Geometric Design Requirements to Improve Surface Drainage

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Arup

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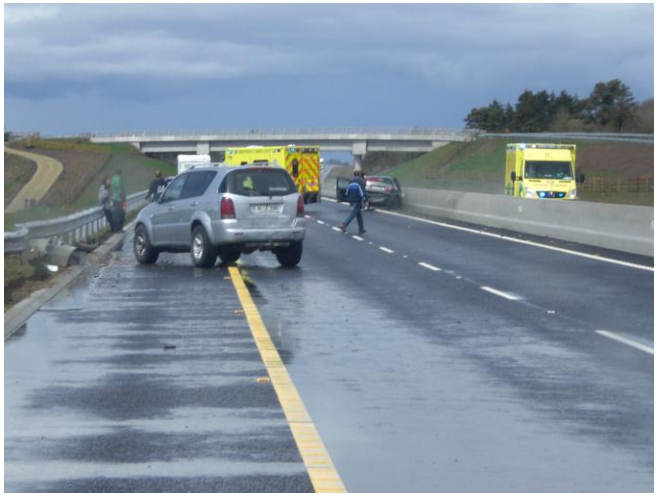
Reason for developing IAN 09/13

- Road geometry constructed that does not facilitate adequate surface drainage of carriageways
- ‘Flat spots’ being created on the National Road Network which can result in aquaplaning and serious accidents.



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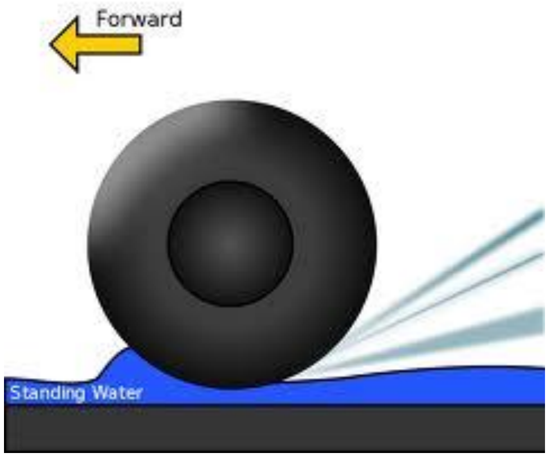
Purpose of IAN 09/13

- To provide mandatory design requirements that shall be implemented by the designer to allow adequate surface drainage of carriageways by:

    1) Providing a methodology for **calculating water depths** on the carriageway (Gallaway) and providing **limiting criteria** for these.

    2) Increasing **the minimum resultant gradient** allowable on the road pavement from **0.5%** to **1%**



What is aquaplaning?

- **Aquaplaning** occurs when a vehicle's tyres are partially or fully separated from the road surface by a film of water which results in loss of control in the vehicle.
- Different to **skidding**, as no separation of the tyre and road when a vehicle skids.
- **Partial Aquaplaning** is a combination of aquaplaning and skidding

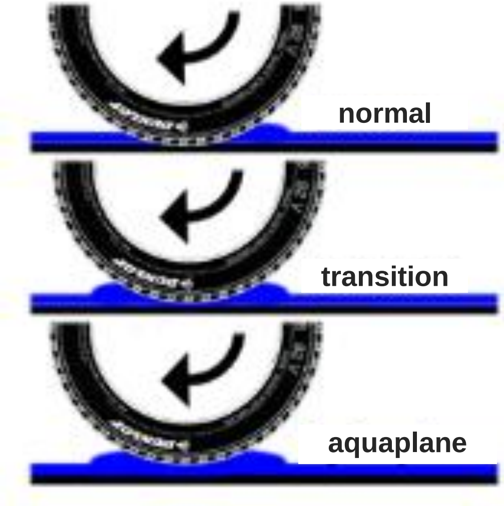
Source : Foucard (2005)

Contributory Factors to Aquaplaning

- Road geometry;
- Drainage design and maintenance regimes;
- Surface characteristics;
- Design / Operating speed;
- Rainfall intensity;
- Water film depth;
- Vehicle characteristics (tyre tread depth, tyre pressure etc.); and
- Driver behaviour.

Aquaplaning potential can be assessed by:

- Determining the expected water film depth, D, for a given flow path across a carriageway
- Checking estimated water depth against acceptable limits



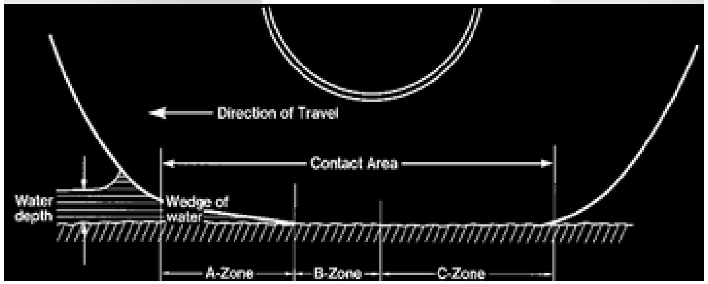
Background to Water Film Depth Calculation

- Formula for Water Film Depth developed in 1968 by the RRL (UK). In use in New Zealand but conservative.

- Methodology developed by Gallaway et al in 1979 in cooperation with the Federal Highway Administration

- Methodology included in the Texas Department of Transportation Hydraulic Design Manual and more recently in Austroads. In use for over a decade with proven results.

- Problematic rollover sections on Irish Roads analysed to ensure robustness.



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How to determine Water Film Depth, D to reduce Aquaplaning

- Equation developed by Gallaway to calculate water film depth, D

$$D = \frac{0.103 \times T^{0.11} \times L^{0.43} \times I^{0.59}}{S^{0.42}} - T$$

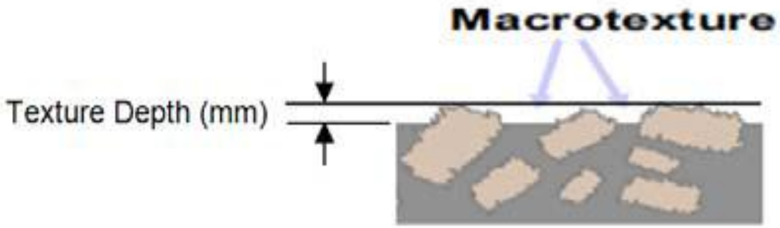
- Where,

  - D = Water film depth above the top of pavement texture (mm)
  - T = Average pavement texture depth (mm)
  - L = Length of drainage path (m)
  - I = Rainfall intensity (mm/hour)
  - S = Slope of drainage path (%)

Step A - Assumptions

- Standard Motorway (D2M) cross section with 120km/h design speed.

- Average **pavement texture depth, T, of 0.4mm** which allows for the deterioration of the road surface



- Minimum **rainfall intensity, I,** of 50mm/hr

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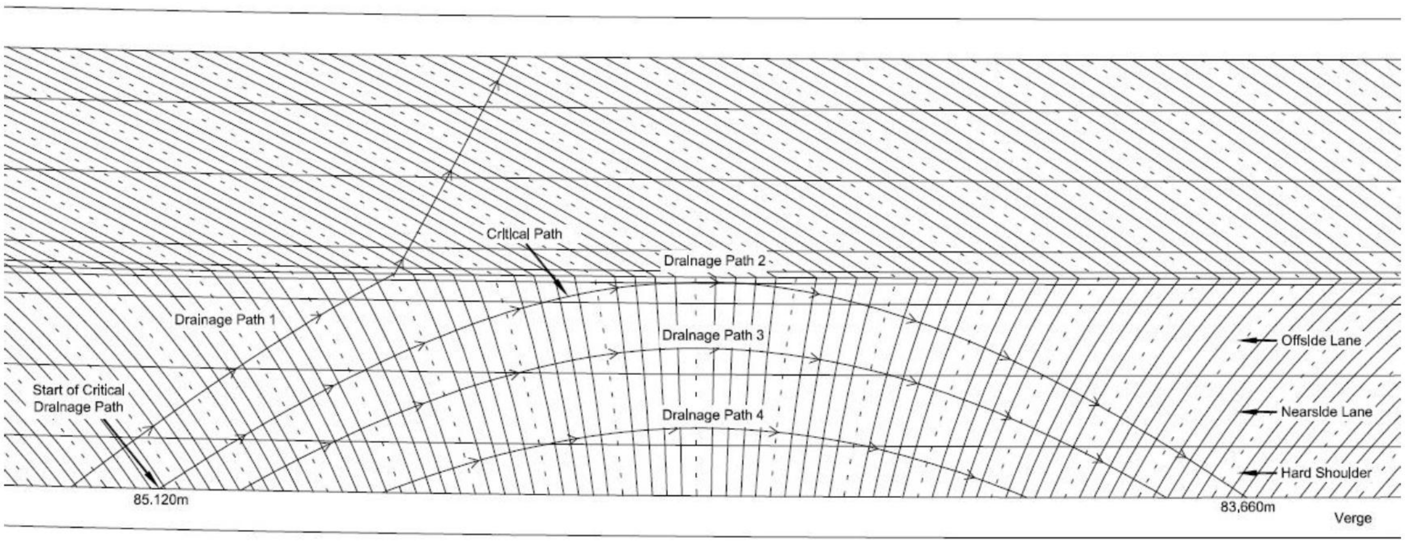
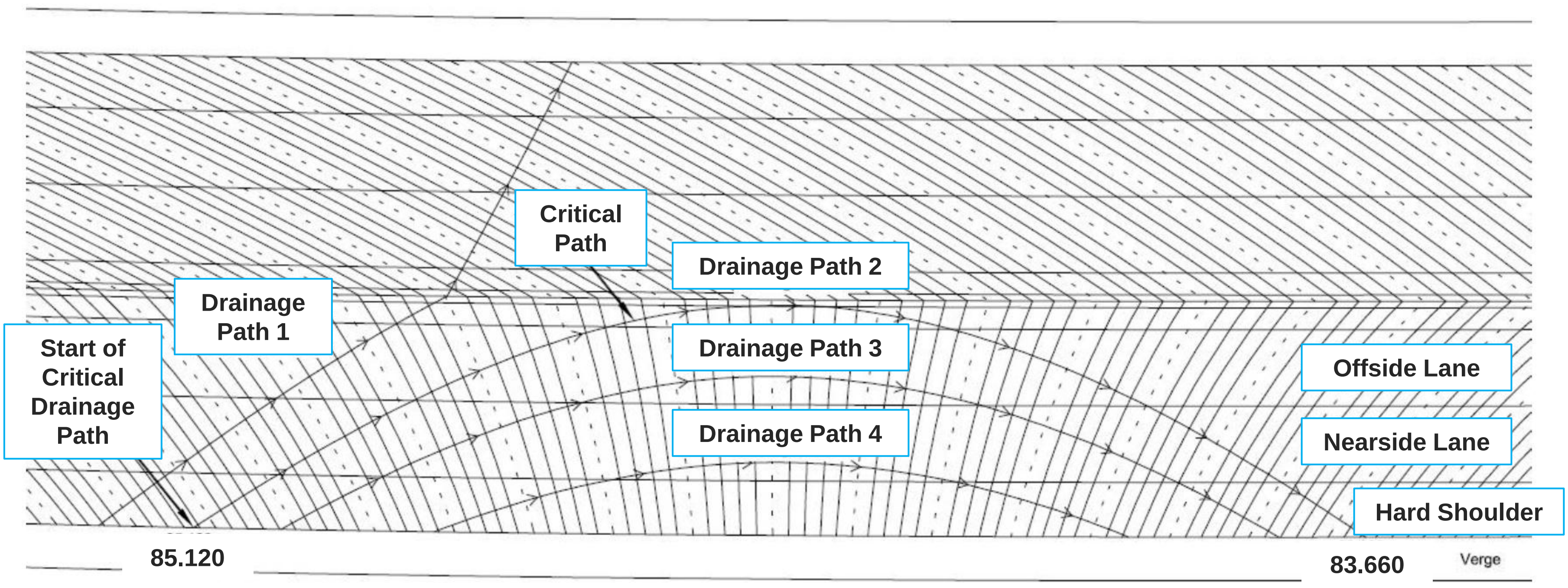
Step B - Calculate Length of Drainage Path, L

- The designer shall determine the **drainage path length** by plotting and assessing the contours on the proposed road surface.
- The **drainage path** is the route taken by rainfall runoff from the point at which it falls on the carriageway to the carriageway edge.
- The water depth analysis shall be carried out on the **critical drainage path**, i.e. the longest drainage path on the carriageway within the assessment location.



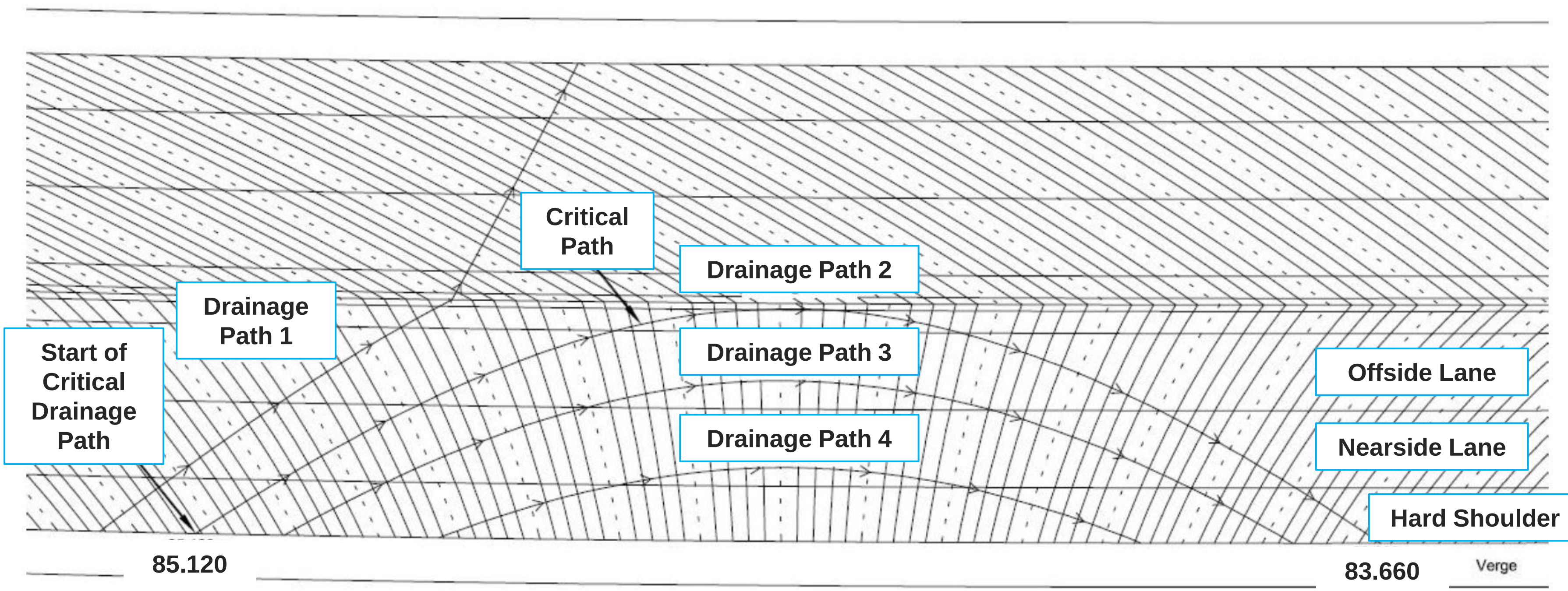
Step B - Calculate Length of Drainage Path, L

- **Drainage path 1** represents the flow path with superelevation still applied, with water flowing from one side of the carriageway to the other and is **not the critical path**.



Step B - Calculate Length of Drainage Path, L

- **Drainage paths 2, 3 and 4** all start on one side of the carriageway, travel towards the other side but then drain off on the same side of the carriageway as they started.
- The longest path is the critical path; therefore **drainage path 2** is assessed to determine the water film depth. The **overall length, L,** of this path is **58.596m.**



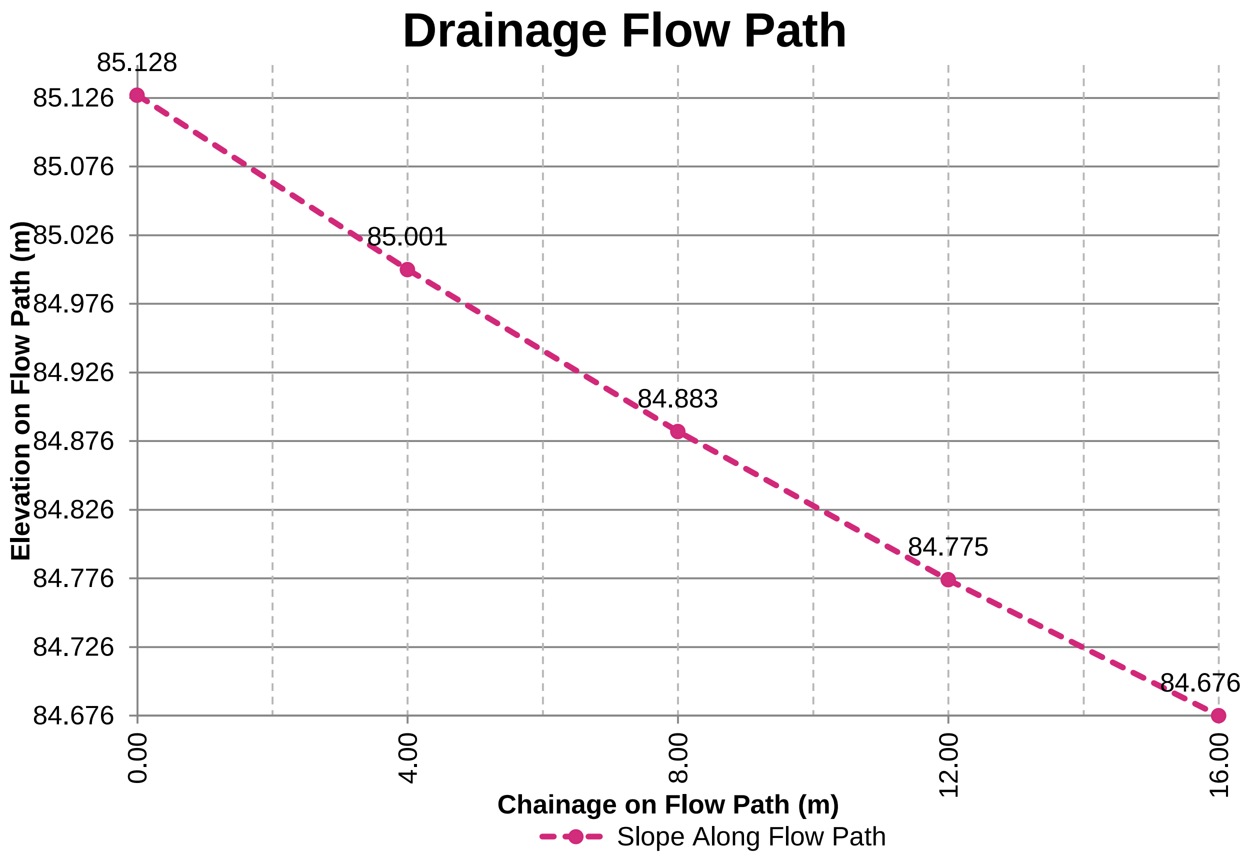
Step B - Length of Drainage Path and Flow Path Elevations

The **drainage flow path lengths** and **flow path elevations** are extracted from the three dimensional model

	Chainage / Drainage Flow Path Length (m)	Flow Path Elevation (m)
Start of Drainage Path 2	0	85.128
	4	85.001
	8	84.883
	12	84.775
	16	84.676
	20	84.584
	24	84.499
	28	84.417
	32	84.336
	36	84.253
	40	84.166
	44	84.071
	48	83.969
	52	83.858
	56	83.737
End of Drainage Path 2	58.596	83.653

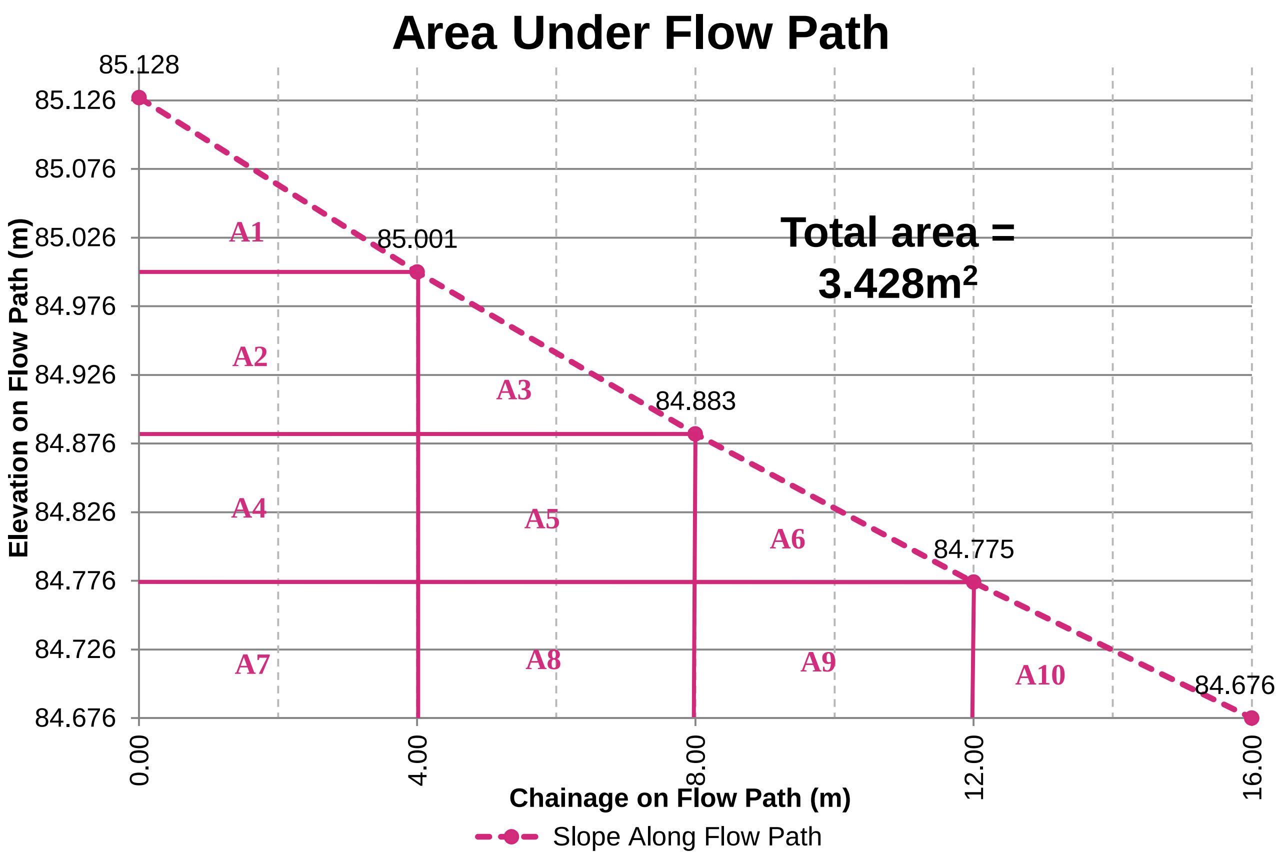
Step C – Estimate Slope of Drainage Path, S

The profile of the flow path is plotted from the **highest point** at the start of the drainage path up to the **point of analysis**



Step C – Estimate Slope of Drainage Path, S

The **total area** under the drainage flow path is calculated from the **start chainage** up to the **point of analysis**



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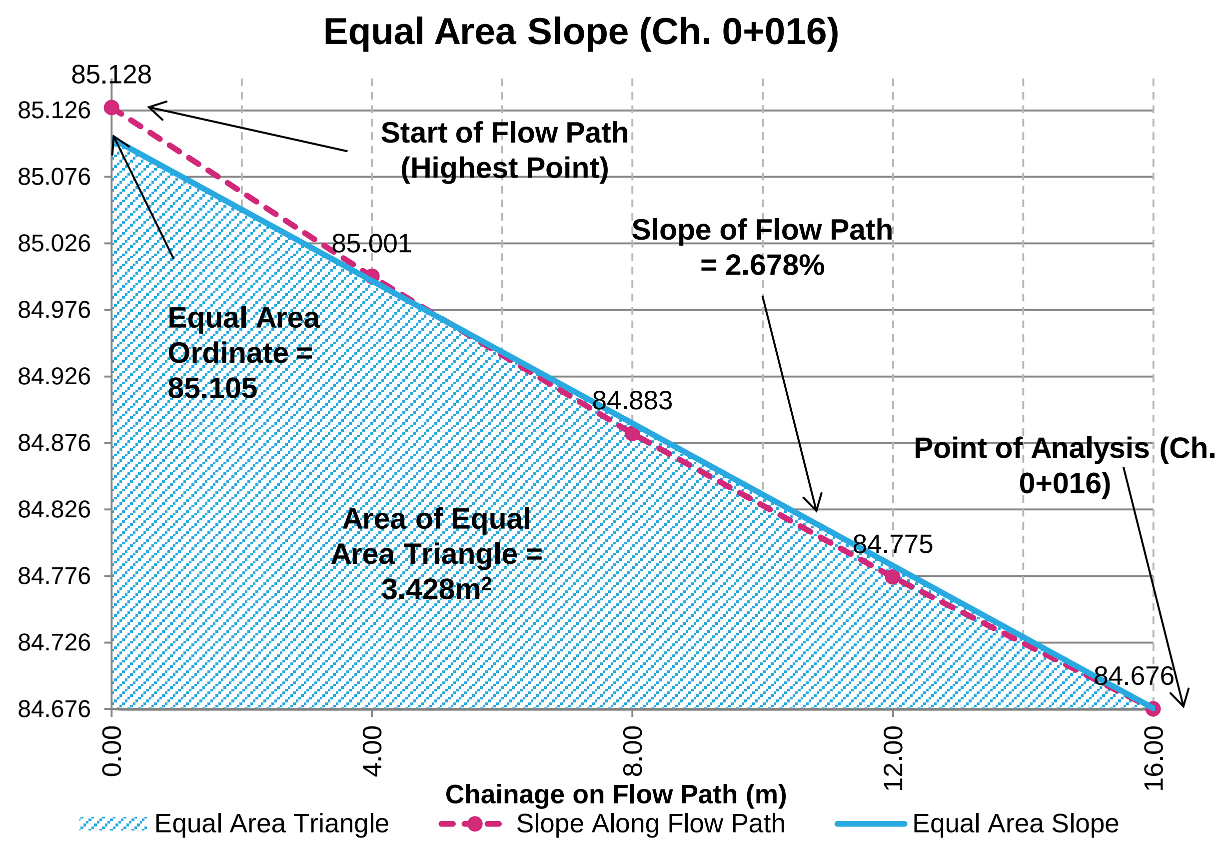
Step C – Estimate Slope of Drainage Path, S

The **Equal Area Slope, S,** is calculated



Vertical Ht of Equal Area Triangle

$= \frac{\text{Area}}{2 \text{ x Length}} = 0.429$

Vertical ordinate of Equal Area Triangle

= 84.676 + 0.429 = 85.105

Slope of Equal Area Triangle =

2.678 %

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Step C – Estimate Slope of Drainage Path, S

Chainage / Drainage Flow Path Length (m)	Flow Path Elevation (m)	Difference in Elevation (m)	Total Area (m^2)	Height of Equal Area Triangle (m)	Equal Area Ordinate (m)	Equal Area Slope (%)
0	85.128	-	-	-	-	-
4	85.001	0.127	0.254	0.127	85.128	3.175
8	84.883	0.118	0.962	0.241	85.124	3.006
12	84.775	0.108	2.042	0.340	85.115	2.836
16	84.676	0.099	3.428	0.429	85.105	2.678
20	84.584	0.092	5.084	0.508	85.092	2.542
24	84.499	0.085	6.954	0.580	85.079	2.415
28	84.417	0.082	9.086	0.649	85.066	2.318
32	84.336	0.081	11.516	0.720	85.056	2.249
36	84.253	0.083	14.338	0.797	85.050	2.213
40	84.166	0.087	17.644	0.882	85.048	2.206
44	84.071	0.095	21.634	0.983	85.054	2.235
48	83.969	0.102	26.326	1.097	85.066	2.285
52	83.858	0.111	31.876	1.226	85.084	2.358
56	83.737	0.121	38.410	1.372	85.109	2.450
58.596	83.653	0.084	43.223	1.475	85.128	2.517

The **Equal Area Slope %** is assessed at **each point**

Step D – Water Film Depth, D

The **Water Film Depth, D,** at each point is calculated $= \frac{0.103 \times T^{0.11} \times L^{0.43} \times I^{0.59}}{S^{0.42}} - T$

Chainage / Drainage Flow Path Length (m)	Flow Path Elevation (m)	Equal Area Slope (%)	Water Film Depth (mm)
0	85.128	-	0
4	85.001	3.175	0.646
8	84.883	3.006	1.042
12	84.775	2.836	1.359
16	84.676	2.678	1.640
20	84.584	2.542	1.895
24	84.499	2.415	2.136
28	84.417	2.318	2.357
32	84.336	2.249	2.557
36	84.253	2.213	2.732
40	84.166	2.206	2.881
44	84.071	2.235	3.000
48	83.969	2.285	3.097
52	83.858	2.358	3.172
56	83.737	2.450	3.229
58.596	83.653	2.517	3.258

$$\text{Maximum water film depth, D max} = \frac{0.103 \times (0.4)^{0.11} \times (58.6)^{0.43} \times (50)^{0.59}}{(2.52)^{0.42}} - 0.4 = 3.258mm$$

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Assessment Criteria / Maximum Water Film Depth Limits

Water Film Depth Limits

- A maximum water film depth of **2.5mm** shall apply to new single carriageway roads.

- On Motorways and Dual Carriageways, as the 2.5mm limit can be very difficult to achieve, a maximum value of **3.3mm** shall be adopted.

- Road surface geometry shall be such that **flow path lengths** are limited **60m.**

Where the design does not comply with these requirements, the aquaplaning potential is considered **too high** and a redesign will be required.

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To Reduce Aquaplaning Potential / Water Film Depths

- **Alter the horizontal or vertical alignments** to reduce drainage flow path lengths
- Alter the alignment to **re-locate the rollover** to a section with sufficient longitudinal gradient
- Adjust the **rate of superelevation development** or **increase crossfalls** to steepen drainage flow paths
- Consider introducing **additional crown lines** (diagonal or longitudinal crowns).

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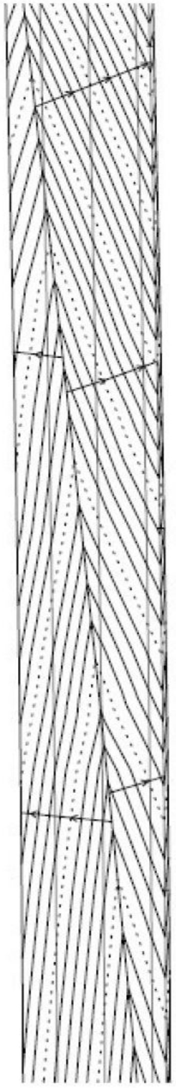
Rolling Crowns

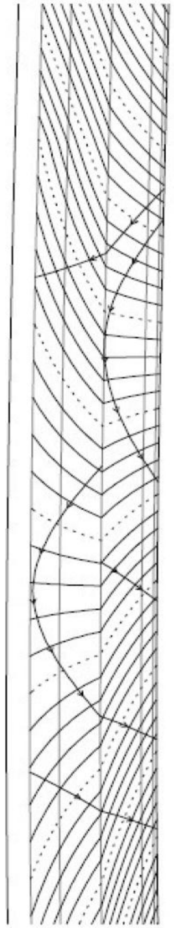
- Solution to surface water problems at rollover locations on existing roadways.
- Eliminates point of zero crossfall
- Edge drainage required on both sides of carriageway
- Alternatives should be sought before use as **issues with constructability**
- A **departure** on high speed roads



Rolling Crown

Independent Lane Rotation (Staggered Rollover application)

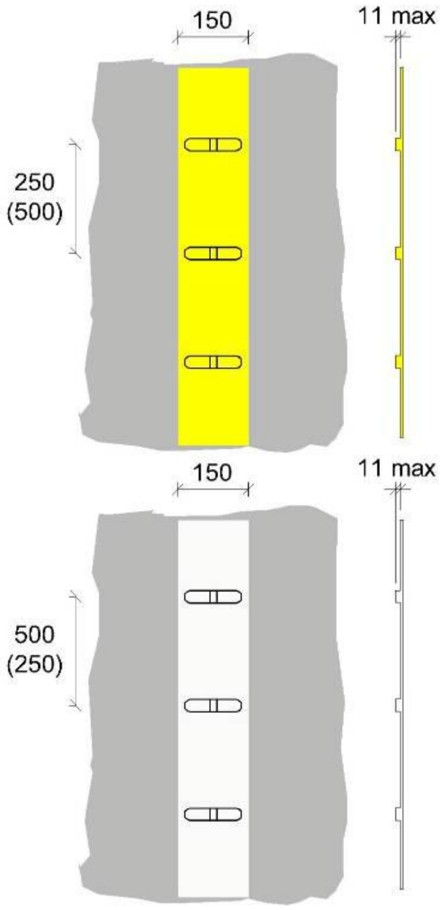
- Independent lane rotation can be used by the designer to apply superelevation using a longitudinal offset between adjacent lanes.
- A **departure** on high speed roads



Longitudinal Crown (Staggered Rollover)

Effect of Carriageway Edge Markings

- Carriageway surface drainage can be affected by continuous edge markings, particularly where **raised rib markings** are used.
- Where continuous edge lines are used **drainage gaps** must be included to prevent surface water ponding
- The **spacing of drainage gaps** shall be **2m** at lower gradients and superelevation rollovers.



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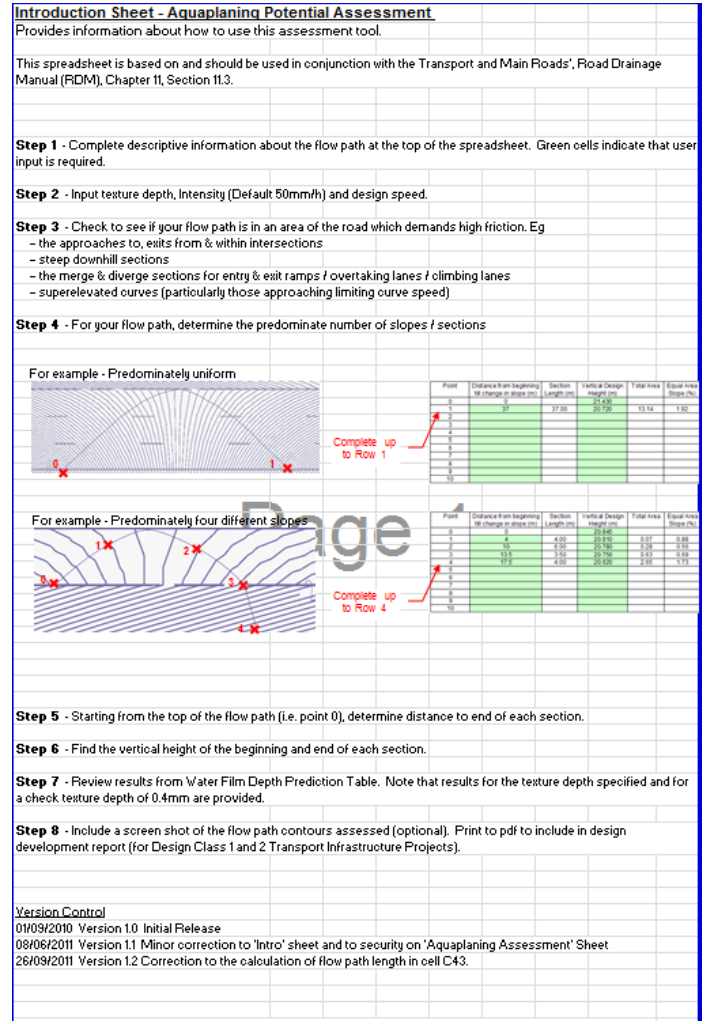
Aquaplaning Assessment Report

- Surface Contour drawings at each location assessed e.g. rollover locations
- Water film depth at each assessed location
- Submitted by e-mail to **Techsubs@nra.ie** under the subject heading **NRA IAN 09/13**



Thank You

Any questions?

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