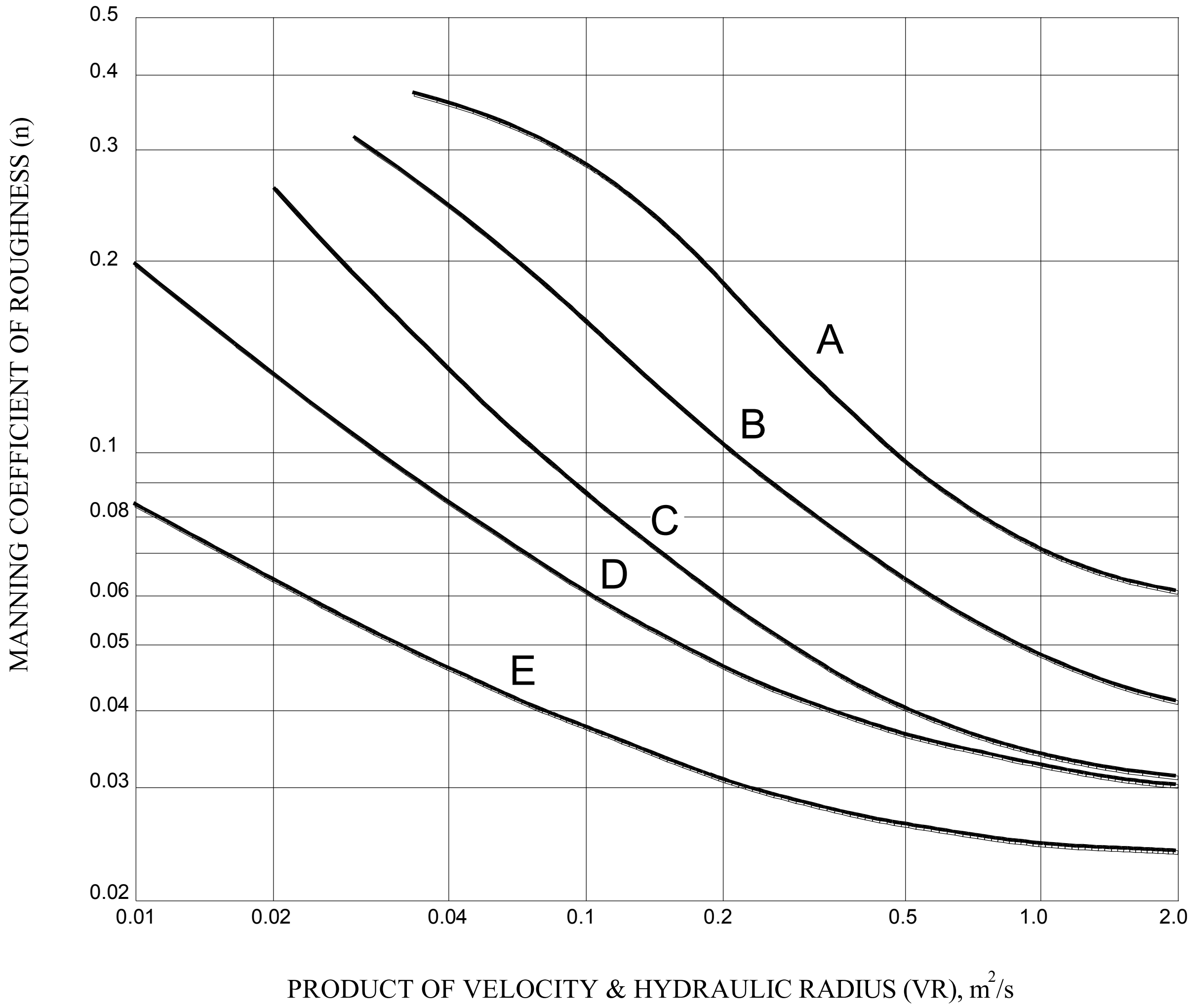
Example

Length of overland flow 200m
Average slope of surface 5%
Densely grassed surface (n= 0.060)
Time of travel = 27.2 minutes

Table A3.1: Values for Manning's n coefficients of roughness (Pilgrim 1987, Queensland Main Roads Department 1979, Ree 1954)

Channels/stream condition	Manning's n
Earth channels subject to intermittent flow and vegetation lining	The n/VR relationship applies (refer to text in Chapter 6)
Contour bank channels	
Smooth and bare	0.02–0.03
Roughly cultivated	0.04
Sparse grass cover	0.05
Wheat crop or standing wheat stubble	0.07–0.15
Sorghum (25 cm rows)	0.04–0.12
Lined channels excavated in rock	
Smooth and uniform rock	0.025–0.040
Jagged and irregular rock	0.035–0.050
Concrete—smooth forms or trowelled	0.012
Small natural streams	
Straight, uniform and clean	0.025–0.033
Clean, winding, with some pools and shoals	0.033–0.045
Sluggish, weedy reaches with deep pools	0.050–0.080
Very weedy reaches with deep pools	0.075–0.150

Figure A3.3: n/VR relationship for five degrees of vegetal retardance



Curve A $n = 0.440 - 1.674\ VR$ $VR < 0.1542$
$n = 0.046 + 0.0223/VR$ $VR > 0.1542$
Ref. Green, J.E.P. & Garton, J.E. (1983)

Curve B $n = 0.032 + 0.01545/(VR)^{7/8}$

Curve C $n = 0.030 + 0.00501/VR$

Curve D $n = 0.027 + 0.00534/(VR)^{3/4}$

Curve E $n = 0.022 + 0.003014/(VR)^{2/3}$

Ref. Findlay, G.H. & Ellul, G.A. (1976)

Figure A3.4: Graphical solution to the Manning formula for retardance A

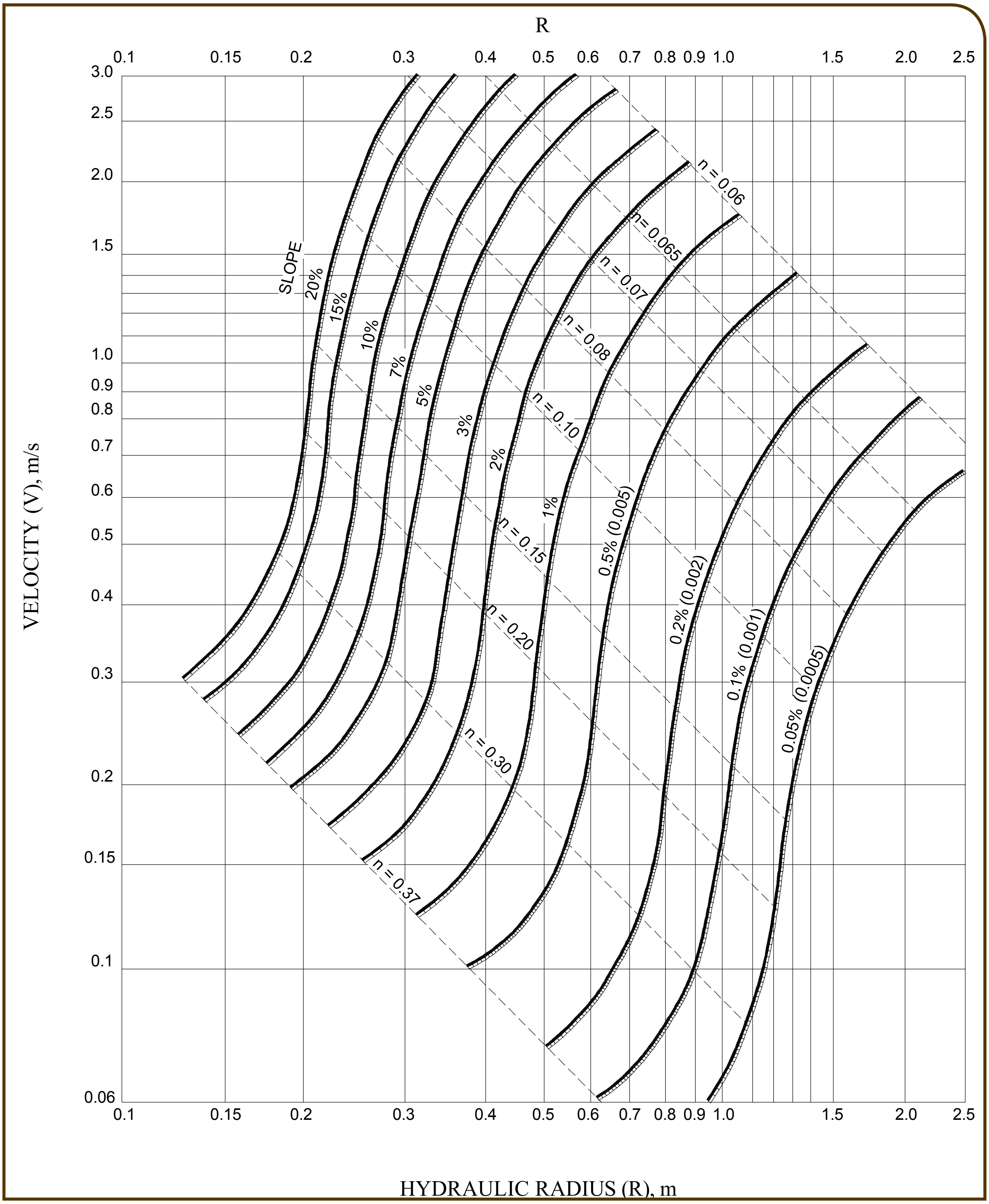


Figure A3.5: Graphical solution to the Manning formula for retardance B

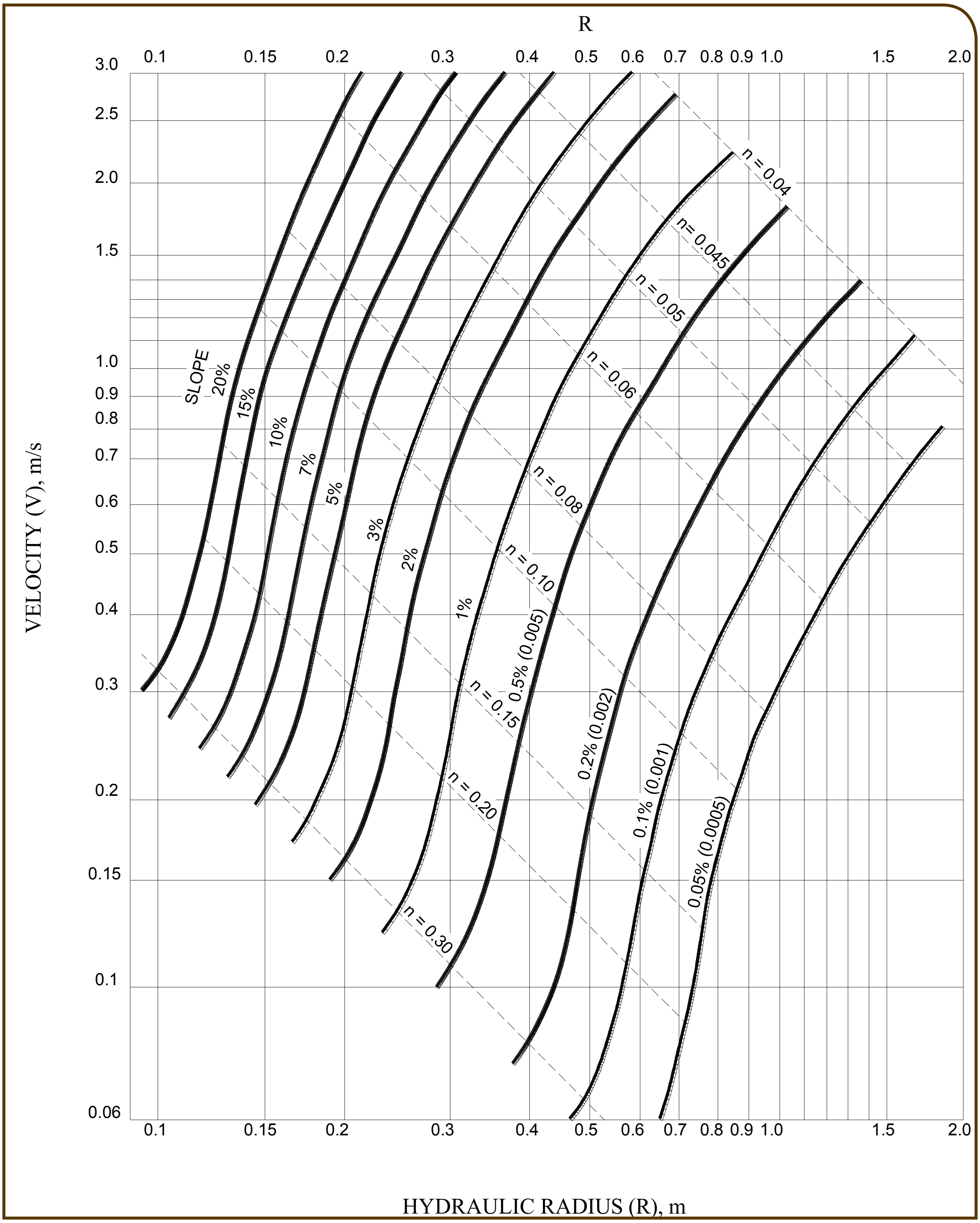


Figure A3.6: Graphical solution to the Manning formula for retardance C

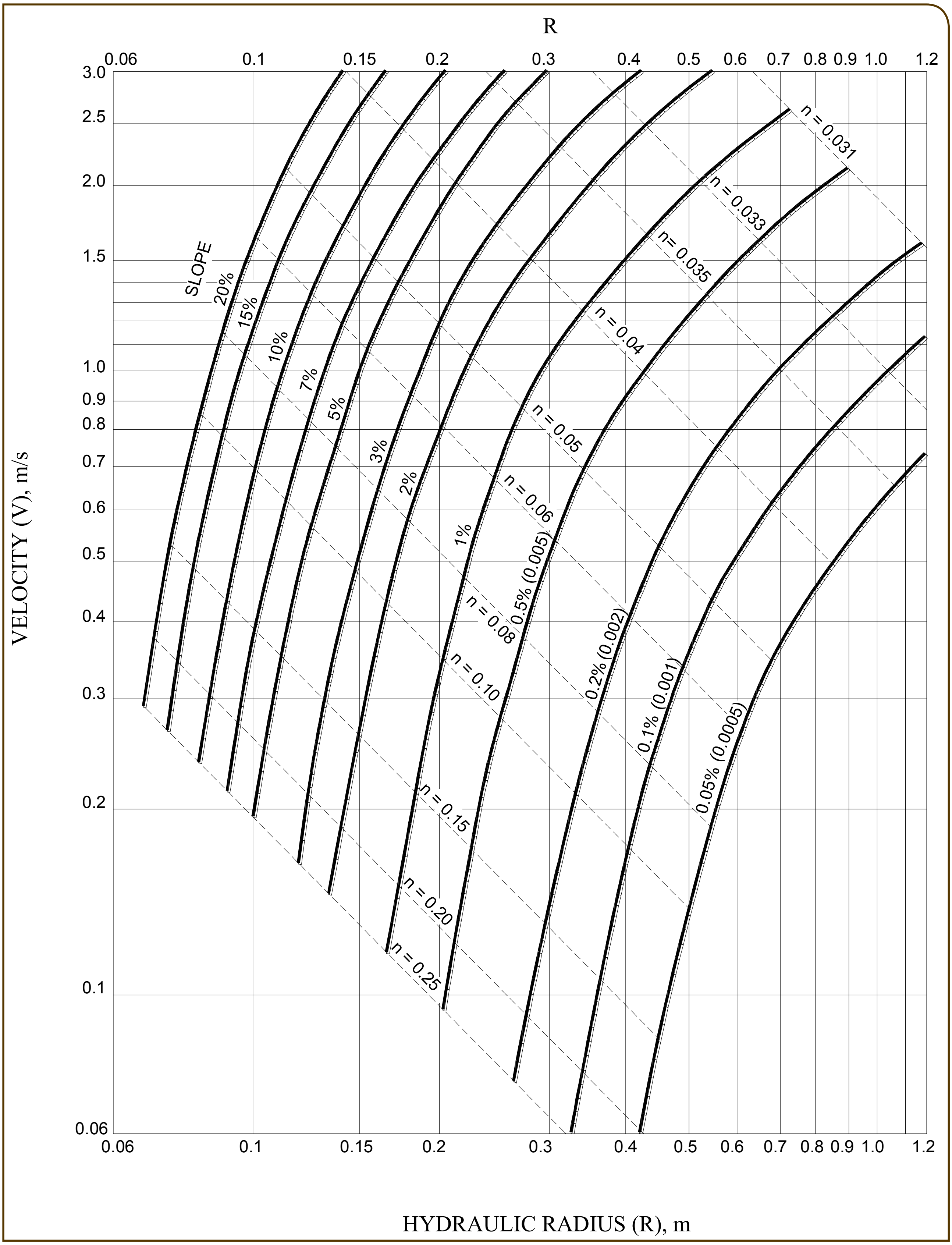


Figure A3.7: Graphical solution to the Manning formula for retardance D

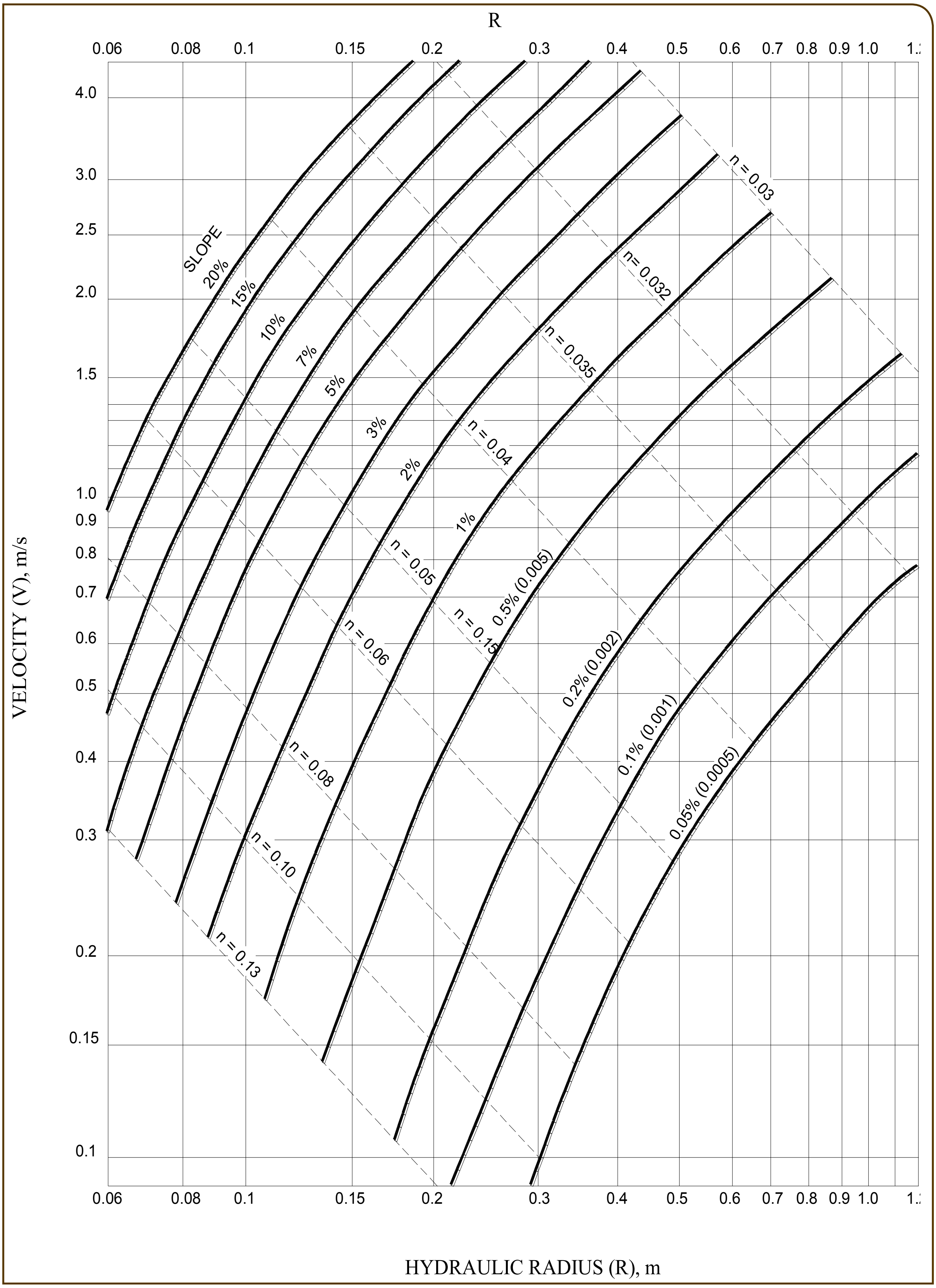


Figure A3.8: Graphical solution to the Manning formula for retardance E

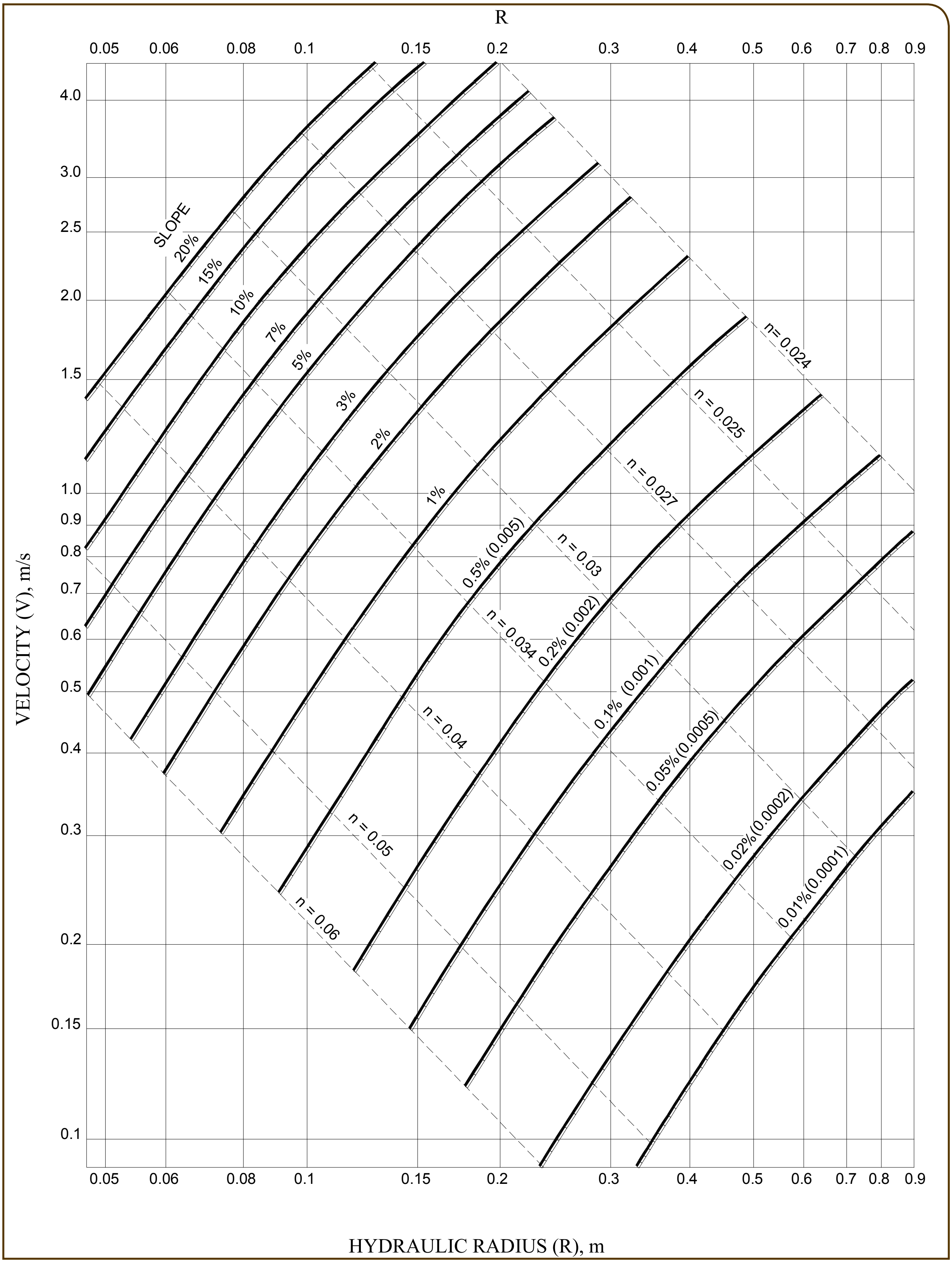


Figure A3.9: Nomograph for solution to the Manning formula

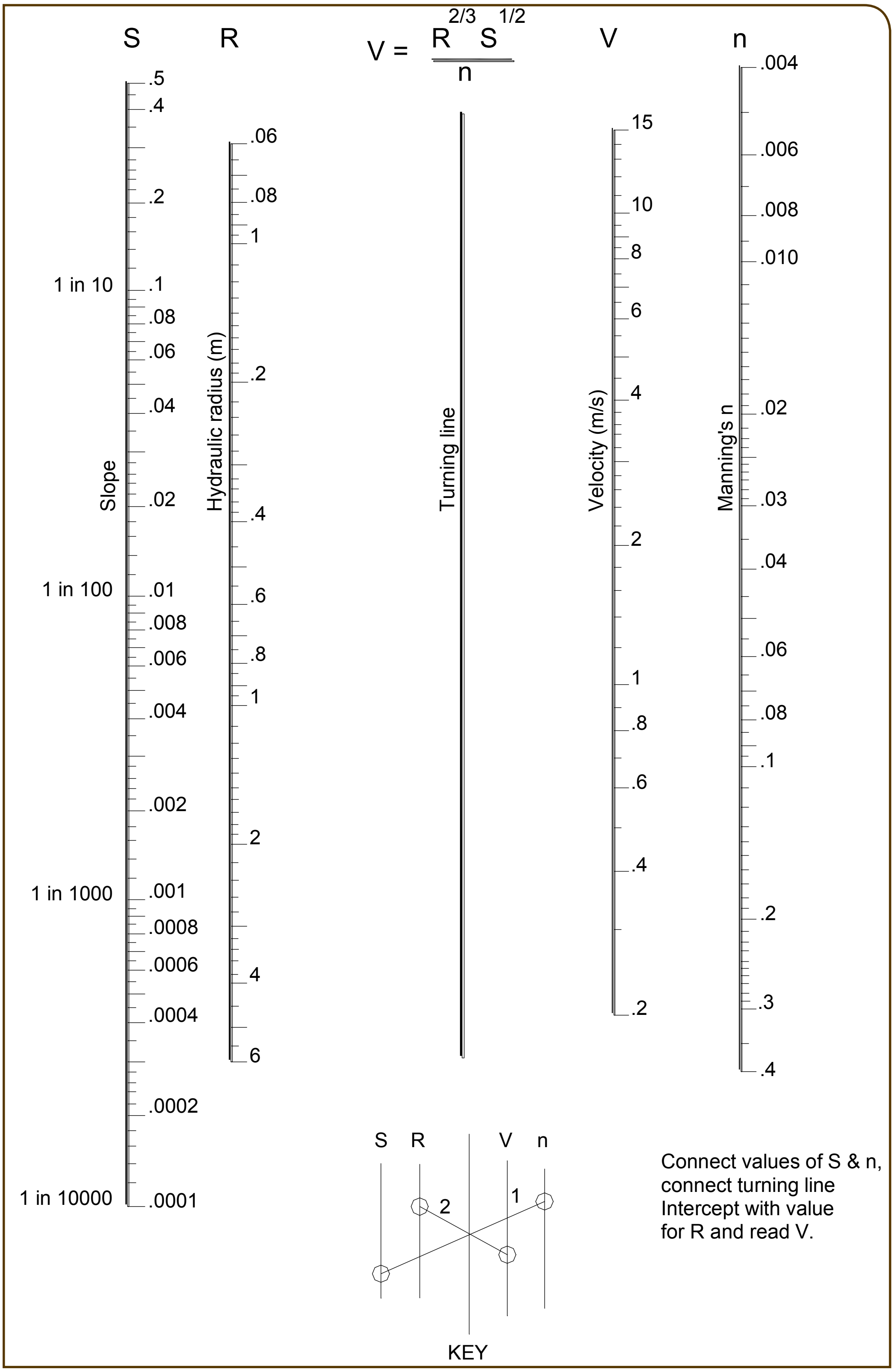
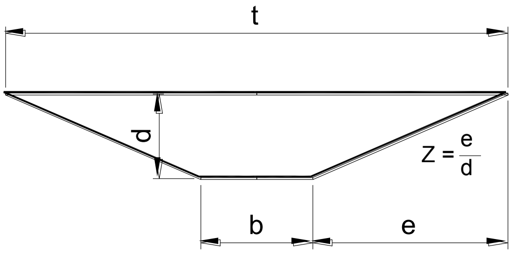
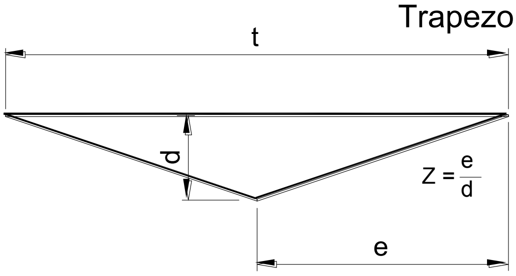


Figure A3.10: Formulae for dimensions for trapezoidal, triangular and parabolic shapes



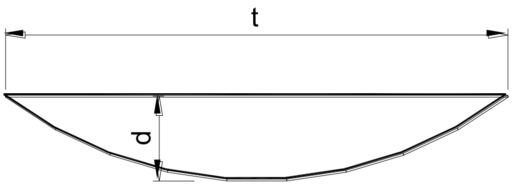
Cross - Sectional Area a	Wetted Perimeter	Hydraulic Radius R
$bd + Zd^2$	$b + 2d\sqrt{Z^2+1}$	$\frac{bd + Zd^2}{b + 2d\sqrt{Z^2+1}}$

Trapezoidal cross section



Zd^2	$2d\sqrt{Z^2+1}$	$\frac{Zd}{2\sqrt{Z^2+1}}$

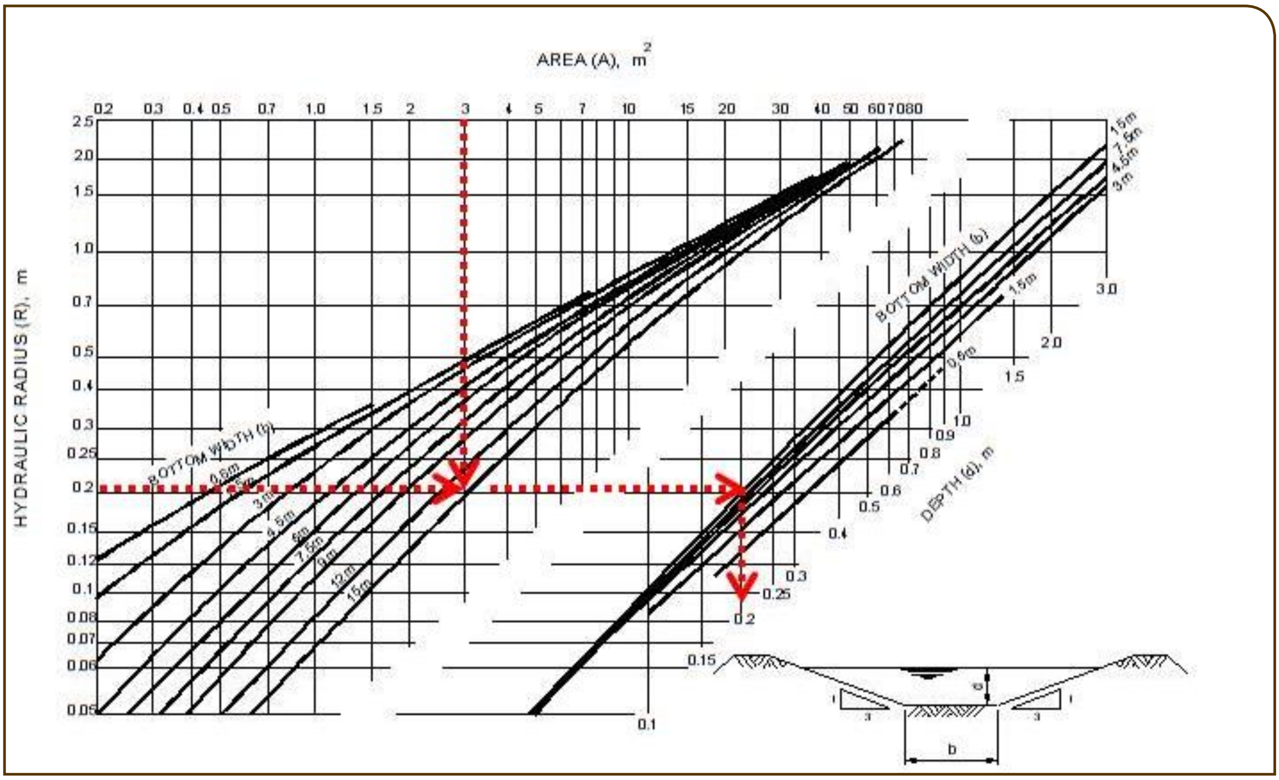
Triangular cross section



0.66td	$t + \frac{8d^2}{3t}$	$\frac{t^2 d}{1.5t^2 + 4d^2}$

Parabolic cross section

Figure A3.11: Demonstration of the use of a chart to determine dimensions of a trapezoidal waterway



Using charts to determine the dimensions of waterway

If the hydraulic radius and cross-sectional area of a waterway are known, the bottom width of the waterway and the depth of flow can be determined using the above chart (for waterways with 1:3 batters).

Figure A3.12: Dimensions of trapezoidal channels with 1:1.5 batter slopes

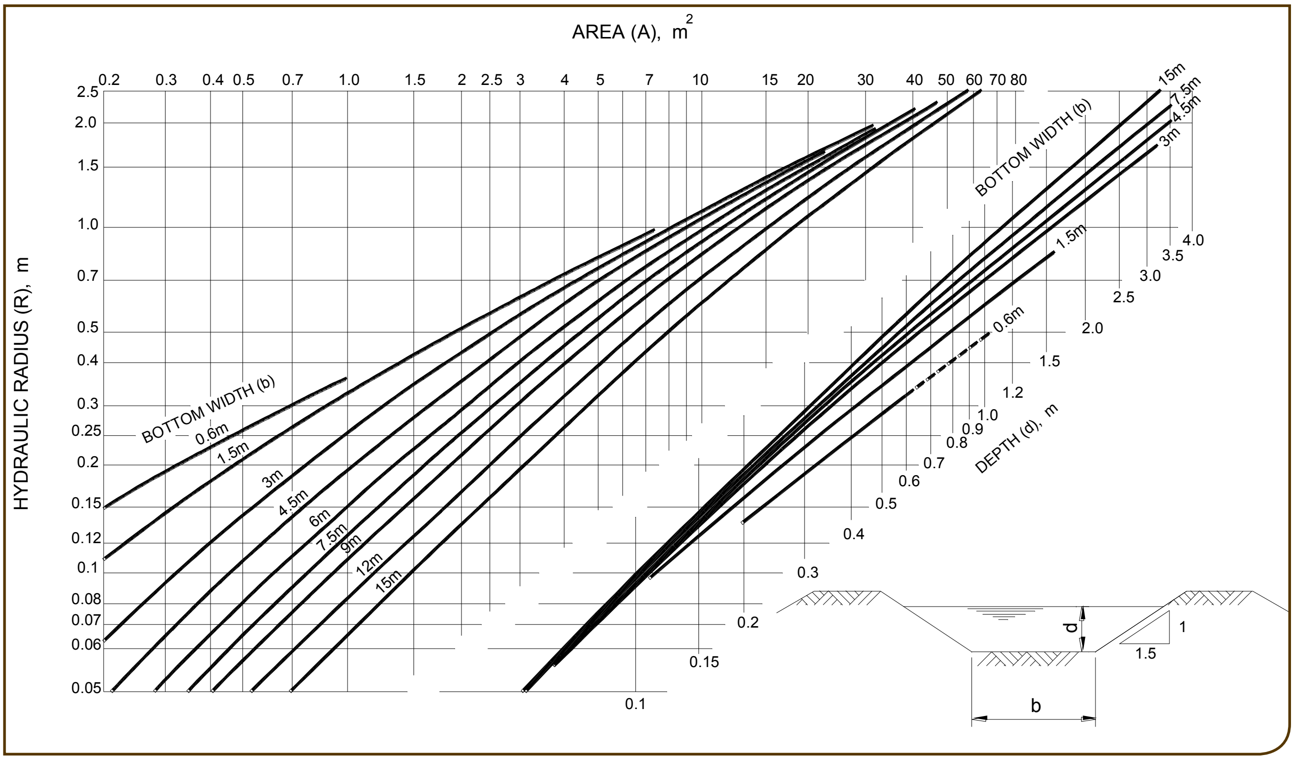


Figure A3.13: Dimensions of trapezoidal channels with 1:2 batter slopes

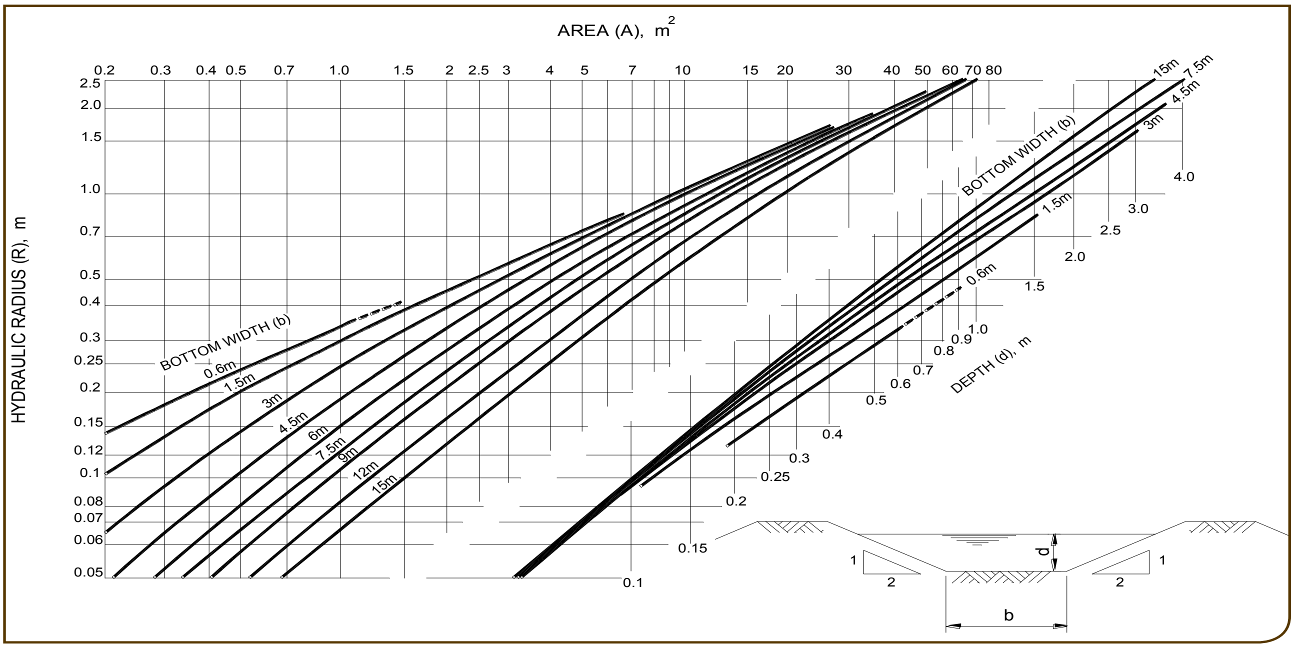


Figure A3.14: Dimensions of trapezoidal channels with 1:2.5 batter slopes

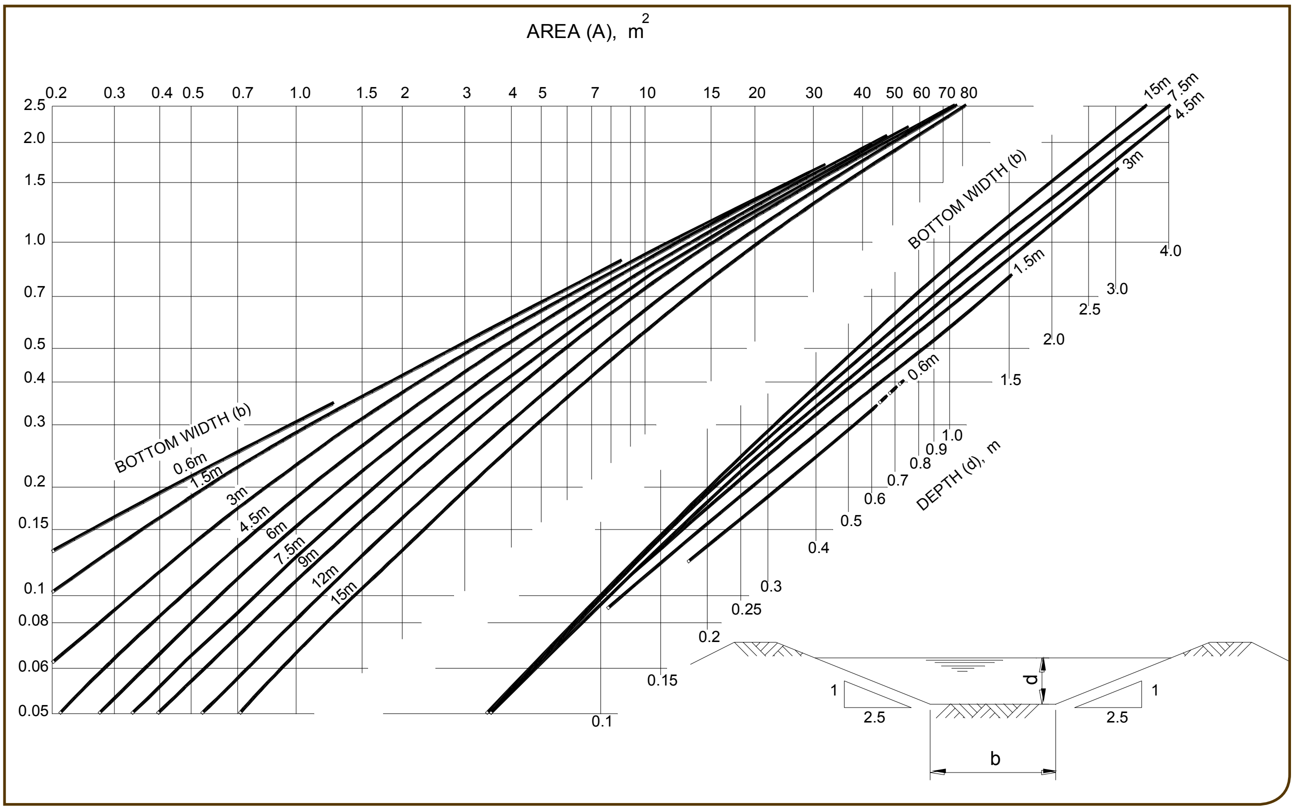


Figure A3.15: Dimensions of trapezoidal channels with 1:3 batter slopes

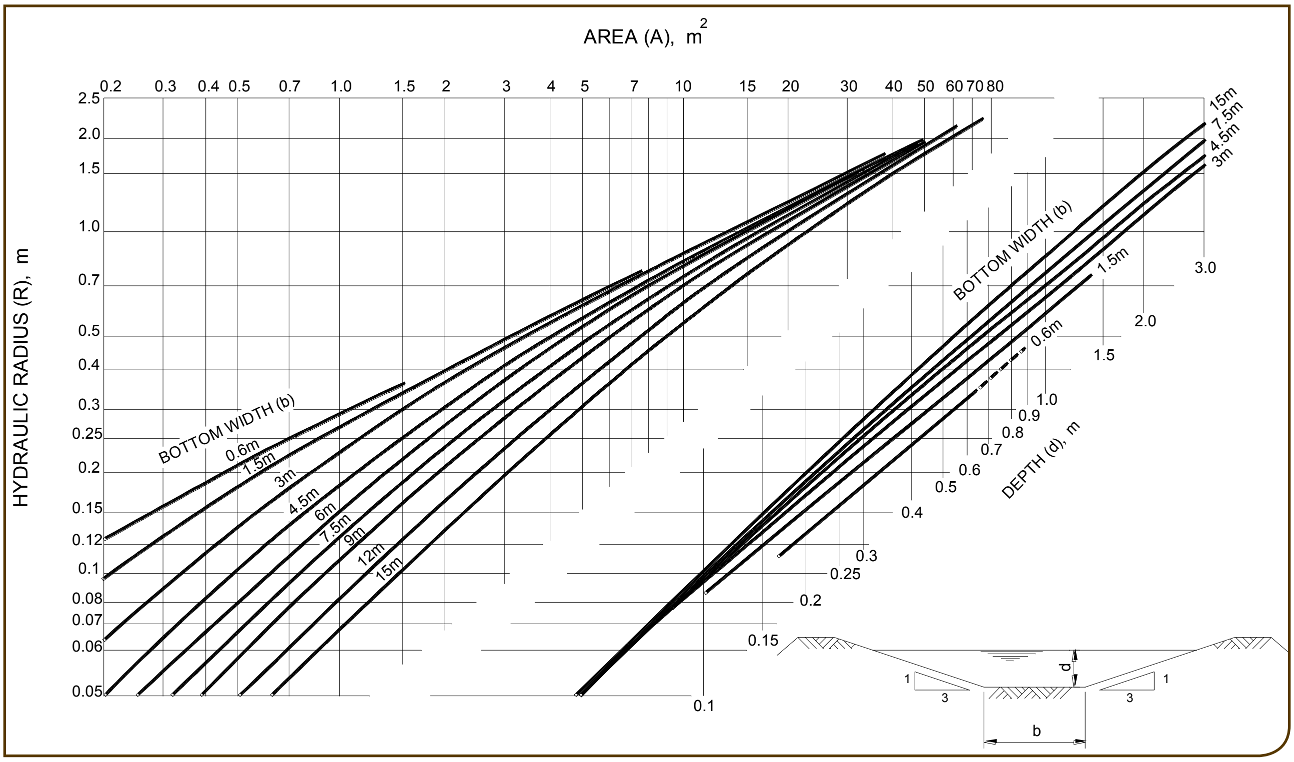


Figure A3.16: Dimensions of trapezoidal channels with 1:4 batter slopes

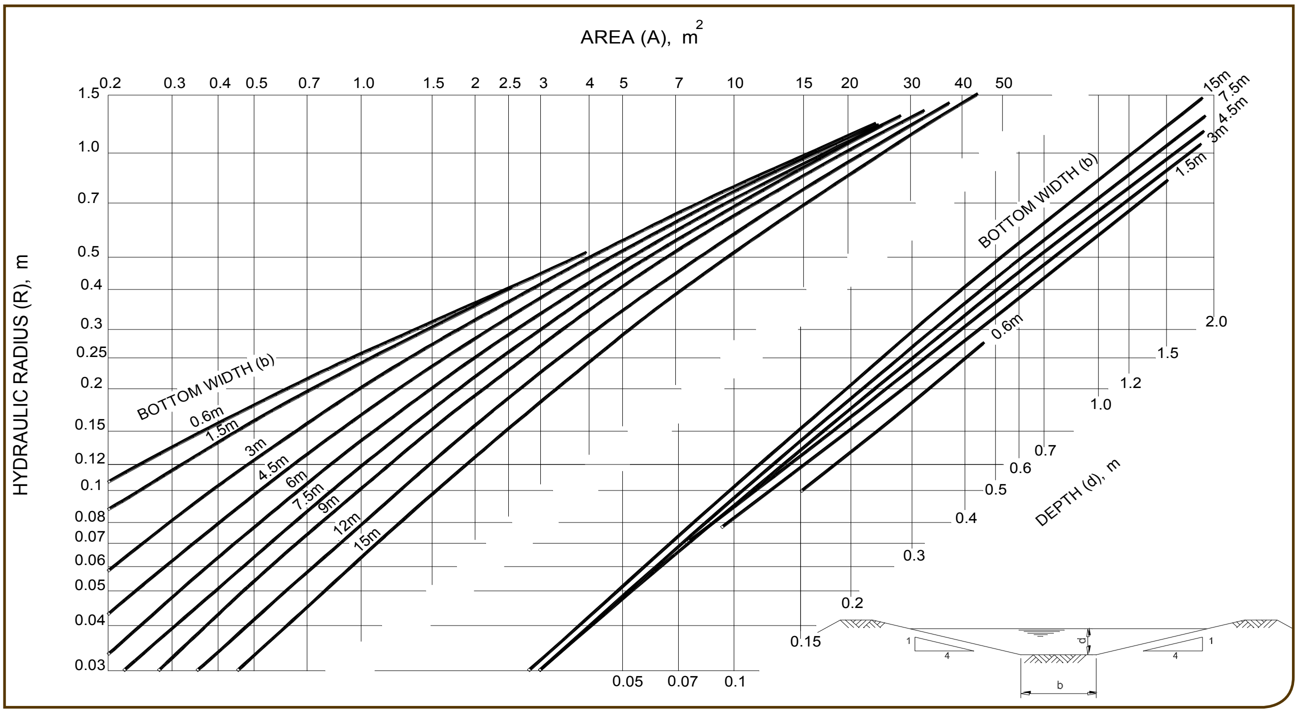


Figure A3.17: Dimensions of trapezoidal channels with 1:5 batter slopes

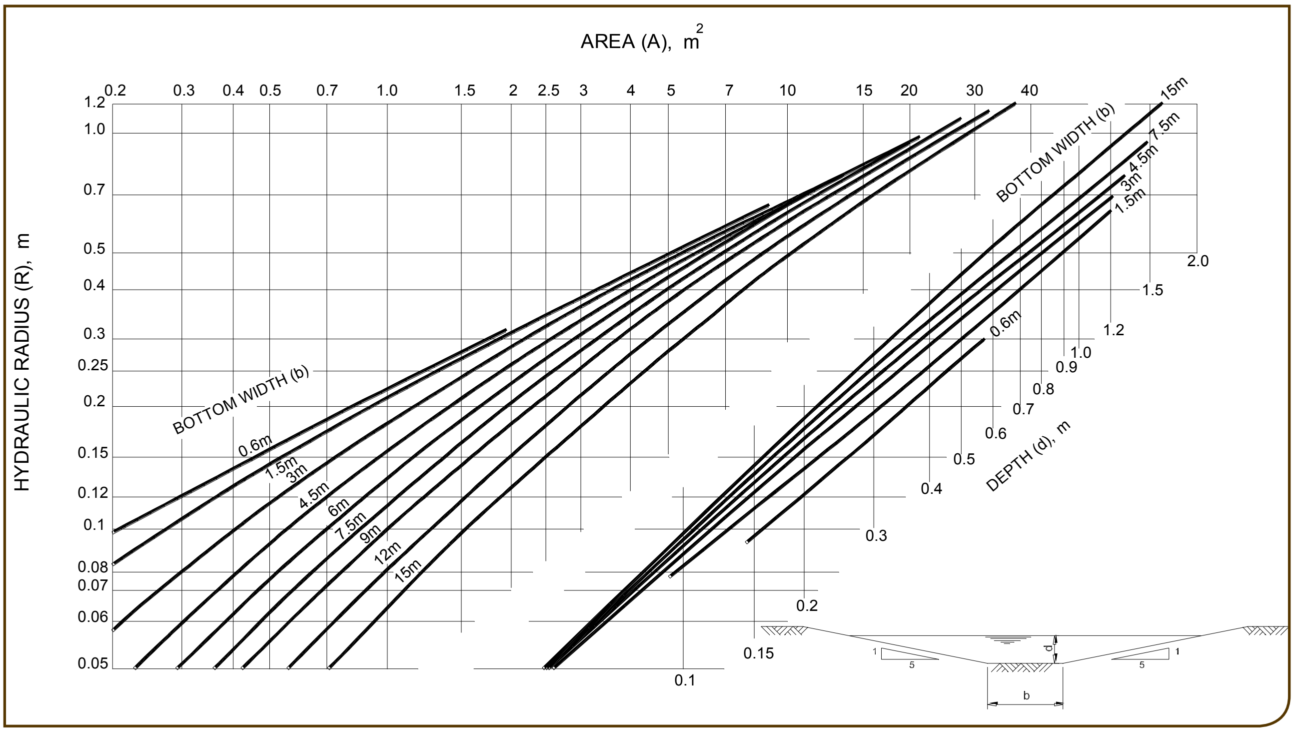


Figure A3.18: Dimensions of trapezoidal channels with 1:6 batter slopes

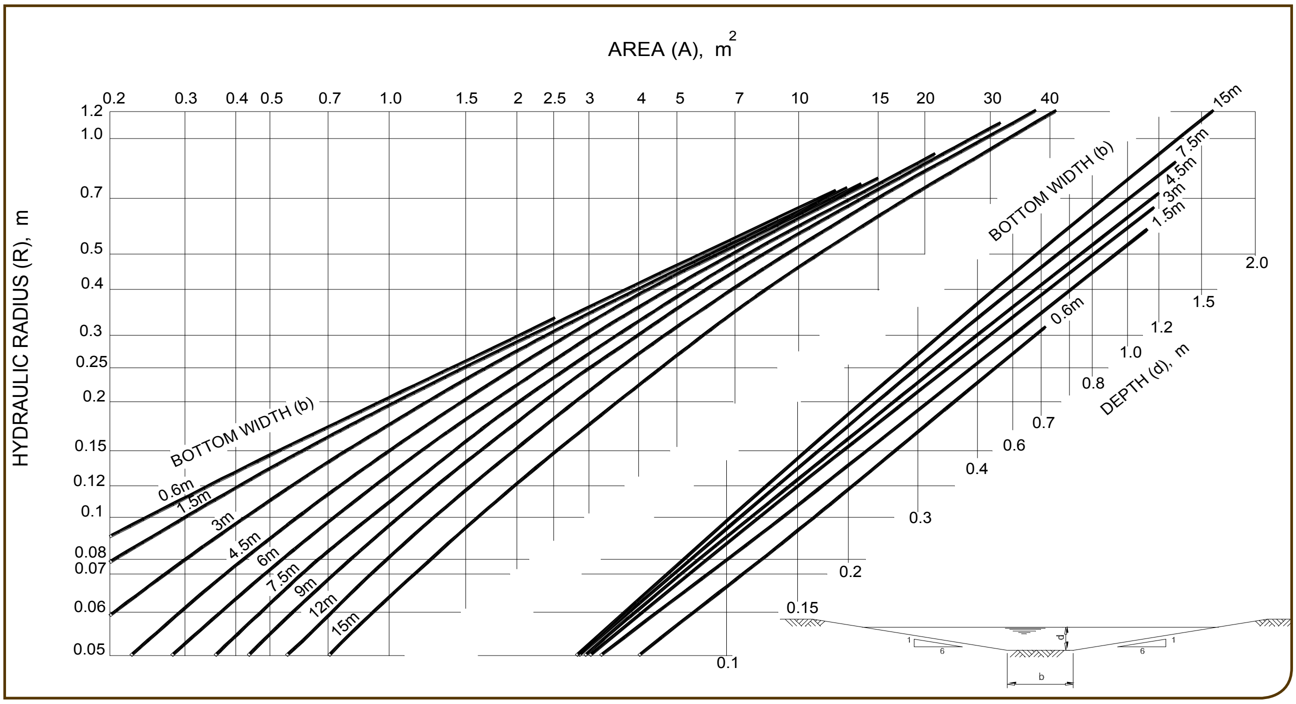


Figure A3.19: Dimensions of parabolic channels (1 of 2)

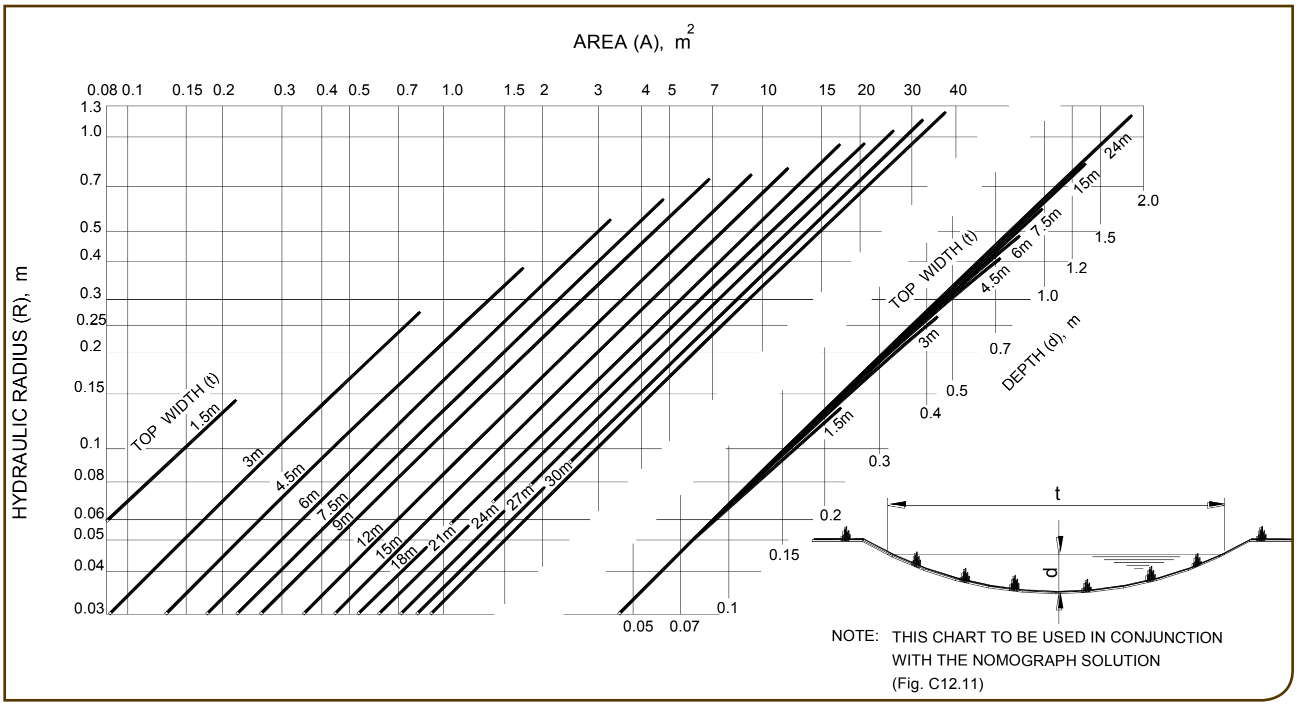


Figure A3.20: Dimensions of parabolic channels (2 of 2)

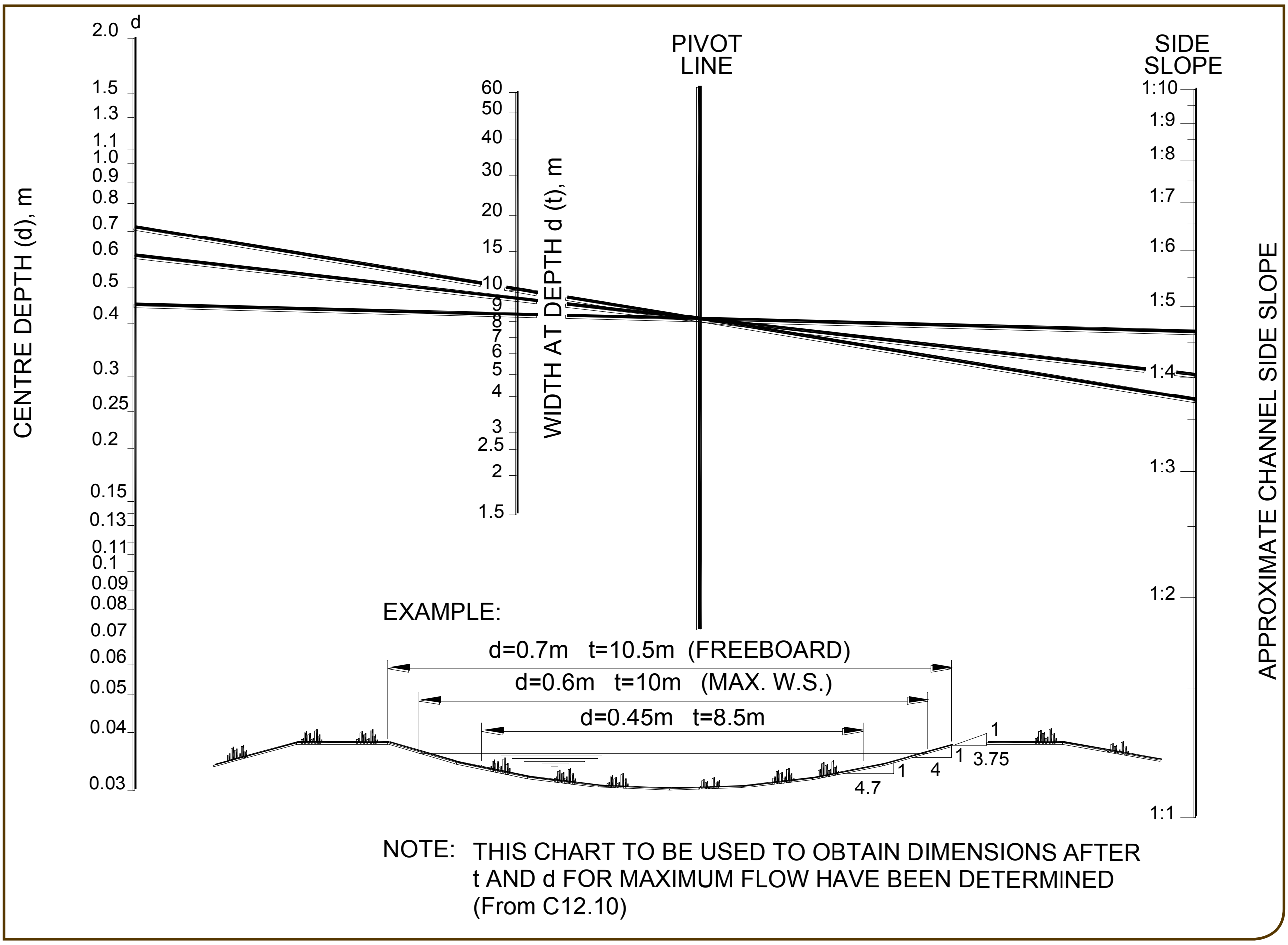


Figure A3.21 Dimensions of triangular channels

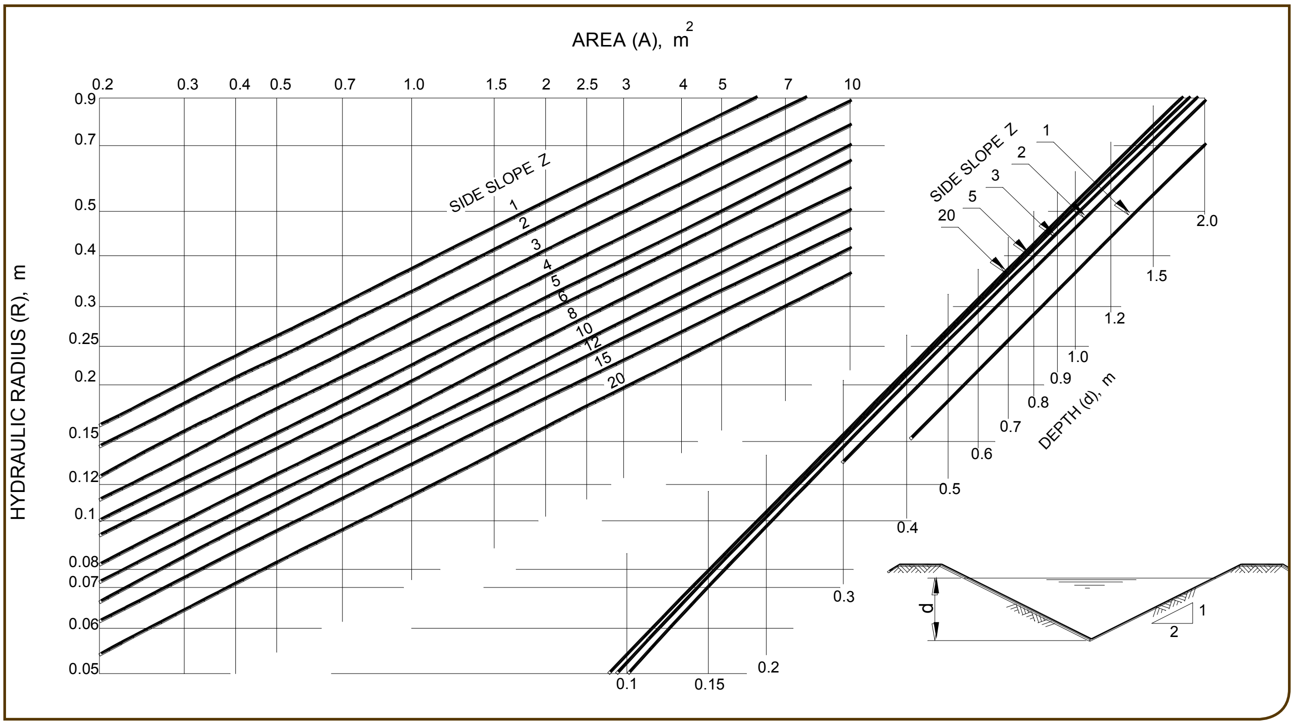


Figure A3.22 Contour bank design chart for a trapezoidal shape and a range of values for Manning's n and flow depth

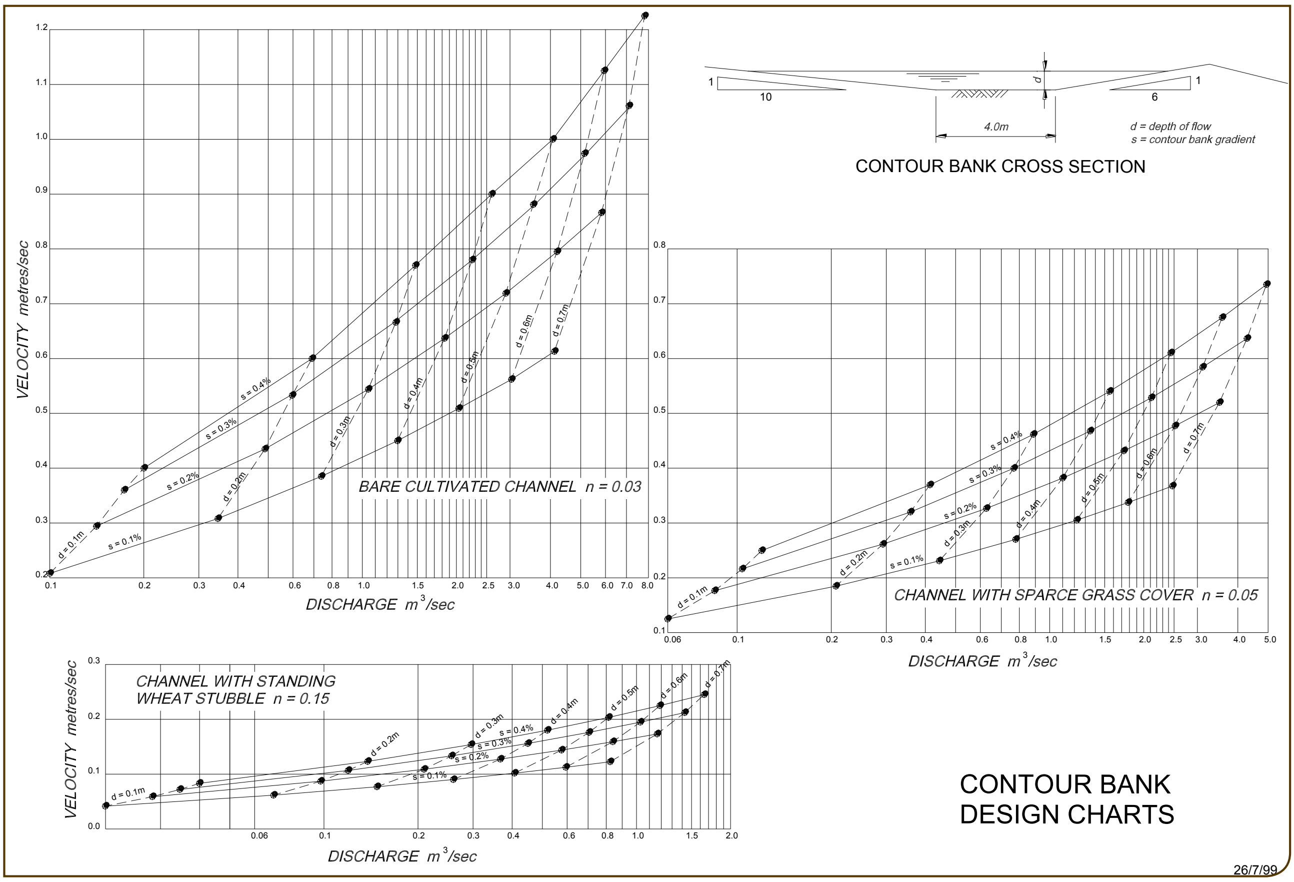
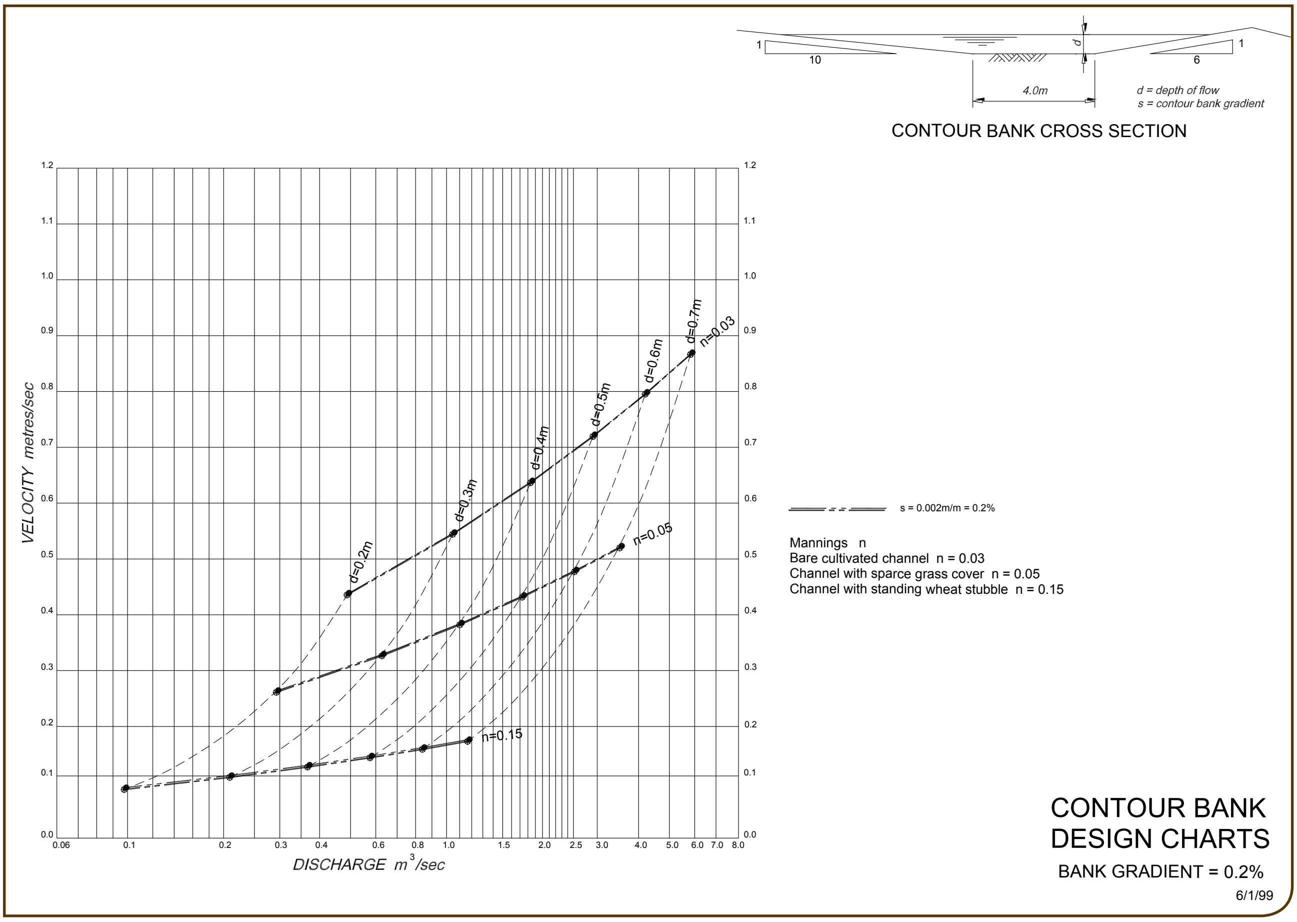


Figure A3.23: Contour bank design chart for a trapezoidal shape and a range of values for Manning's n and flow depth and bank gradient 0.2%



Waterway design tables

A series of waterway design charts for trapezoidal channels for retardance C and retardance D for a range of slopes from 0.2–10% are available in the publication Waterway design tables produced by Queensland Department of Primary Industries (Watt 1984). This suite of charts covers the typical conditions for waterways in the broadacre cropping areas in Queensland. Examples of these charts are provided in Figures 9.9 and 9.10 in Chapter 9 Waterways. The Waterway design tables publication can be downloaded as a PDF file from the Queensland Department of Environment and Heritage Protection library catalogue, accessible online at ‹qld.gov.au/environment/library/›.

Wide waterway design charts

This set of four charts covers design conditions where bottom width exceeds 20m and depth is less than 45cm

Figure A3.24: Wide waterway design, retardance C and velocity 1 m/s

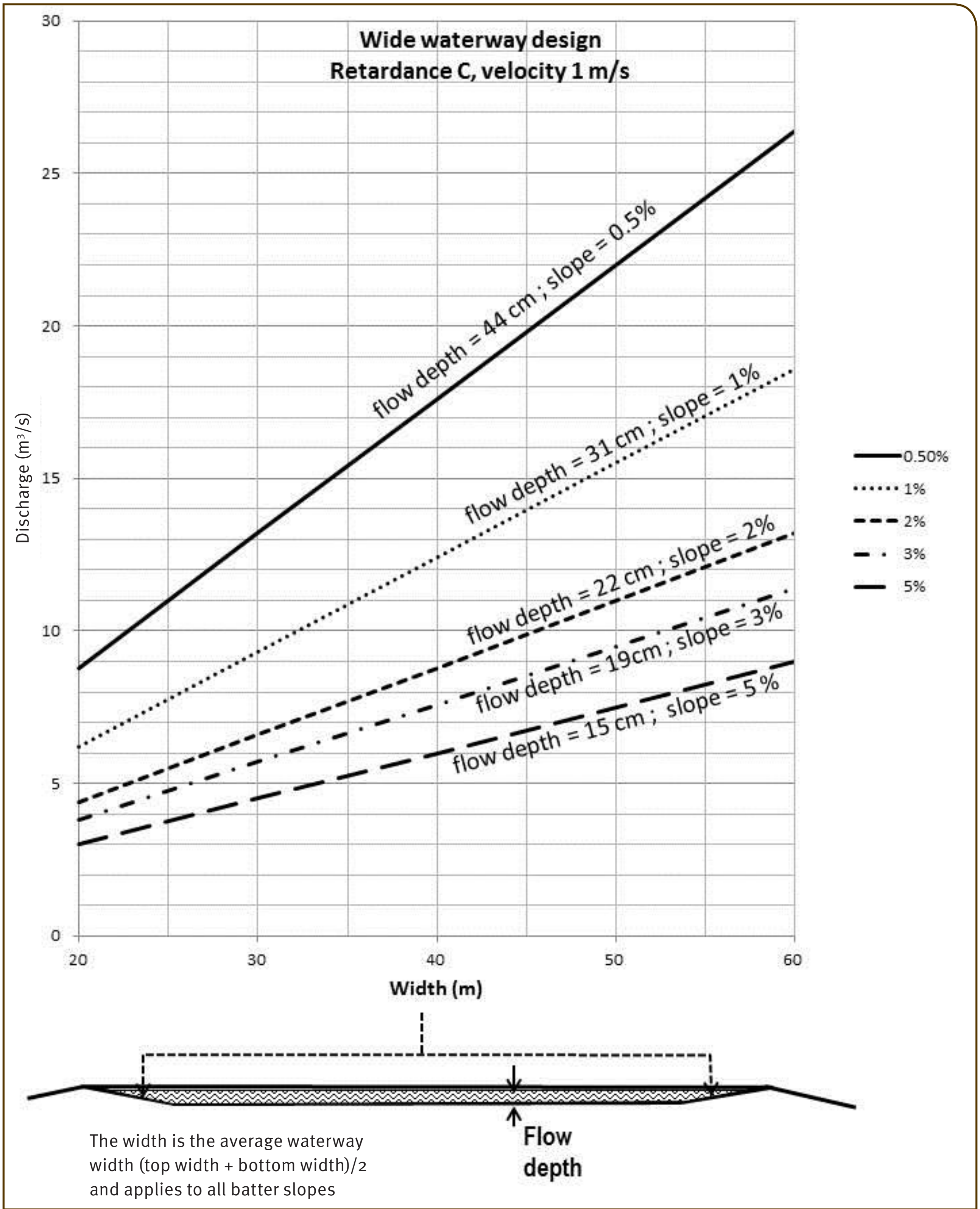


Figure A3.25: Wide waterway design, retardance C and velocity 1.2 m/s

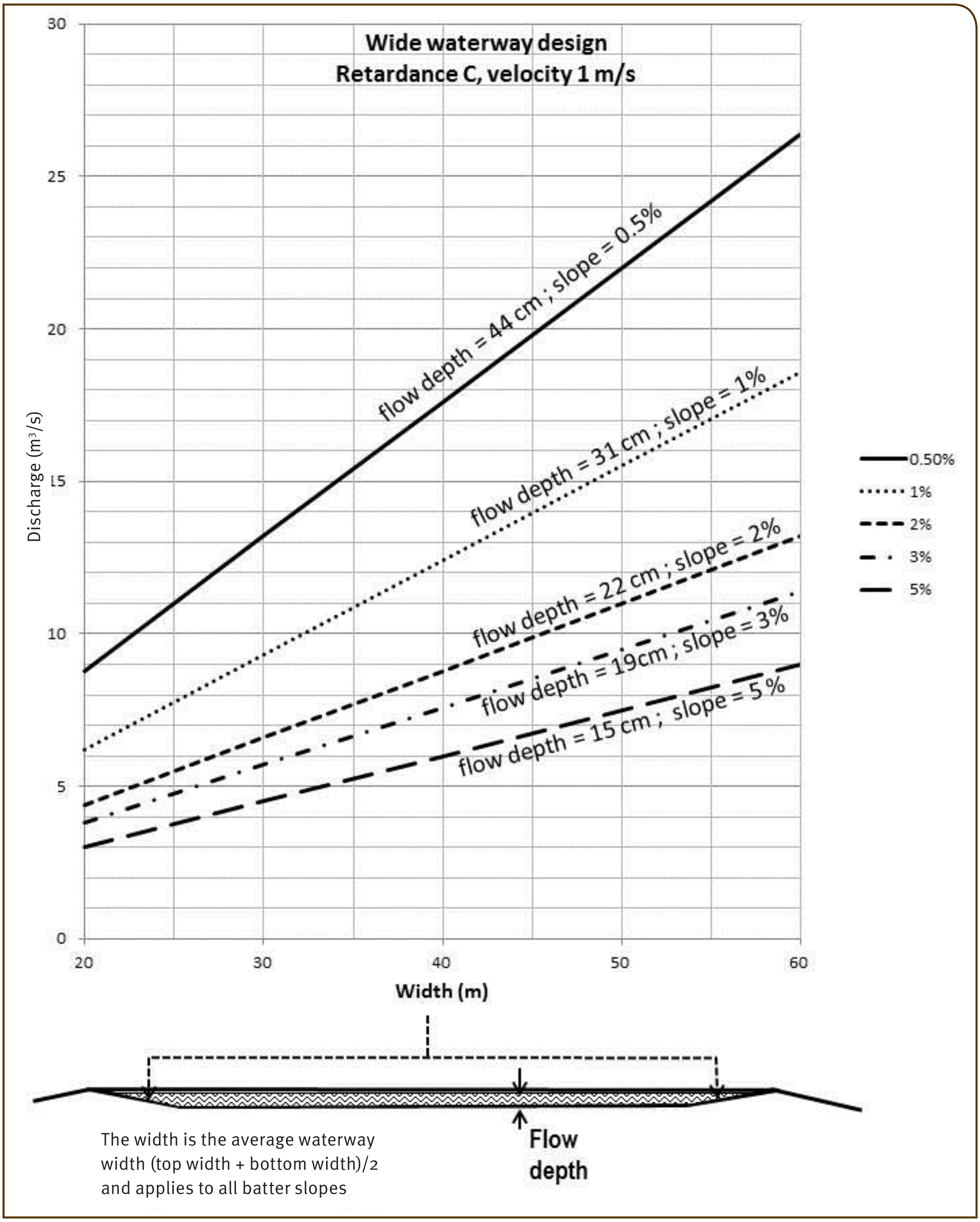


Figure A3.26: Wide waterway design, retardance D and velocity 1 m/s

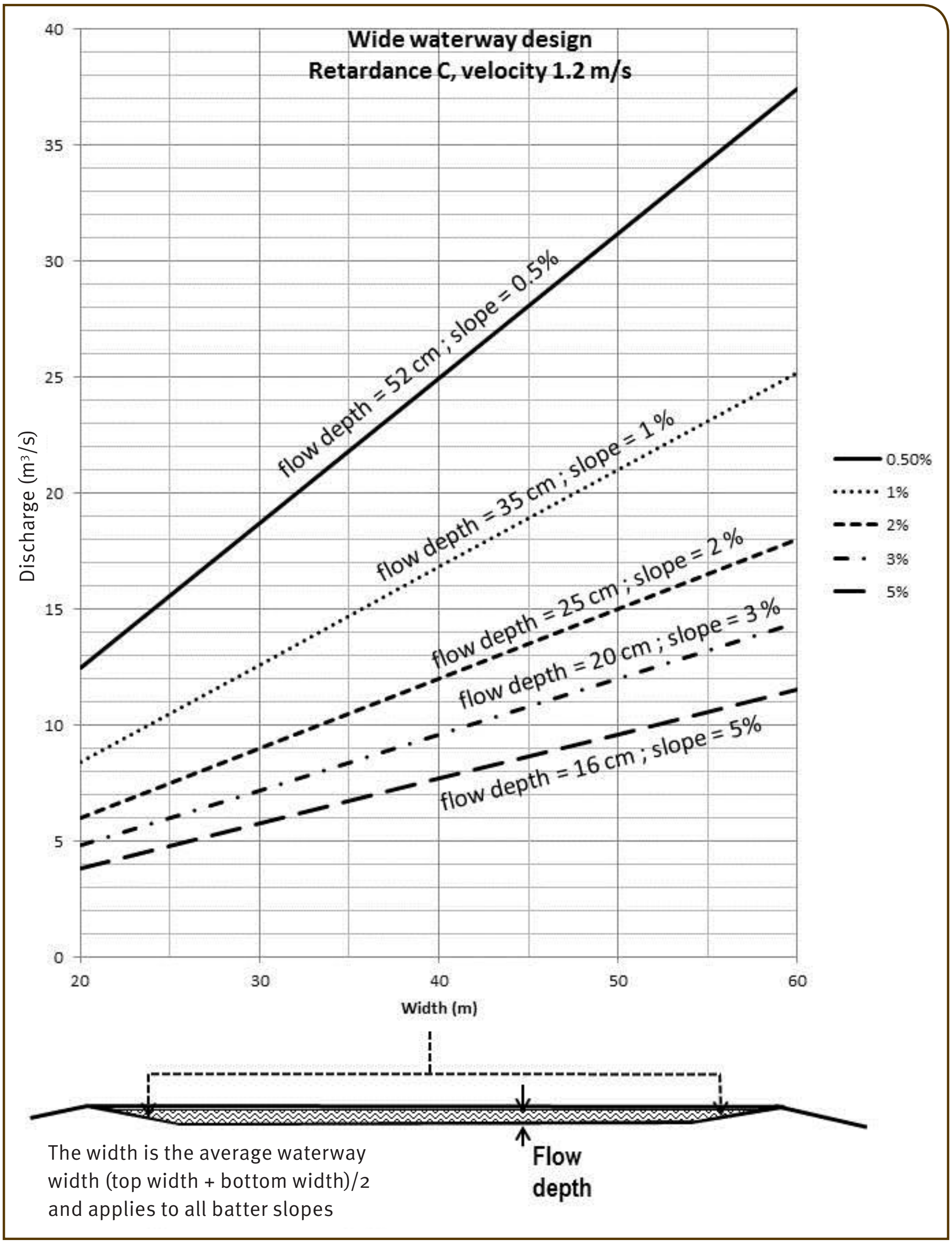
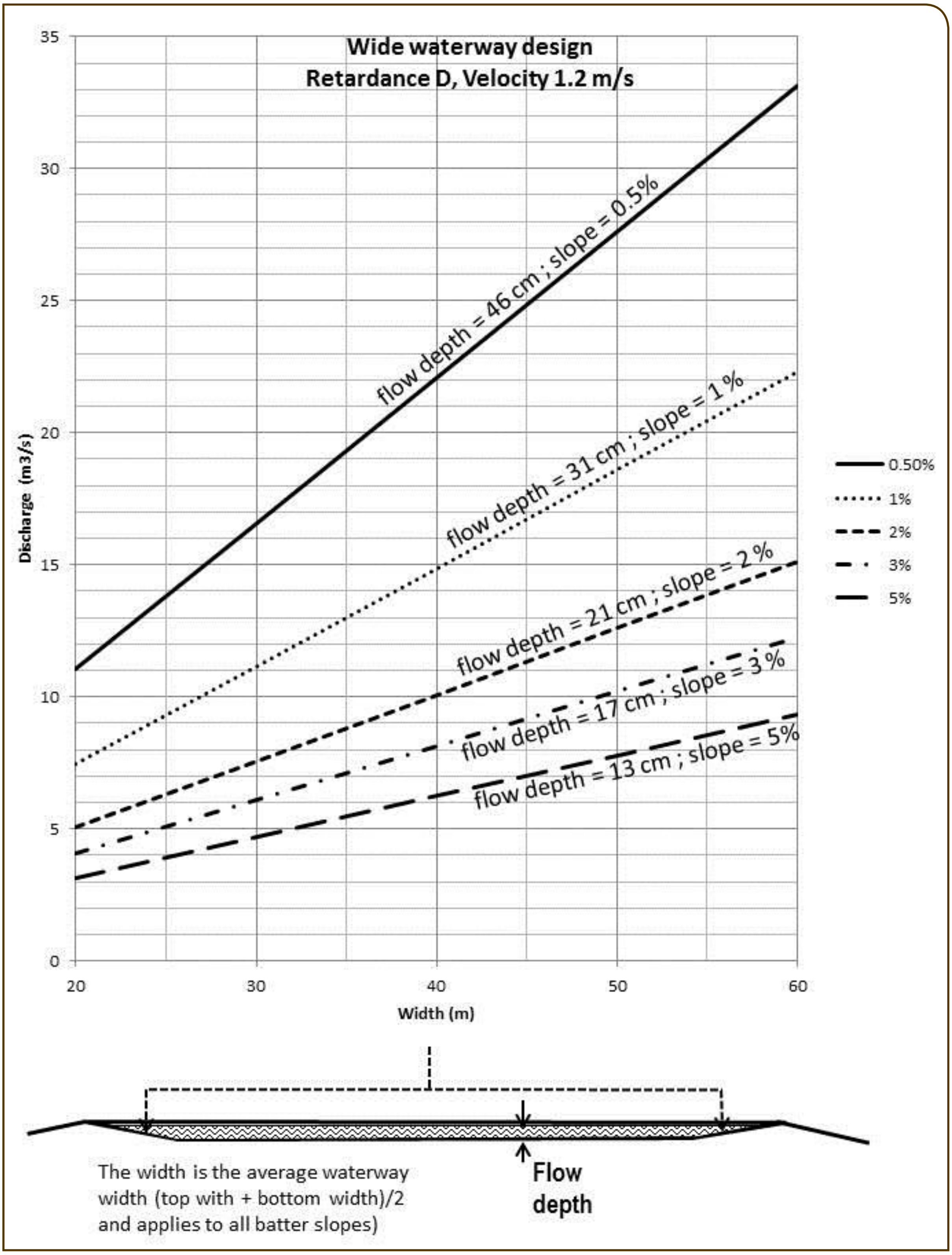


Figure A3.27: Wide waterway design, retardance D and velocity 1.2 m/s



Appendix 4: Plants for stabilising runoff management structures

All plants, including weeds, provide at least some protection from soil erosion. Plants growing on the soil surface protect against raindrop impact, surface flows and wind erosion. Plant roots improve soil strength on steep slopes such as mountains and streambanks. Leaves and branches help to dissipate energy from flood flows in streams and strong winds.

For soil conservation projects, plants are often required to provide protection against the erosion caused by runoff flowing over the soil surface. Such runoff is likely to occur on an irregular basis, which might be only a few times a year, or in dry climates every one or two years. Such situations include grassed waterways in cropping areas, dam by-washes, gully control measures, and corridors used for roads, railway lines, pipes and power lines.

Criteria to consider when selecting a plant species that provides protection from erosion caused by flowing water include:

- root structure—sod-forming grasses with runners (stolons) or rhizomes and a dense root system offer the best erosion protection
- availability and viability of seed
- speed of establishment
- whether the plant is a perennial or an annual
- palatability to livestock
- ease of establishment and regeneration—plants with non-viable seed can be planted vegetatively
- size—tall plants retard flows and require regular slashing
- climate and soil type preferences
- tolerance to drought, frost, salinity and shade
- weed potential.

Table A4.1 lists plants that are suitable for managing runoff in soil conservation projects. The list also provides guidance on where these plants can be expected to grow best and describes some characteristics relevant to their use. The species in Table A4.1 are best suited for dryland situations where runoff from overland flow is the main cause of erosion. Chapter 11 provides information about species suitable for stabilising streambanks.

The plants listed in Table A4.1 are mostly perennial, exotic pasture grasses that are commonly grown in agricultural areas. Native Australian pastures are mostly tussocky species and, in general for the grazing lands, are better adapted to Queensland climatic conditions, although they may be less resistant to erosion than the stoloniferous, exotic species. Native species may be the best option where stands of suitable species already exist in a drainage line that will be used as a soil conservation waterway. The native tussock species generally have deeper root systems, provide increased roughness—and therefore increased infiltration—and produce more biomass and shed more litter. In any situation local advice should be sought regarding suitable species, or cultivars; and their management requirements.

A feature of Queensland's climate is its high rainfall variability, with total rainfall decreasing and variability increasing from the coast to inland. Annual average rainfall totals vary from 2000–4000 mm on the wet tropical coast to 150–250 mm in the south-west arid zone. In high rainfall areas, there is a long list of suitable species to choose from; in the arid zone, the choice of species is much more limited.

Buffel (*Cenchrus ciliaris*) or Indian couch (*Bothriochloa pertusa*) has been widely used for rehabilitation projects in the lighter arid inland soils in the past. However, these species are no longer recommended due to their weed potential. In dry inland areas that receive some run-on water and where there is the opportunity to hand plant and aid establishment with supplementary watering, plantings of native couch (*Brachyachne convergens*) may be possible in small areas if there is a local supply of material. Other native species that could have potential for use in runoff control structures are spider grass (*Digitaria divaricatissima*) and windmill grass (*Chloris truncata*) in southern Queensland; and graceful grass (*Ottochloa gracillima*) on poorer soils in Central Queensland. Kangaroo grass (*Themeda triandra*) and black spear grass (*Heteropogon contortus*) are also suitable for much of Queensland.

In northern Australia, native blady grass (*Imperata cylindrica*) has potential for use in soil conservation projects, as it is hardy and deep-rooted. This species is used for erosion control around the world; however, its use in Australia has been limited due to difficulties in sowing and the restricted availability of seed. Blady grass is especially appropriate for native grasslands not yet dominated by exotic Indian couch or Sabi grass (*Urochloa mosambicensis*) (Jeffrey Shellberg, personal communication).

As most of the recommended species in the table are also pasture species, any planted areas will be attractive to livestock. Excessive grazing will reduce ground cover and can change stoloniferous grasses to a tussock form that will reduce their effectiveness in erosion control. For this reason, erosion-control areas should be fenced to manage grazing pressure.

Many grass species have small seeds that are difficult to germinate in some soils such as self-mulching clays. Where rapid protection is a priority, sowing of annual species such as wheat or oats in winter and millet in summer should be considered. Perennial grass species can then be planted into the stubble provided by the annual species. Where the budget allows, immediate protection against erosion can be provided by artificial solutions such as hydro-mulching or the use of a compost blanket. A compost blanket is more expensive but is much more conducive to plant establishment because it is comparable to topsoil in that it provides plant nutrients and moisture as well as a medium for the plants to grow in.

Vetiver grass

Vetiver grass (*Chrysopogon zizanioides* L., syn.: Vetiveria z.) is not suitable for planting on a broad scale as in a grassed waterway. However it is suitable for erosion control in some specialist situations. Field trials on the adaptability and application of the Monto strain of vetiver grass were conducted throughout Queensland in the 1990s. It was used successfully for:

- gully stabilisation
- drainage channel stabilisation
- steep batter stabilisation
- improving water quality by filtration of sediment from runoff water that may be carrying nutrients and chemicals
- rehabilitation of contaminated sites such as old rubbish dumps
- rehabilitation of old quarries, and degraded and disturbed lands
- spreading and diverting of runoff water
- rehabilitation and control of erosion on acid sulfate soils
- rehabilitation of mine spoils and tailings
- disposal of effluent and waste water from domestic and industrial sources.

Vetiver grass can be established on very acid, sodic, alkaline or saline soils. It also tolerates very high levels of aluminium, manganese and a range of heavy metals in the soil. Due to its extensive and deep root system, vetiver is tolerant to drought. It can be grown in areas with an annual rainfall greater than a modest 450–500 mm. However, some difficulties have been encountered when establishing it in the drier parts of inland cropping areas. Established plants can stand extreme heat (50°C), and frost (–10°C), although plants are susceptible to frost during the establishment phase.

Further information

The land management field manuals listed in Chapter 2 *Soil conservation planning* provide information about suitable plant species for use in different cropping districts for Queensland.

Department of Natural Resources and Water (2006). *Monto vetiver grass for soil and water conservation*, NRW fact sheet series L34, Department of Natural Resources and Water, Brisbane.

The following websites provide relevant information:

- tropicalgrasslands.asn.au
- deedi.qld.gov.au
- pasturepicker.com.au
- nativeseeds.com.au
- qtpa.com.au (Turf Queensland)
- weeds.org.au.

Table 4.1: Species to consider for use in soil conservation projects in Queensland
Seek local advice before choosing a species (or one of its cultivars) for a specific situation.

Soil: S = sand | L = loam | C = clay | SL = sandy loam | CL = clay loam | HC = heavy clay

Species	Darling Downs	Western Downs	SE Queensland	Central H'lands	North Qld	Soil	Stolons/runners	Comment
African star grass (*Cynodon nlemfuensis*)	✓	✓	✓		✓	CL–L	✓	Propagated vegetatively. Does not survive dry conditions in the Central Highlands. Is potentially weedy in high rainfall areas (>850 mm).
Angleton grass (Dicanthium aristatum)	✓	✓	✓	✓	✓	L–C	×	Also called Floren bluegrass. Has no stolons but provides reasonable ground cover. Especially suited to heavy clays.
Black spear grass (*Heteropogon contortus*)	✓	✓	✓	✓	✓	L–C	×	A common component of native pastures where the average annual rainfall is 600–1000 mm. Grows on a wide variety of soils but is less common on heavy clay soils. While well adapted to low fertility, it is not tolerant of extremely low fertility, nor poor drainage or high levels of salinity. Seed can be difficult to obtain in commercial quantities.
Blue couch (*Digitaria didactyla*)	✓		✓			S–L	×	Fine-leaved, creeping grass commonly used in lawns. Browns off in drought but responds quickly to rainfall. Suitable for sandy, low-fertility soils.
Buffalo grass (*Stenotaphrum secundatum*)		✓		✓	✓	L–C	✓	Many varieties available, including Sir Walter, which is widely used in amenity horticulture. Also called soft-leaved buffalo grass. A common lawn species. Propagated vegetatively. Tolerates shade.
Creeping bluegrass (*Bothriochloa insculpta*)	✓	✓	✓	✓	✓	L–C	✓	Tolerates drought and low fertility. Common varieties are Hatch (which grows best on clays) and Bissett (which prefers clay loams and has runners which root better than those of Hatch).
Golden Beardgrass (*Chrysopogon fallax*)		✓		✓	✓	L–C	✓	A deep-rooted, tussocky, perennial grass. Grows in a variety of soil types and locations favourable to moisture accumulation. Often associated with Mitchell grass (*Astrebla lappacea*) in low-lying parts of black soil plains and along creek lines.
Green couch (*Cynodon dactylon*)	✓		✓		✓	S–C	✓	A low-growing species commonly used in lawns. Salt-tolerant.
Humidicola (*Urochloa humidicola*)					✓	S–C	✓	Also called Koronivia grass or Tully grass. A vigorous, creeping grass suited to high-rainfall areas. Tolerant of waterlogging, salinity and very acid soils.
Kikuyu (*Cenchrus clandestinus*)	✓		✓		✓	L–C	✓	Propagated by runners or seed. A dense, creeping grass on highly fertile soils in subtropical areas or tablelands. Prefers annual rainfall >750 mm.
Makarikari grass (*Panicum coloratum*)	✓	✓	✓		✓	C	×	Also called Bambatsi panic grass. Develops a deep, fibrous root system. Drought-resistant and best suited to heavy clays. Can require regular slashing.

Species	Darling Downs	Western Downs	SE Queensland	Central H'lands	North Qld	Soil	Stolons/runners	Comment
Narrow-leaved carpet grass (*Axonopus fissifolius*)			✓		✓	S–LC	✓	Also referred to as mat grass. Propagated vegetatively. Common in low-fertility, run-down dairy pastures in South Queensland.
Pangola grass (*Digitaria decumbens*)			✓		✓	SL	✓	Propagated vegetatively. Suitable for light-textured soils. May need irrigation to get established.
Paspalum (*Paspalum dilatatum*)			✓		✓	S–C	×	Lacks stolons. Can grow vigorously and require regular slashing. Suitable for wetter conditions but has some drought tolerance. Prefers highly fertile soils.
Pinto peanut (*Arachis pintoi*)			✓		✓	S–L	✓	Used as a ground cover in frost-free areas but would be suitable for waterways in higher rainfall areas. Requires an inoculant.
Premier digit grass (*Digitaria eriantha*)	✓	✓	✓		✓	S–CL	×	A tussock species. Suitable for poorer, light-textured soil types. Can be slow to establish, but tolerates low temperatures and is very persistent.
Queensland blue grass (*Dicanthium sericium*)	✓	✓	✓	✓	✓	C–HC	×	A native species. Seed can be difficult to obtain. Does not produce runners but still provides good cover. Often colonises waterways after other species no longer persist.
Rhodes grass (*Chloris gayana*)	✓	✓	✓	✓	✓	C–HC	✓	A number of cultivars available. Often used in waterways on brigalow soils on the Western Downs. Does well on sodic soils in the south-east. Does not persist on open downs clay soils such as in the Central Highlands.
Sabi grass (*Urochloa mosambicensis*)			✓	✓	✓	L–C	×	Not stoloniferous, but forms a reasonable mat when slashed and has a tendency to root down at the nodes to some extent. Some tendency to 'disintegrate' during winter, but responds rapidly to rain. Grows on a wide variety of soils from sandy loams to heavy clays. Seed is available in commercial quantities.
Signal grass (*Urochloa decumbens*)					✓	S–C	✓	Provides a dense cover. Grows in a wide range of soils in higher rainfall areas but is susceptible to water-logging. Responds to good fertility.
Strickland grass (*Digitaria milanjiana*)	✓	✓			✓	S–CL	✓	Also called tall finger grass or Jarra digit grass. Suitable for poorer, light-textured soil types. May require irrigation in North Queensland.
Sweet smother grass (*Dactyloctenium australe*)			✓		✓	S–L	✓	Also called Durban grass. Propagated vegetatively. Suitable for shady conditions. Used as a ground cover in orchards and in lawns.
Vetiver grass (*Chrysopogon zizanioides*)	✓	✓	✓	✓	✓	S–C		Can only be propagated vegetatively. Has a deep root system. It can be grown in areas with an annual rainfall greater than 450–500 mm. However, there have been some difficulties associated with establishing in the drier parts of inland cropping areas.
Water couch (*Paspalum distichum*)			✓		✓	L–C	✓	High salt tolerance, suitable for poorly drained waterways.
Zoysia (*Zoysia japonica*)			✓		✓	L–C		Used in lawns. Slow to establish (the variety Empire is the fastest) but provides good cover and is shade-tolerant.