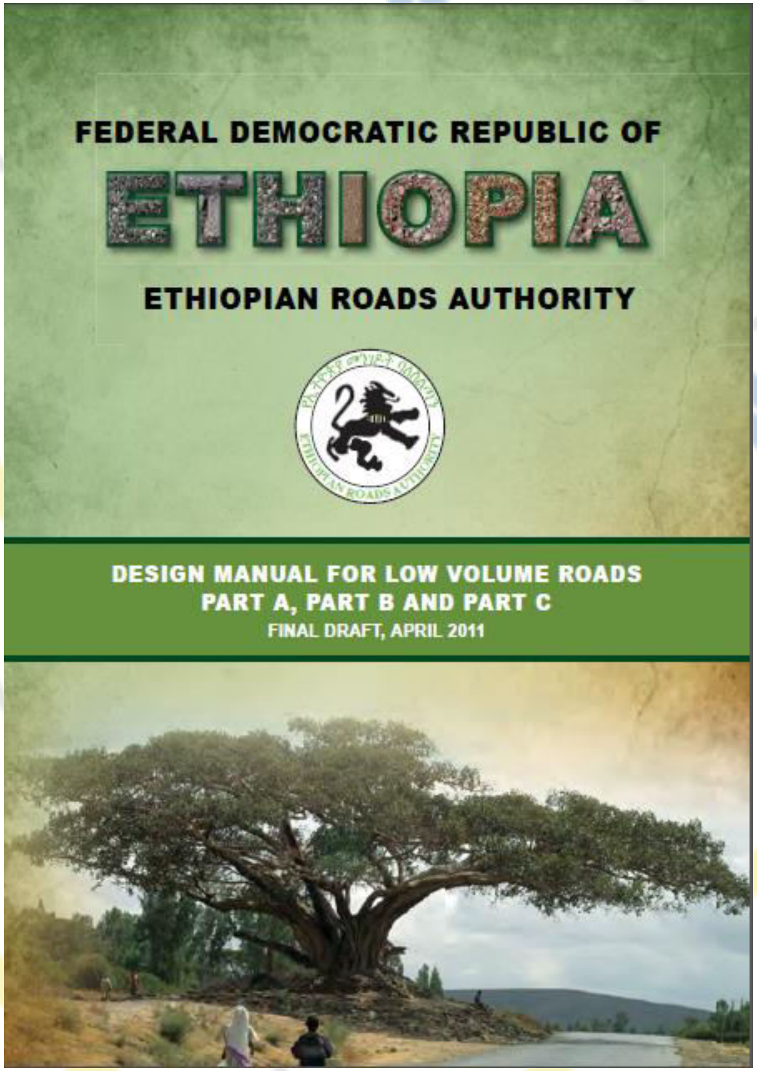
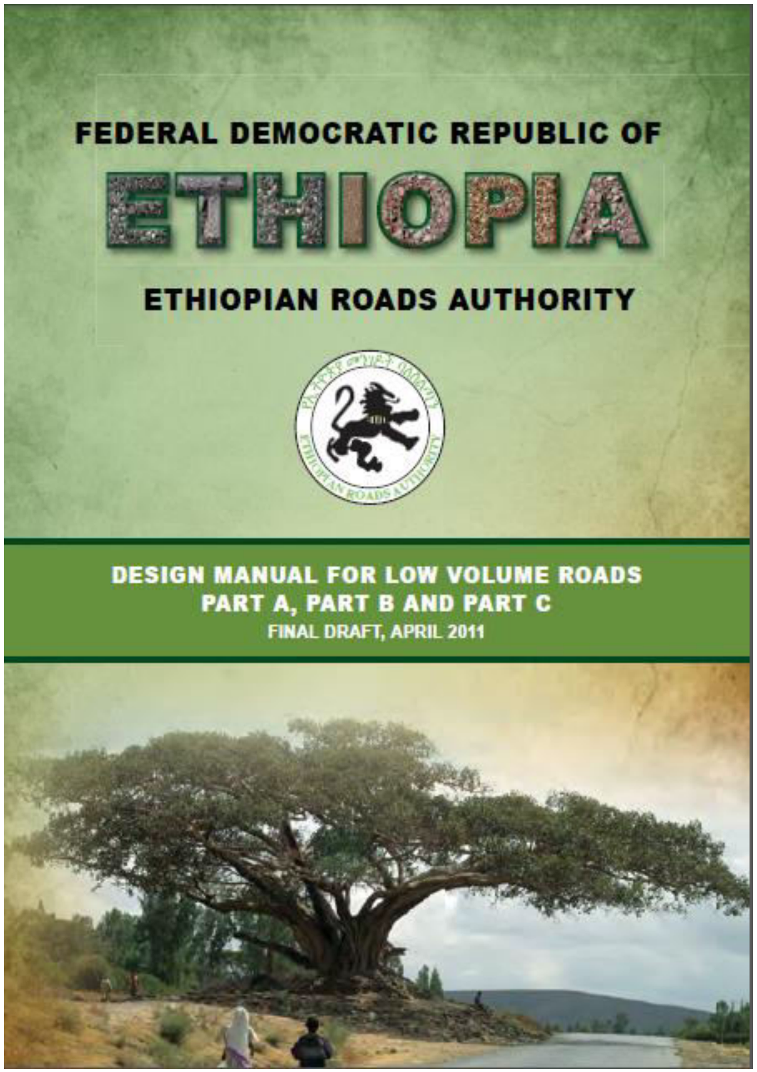
Training on

Roads for Water and Resilience

ESTIMATING DRAINAGE FLOWS


FEDERAL DEMOCRATIC REPUBLIC OF
ETHIOPIA
ETHIOPIAN ROADS AUTHORITY
ETHIOPIAN ROADS AUTHORITY
DESIGN MANUAL FOR LOW VOLUME ROADS
PART A, PART B AND PART C
FINAL DRAFT, APRIL 2011

Information taken from ERA Road Manuals (Vol 2)



Further information and explanation is provided in these manuals

Factors that determine maximum design catchment runoff

1. Rainfall intensity (storm type)
2. Catchment area
3. Runoff coefficient
4. Time of concentration (shape of catchment)
5. Slope
6. Soil infiltration capacity
7. Land surface roughness
8. Antecedent moisture
9. Design life/return period

ERA uses combination of 3 methods

The maximum water flow in a watercourse can be estimated using the following methods:

- ❖ Direct observation of the size of watercourse, erosion and debris on the banks, history and local knowledge;
- ❖ The Rational Method.
- ❖ The SCS method (USA Soils Conservation Services, TR-55)

A combination of these methods should be used to provide the maximum level of reliability.

1. Size of watercourse

Watercourses enlarge to a size sufficient to accommodate the maximum water flow.

X-sectional area of the water course is measured and a cross-sectional area of apertures (or spillway) of the structure is equal to that of the water course…….

High water levels can be estimated from recorded history, including measurements taken in the watercourse or from the recollections of local residents.

1. Size of watercourse

When might this method underestimate the peak flood?

When talking to local residents what other questions about the floods could you ask?

How can the accuracy of the information be checked?

2. Rationale method

The flow of water in a channel, q, is calculated from the following equation (Eq.1).

$$q = 0.278 \times C \times I \times A \ (m3/s)$$

Where:

C = the catchment runoff coefficient

I = the intensity of the rainfall (mm/hour)

A = the area of the catchment (km2)

Catchment runoff coefficient, C

Humid catchment

Average Ground Slope		Soil Permeability			
		Very low (rock & hard clay)	Low (clay loam)	Medium (sandy loam)	High (sand & gravel)
Flat	0-1%	0.55	0.40	0.20	0.05
Gentle	1-4%	0.75	0.55	0.35	0.20
Rolling	4-10%	0.85	0.65	0.45	0.30
Steep	>10%	0.95	0.75	0.55	0.40

Semi-arid catchment

Average Ground Slope		Soil Permeability			
		Very low (rock & hard clay)	Low (clay loam)	Medium (sandy loam)	High (sand & gravel)
Flat	0-1%	0.75	0.40	0.05	0.05
Gentle	1-4%	0.85	0.55	0.20	0.05
Rolling	4-10%	0.95	0.70	0.30	0.05
Steep	>10%	1.00	0.80	0.50	0.10

Intensity of rainfall (I)

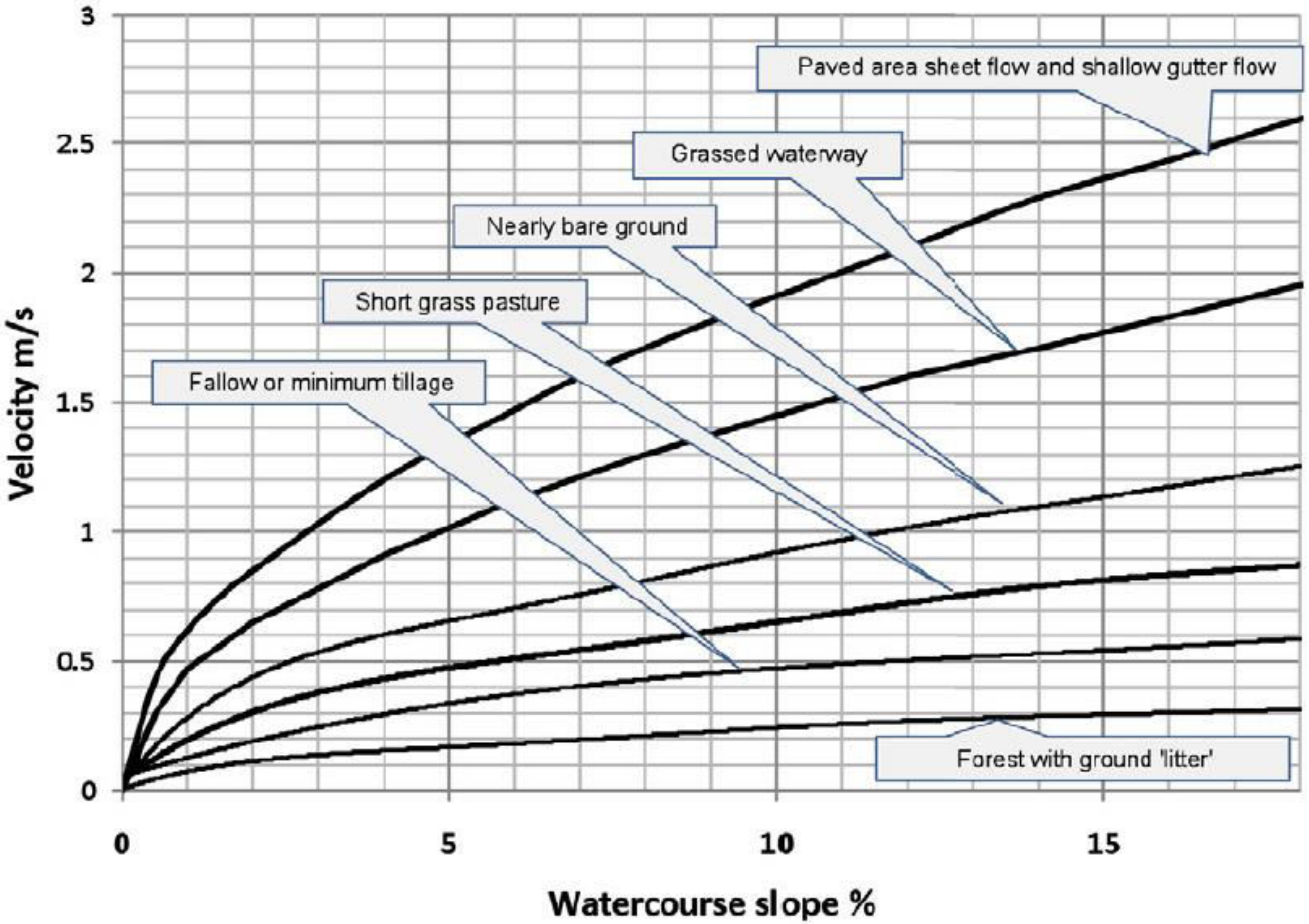
The intensity of rainfall (I) is obtained from the Intensity-Duration-Frequency charts

The storm duration is equal to the Time of Concentration (Tc).

Tc = Distance from farthest extremity (m) / Velocity of flow (m/s)

Velocity of flow depends on catchment characteristics and slope.

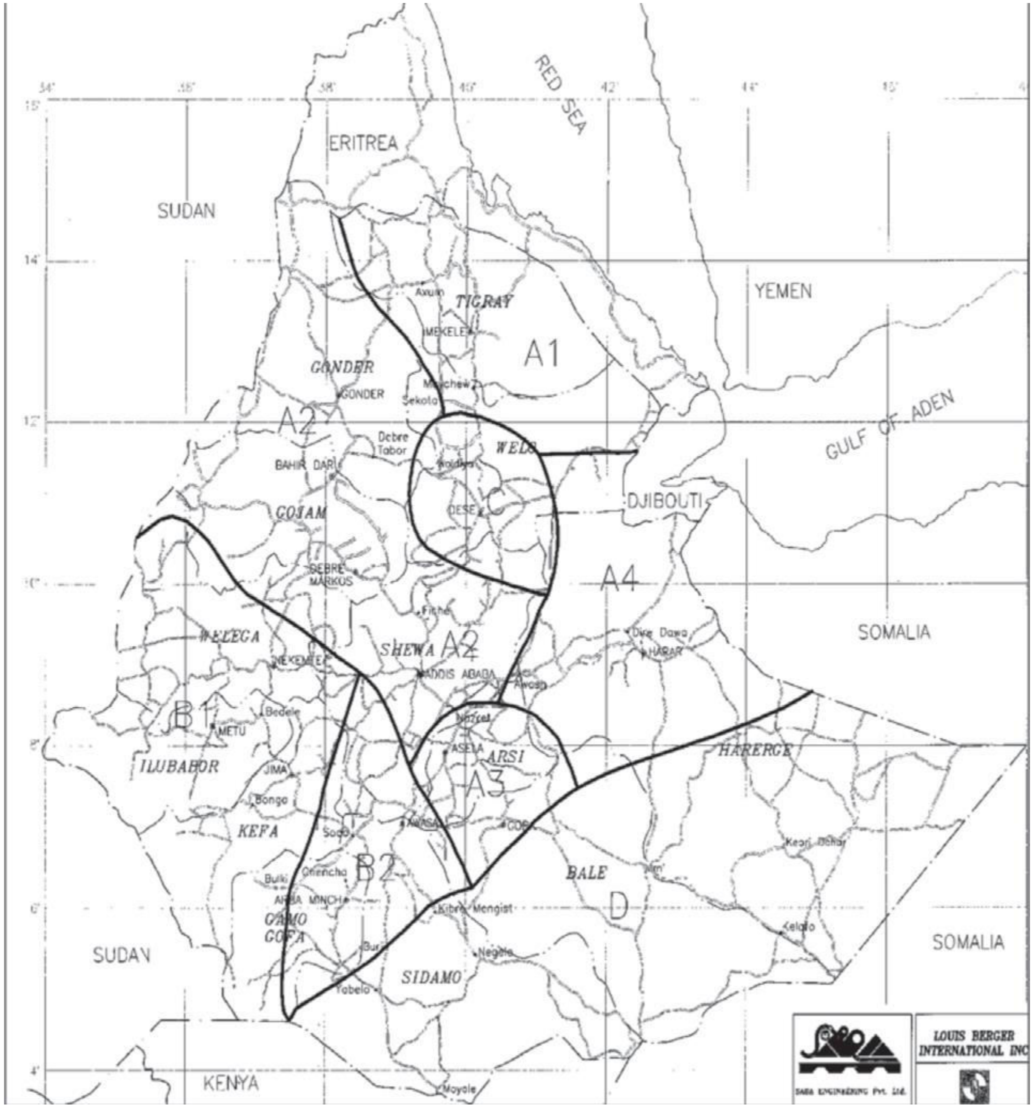
Velocity of flow



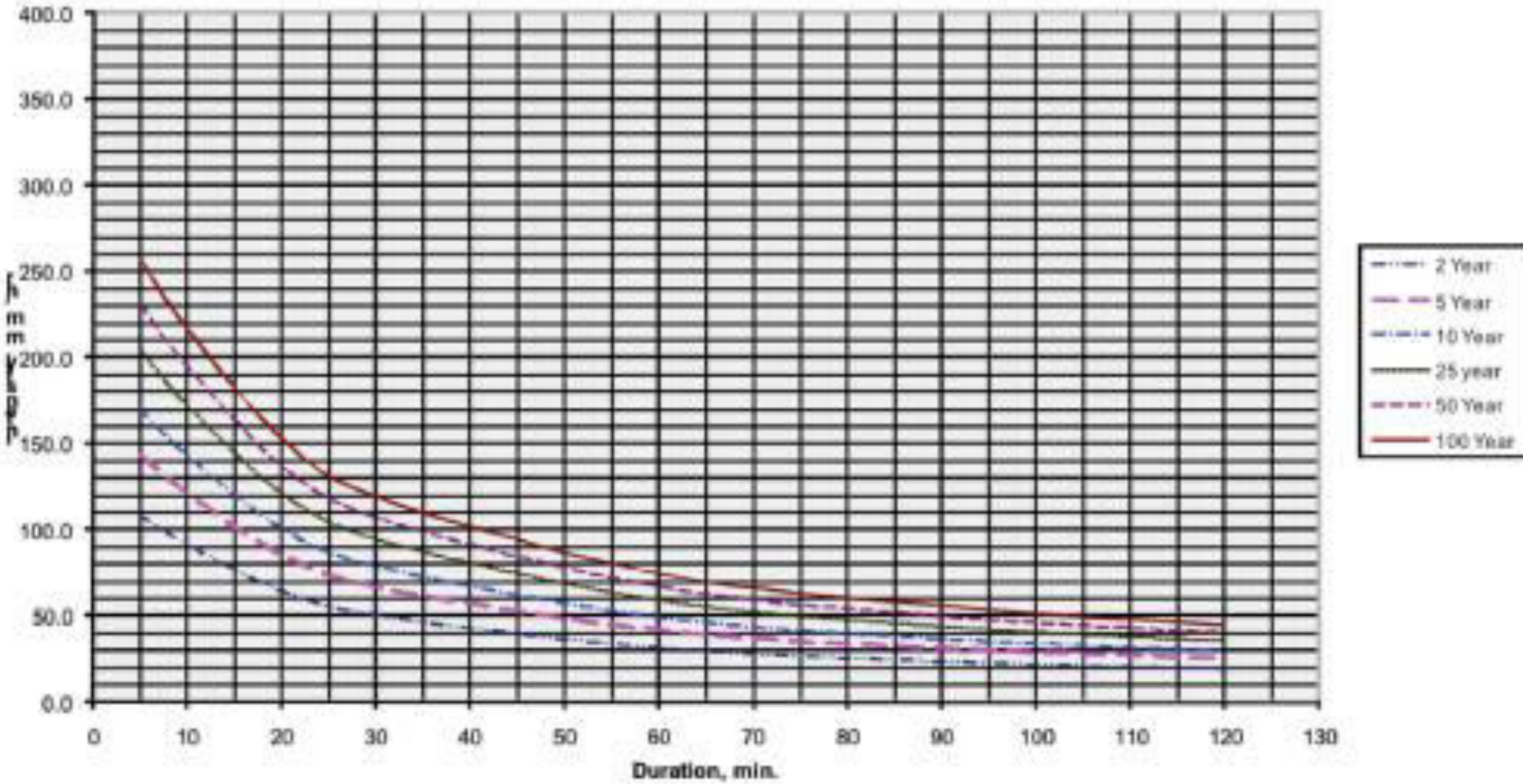
Storm design return period (years)

Structure type	Geometric design standard			
	DC4	DC3	DC2	DC1
Gutters and inlets	2	2	2	1
Side ditches	10	5	5	2
Ford	10	5	5	2
Drift	10	5	5	2
Culvert diameter <2m	15	10	10	5
Large culvert diameter >2m	25	15	10	5
Gabion abutment bridge	25	20	15	-
Short span bridge (<10m)	25	25	15	-
Masonry arch bridge	50	25	25	
Medium span bridge (15 – 50m)	50	50	25	-
Long span bridge >50m	100	100	50	-

Intensity-Duration-Frequency charts



Intensity-Duration-Frequency charts A1 and A4



Rationale method worked example

Catchment location	Tigray, A1
Catchment area, A	3.6 x 2.2 = 8 km2
Slope	12%
Ground surface	Nearly bare ground
Overland velocity	1m/s
Soil permeability	Low
Climate	Semi-arid
Run-off coefficient, C	80%

Tc = 3600(m)/1(m/s) = 3600 seconds = 1 Hour

Design period	25 years
Rainfall, I	60mm

Rationale method worked example

$$q = 0.278 \times C \times I \times A \ (m3/s)$$

$$q = 0.278 \times 0.8 \times 60 \times 8$$

$$q = 107 \ m3/sec$$

Modifying runoff coefficient for antecedent moisture conditions

CN values		
Average conditions	Dry	Wet
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50

Larger catchments

A simple modification can be made to take account of spatial variation in rainfall intensity across a larger catchment. The effective area of the catchment is reduced by multiplying by the areal reduction factor (ARL):

$$ARL = 1 - 0.04 \times t^{1/3} \times A^{1/2}$$

Where,

t = storm duration in hours

A = catchment area in km2

Weaknesses in the rational method?

Very broad classes and assumptions assumed to hold across a catchment. On larger catchments

For example:

- ❖ Soil types and permeability
- ❖ Rainfall areas and climate categories
- ❖ Run-off velocity

Use real life experience to test validity of estimate and adjust accordingly

Good luck

Supported by:

Developed by: