Overview

PART 1 OF 5

The importance of road drainage

A steep, wet, sparsely gauged country with varying infrastructure standards

Roads are the only network there is

Two-thirds of the population live rurally. Roads are the only way to reach a market, a clinic or a school.

7,923 km	Total road network (DGRBPFC, 2025)
4,702 km	Rural roads — 59% of the network, mostly unpaved
One route	Most municipalities have a single primary connection to Dili

Where a failure hurts most

- Highest-criticality corridors: Dili–Baucau, Dili–Aileu–Same–Suai, and access to Tibar and Hera ports and the airport
- 35–40% of national roads traverse moderate to high landslide susceptibility
- Rural roads serving more than 5,000 people with no alternative route

What a closure costs

- US$15–25 million a year in emergency repair, at 3–5× the unit cost of preventive work
- Post-harvest losses of 10–15% in affected areas
- School attendance falls 30–50% while roads are impassable

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The network and its condition

Much of the network was built or rehabilitated 15 to 25 years ago, generally without climate considerations in the original design.

Classification	Length (km)	Surface	Reported condition
National	1,441	Mostly sealed	45% poor, 30% fair
District / collector	1,014	Mixed seal and gravel	60% require rehabilitation
Urban	766	Mostly sealed	Varies
Rural	4,702	Gravel and earth	60% poor; 30–40% impassable in the wet
Total	**7,923**		

Where the standards come from

National road geometry traces back to Indonesian manuals of 1980s and 1990s vintage. Drainage structures are frequently undersized for current rainfall intensity patterns.

Read the condition data with care

Percentages come from JICA (2019) and World Bank (2021) surveys, taken against an earlier network definition and before Cyclone Seroja. Actual condition is likely worse.

Terrain sets the problem

Short, steep catchments responding in minutes — not large river systems responding in days.

- More than 70% of the land area has slopes steeper than 15%; the central spine reaches 2,900 m
- Weathered sedimentary rock, volcanic deposits and limestone karst — erodible and slide-prone
- Alignments follow unstable hillsides and narrow valleys, so cut slopes and embankments are unavoidable
- Catchments are short and steep: runoff concentrates in under an hour and carries sediment and debris with it
- Wet season November to April; daily falls above 100 mm occur two to four times each season
- Mean annual rainfall ranges from about 800 mm on the north coast to 2,800 mm in the highlands

Timor-Leste is a flash-flood country and a floodplain country. The design event can vary from a intense half hour to a wet week.

What a culvert actually has to do

1 Take the water that arrives

Rain falls on the hillside above the road. Some soaks in; the rest runs downhill and arrives at one low point. The culvert has to accept whatever shows up in the worst storm we design for.

2 Carry it under the road

The pipe has to be big enough that the water fits. Too small, and the water backs up, ponds, and eventually flows over the road surface instead of under it.

3 Let it go safely

Water leaving a pipe is fast and concentrated. If the outlet is not protected it digs a hole, and that hole works its way back until it undermines the road.

4 Keep doing it when neglected

The pipe must still work after a season of leaves, branches and silt, in a place where nobody may inspect it until something goes wrong.

What actually fails: Cyclone Seroja, April 2021

Over 200 mm in 24 hours, with peak intensity above 70 mm/hr. Seroja was a stress test, not an anomaly.

US$307.7m
Total damage and losses

US$170m
Road and bridge damage

100+
Culvert washouts

15+
Major bridge failures

The recurring failure modes

- Small culverts under 1.5 m — blockage by debris is the most frequent failure mode, then scour
- Earthen embankments — erosion and saturation-induced slope failure where side drainage is inadequate
- Cut slopes — progressive wet-season failures where drainage or protection is absent
- Dili–Baucau corridor closed five days; Manufahi and Ainaro isolated for two to three weeks

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A sample of varying infrastructure

A changing climate - in intensity, not volume

The projected change is in intensity rather than annual volume, which is precisely what drainage design is sensitive to.

Hazard	Current frequency	Projected change by 2050	Primary road impact
Intense rainfall (>100 mm/day)	2–4 events per year	+15 to 30%	Flooding, washouts
Landslides	10–20+ major events per year	+20 to 40%	Road blockages
Coastal flooding	1–2 events per year	Increasing frequency	Inundation of low sections

What the models agree on

- 1-in-20 year daily rainfall: +10 to 25% by 2050 (CMIP6, SSP2-4.5) — high confidence
- Very wet days above the 95th percentile: +15 to 30% by mid-century
- Maximum 5-day totals: +10 to 20%
- Peak flood flows: +20 to 30%; today's 1-in-20 becomes a 1-in-8 to 1-in-10 event

What they do not agree on

- Annual total rainfall could move anywhere from −5% to +10% by 2050
- The dry season is likely to lengthen, but by how much is uncertain
- Cyclone frequency and track migration remain poorly constrained
- Designing to annual averages would miss the signal entirely
- Local subsidence rates, which may add 10 to 30% to relative sea-level rise in some areas

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What that changes in the design inputs

The climate signal converts into specific, checkable changes to design parameters.

Design element	Current practice	Climate-resilient update
Rainfall (IDF) inputs	Historical data, pre-2000s, or none	Climate-adjusted, 1.15–1.25 multipliers
Culvert design storm	1-in-10 to 1-in-20 year	1-in-50 year on national roads; 1-in-20 secondary
Minimum culvert diameter	600–900 mm common	1,200 mm in debris-prone catchments
Drainage freeboard	Minimal or none	0.3 to 0.5 m above design flood level
Blockage and debris	Rarely considered explicitly	Explicit allowance; inlet and outlet protection
Maintenance regime	Reactive, budget-limited	Proactive and climate-triggered

Three of these are what the rest of this presentation is about: a climate multiplier on rainfall intensity, a rainfall zone drawn from the spatial variation, and an explicit blockage allowance.

Design for intensity, not for annual totals. A day of rain and an intense half hour storm are different design problems.

The standards are older than the climate

- Timor-Leste has largely relied on rainfall design data developed before independence — now more than twenty-five years old, and of uncertain provenance
- There is no single national road design manual integrating geometry, pavements, drainage, structures and maintenance
- Those rules carry no allowance for climate change, because they predate its routine inclusion in engineering practice
- Blockage is not addressed at all: the rules quietly assume drainage is cleaned
- Design intensity is backward-looking - and outdated rules cause waste as well as failure

The consequence cuts both ways

Outdated standards do not only cause failures. They also cause waste.

Some structures are under-designed and fail. Others are over-designed and consume scarce capital that the strategic corridor needed.

Right-sizing is a development argument, not only a safety one.

The data that does not exist

What Timor-Leste has

- 37 rainfall stations, around 15 years of record
- Daily totals: how much fell that day
- Good enough to describe climate and seasonality
- Good enough to map wet regions against dry ones
- Well-distributed across the country
- A genuine asset — just not at the resolution this particular job needs

What drainage design needs

- Rainfall measured every 5 minutes, not every day
- Peak intensity inside the storm, not the daily sum
- Because a hillside culvert responds in 10 to 30 minutes
- Road drainage is governed by 10- to 60-minute durations
- A daily total says almost nothing about the hour that caused the failure

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Capacity, maintenance and software

Three institutional constraints that change what a correct design looks like.

1

Few specialists, many culverts

A national network holds thousands of drainage structures. The number of engineers who can run a full hydraulic model is very small, concentrated in the capital, and in demand elsewhere. Any method that requires that scarce skill for every routine culvert will not be applied at the scale needed.

2

Maintenance cannot be assumed

Routine drainage cleaning competes with emergency repairs. Culverts here need clearing two to four times a wet season; many are cleared only after a visible failure.

3

The software that never arrives

Specialist hydraulic packages carry per-seat licence costs hard to justify against a district roads budget. Licences expire, dongles are lost, trained staff move on, and model files become unreadable. The design then gets done by rule of thumb, and nothing is written down.

A tool that is technically superior and never opened is worth less than a rough tool that is used on every culvert.

The design principle behind everything that follows

PART 2 OF 5

The background work: a design rainfall basis

Why this matters | **Design rainfall** | The two tools | Why simple & open | Limits & roadmap

Two gaps the February 2026 workshop identified

The Terms of Reference for the Climate-Resilient Road Infrastructure Standards Study named both, and this assignment provides the specialist input.

1 Rainfall measurement

No Timor-Leste intensity–duration–frequency dataset exists. Design rainfall is borrowed and scaled. Short-duration intensity — the driver of culvert capacity — is the least reliable part of it.

2 Treatment of blockage

Blockage is not represented in hydraulic design. There is no repeatable, documented way to decide how much of a culvert to assume is unavailable, or which culverts to inspect first.

What the Terms of Reference asked for

- Conduct a rapid desktop assessment of selected culverts within the project area
- Identify environmental, hydraulic and design factors contributing to blockage risk
- Develop a tool to estimate likely percentage blockages for culverts
- Provide recommendations for risk-based inspection and maintenance prioritisation
- Recommend rainfall gauges capable of recording at 5-minute intervals
- Deliver something usable by engineers without specialised modelling software

Design rainfall is the anchor

1

It must match reality, now and later

Design rainfall has to reflect what actually occurs at the site, and what will occur across the design life of the road — a culvert built today will still be in service in the 2050s.

2

It underpins every calculation

Culverts, bridges, infiltration, scour protection and energy dissipation are all sized from it. It is not one input among many.

3

An error propagates everywhere

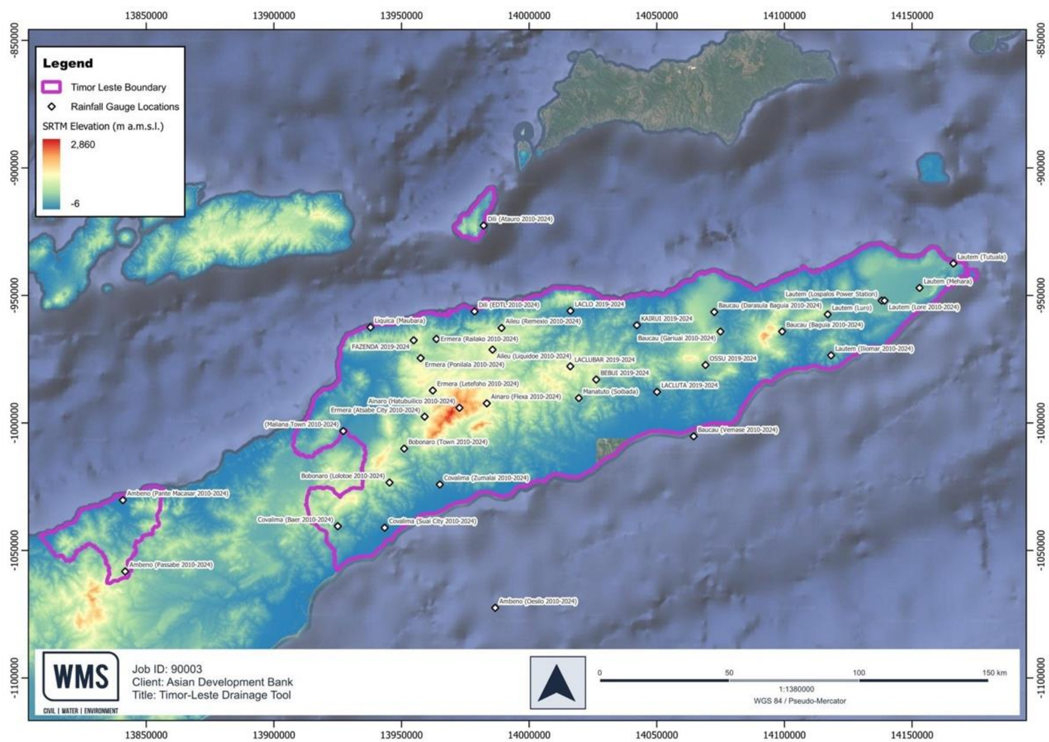
Get the intensity wrong and every structure on the corridor has the potential to be under or oversized.

The task we set ourselves

- Build an intensity–duration–frequency relationship for Timor-Leste
- Make it valid at durations under one hour, where the catchments respond
- Cover the whole country, not only the gauged sites
- Allow it to be factored for climate projections
- Make it replaceable once local data exists

Available rainfall data

Timor-Leste has 37 rainfall gauges with about 15 years of record. They are well distributed — but they measure daily totals.



Rainfall gauge locations, Timor-Leste

The mismatch

- 37 gauges, roughly 15 years of record
- Daily rainfall only — one number per day
- Catchments here often respond in under an hour

What that record can and cannot do

It is genuinely good data — long enough and well enough distributed to describe where the country is wet and where it is dry.

It simply cannot tell you the intensity of the half hour that washed the culvert out.

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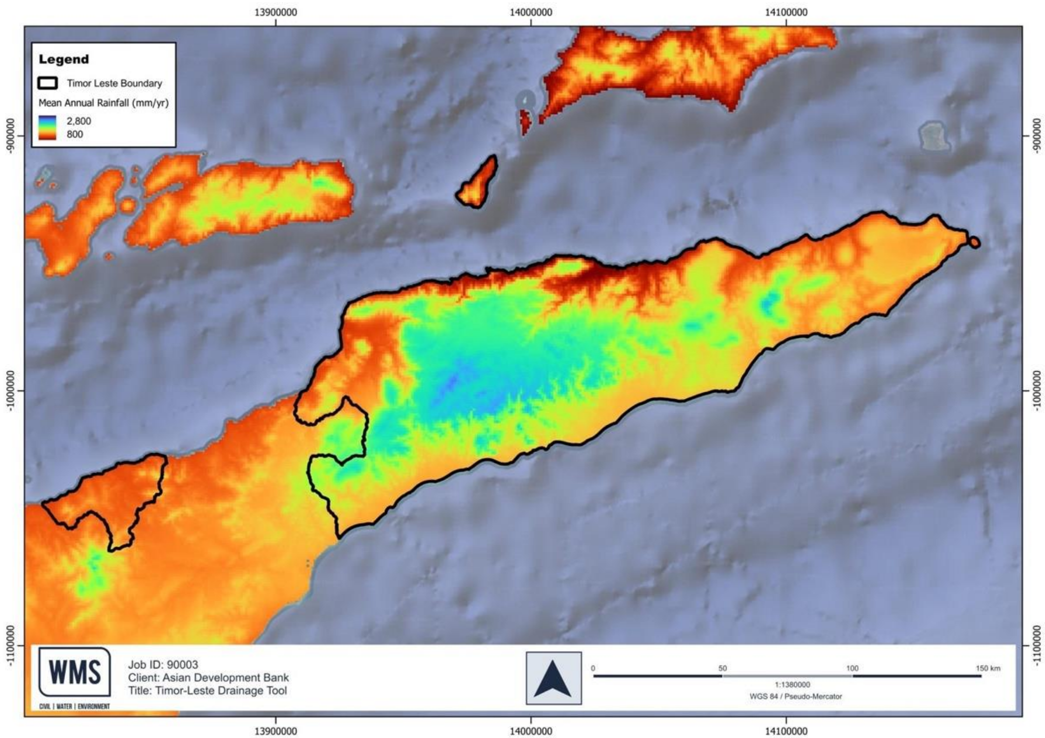
What the gauges do tell us

Mean annual rainfall varies from about 800 mm to 2,800 mm, and the variance largely follows the topography.



Mean annual rainfall — strongly orographic

Why this matters

A single national design rainfall would be wrong nearly everywhere.

- North coast: 1,000–1,500 mm annually, strongly seasonal, in a rain shadow
- South coast: 1,500–2,000 mm, more evenly distributed, direct monsoon exposure
- Central highlands: 2,000–2,500+ mm, orographic enhancement, highest intensities
- The highlands receive more than three times the driest coastal total
- The pattern is spatially continuous — which means it can be mapped, and therefore zoned

What an IDF relationship really needs

Ideally 30 years or more of continuous pluviograph record at sub-hourly resolution. That is a demanding standard almost anywhere.

The ideal

- 30 years or more of continuous pluviograph record at 5-minute intervals
- Wide spatial distribution of gauges, for a country with this geography
- Rigorous, documented quality control of the record

The reality, everywhere

- Gauges must be well located and well maintained — both are demanding over 30 years
- A large share of sub-daily data typically has to be discarded when developing IDFs
- Gauges suited to disaster management are not always suited to IDF development
- Even where everything is perfect, the record looks backwards in time

Timor-Leste is not unusually badly off. Very few countries in the region hold a thirty-year, five-minute record either - which is why a defensible interim basis matters more than waiting for a perfect one.

Working around missing sub-daily data

Three options, none of them free of compromise.

1

Satellite-derived rainfall

Continuous spatial coverage, and it exists today. But the intensity estimates are indirect and need calibration against ground gauges to be trusted at sub-hourly durations.

2

Formulas that split daily totals

Divide a daily total into shorter increments using an empirical relationship. Cheap, and it uses the data we actually have. The Mononobe formula is the most widely used, largely because it is the simplest.

3

Borrow another country's data

Take an IDF from a climatically comparable location that does hold a proper pluviograph record, and scale it. Transparent, and immediately available.

Option 2 in practice

- Mononobe's weakness is durations shorter than six hours — and durations under one hour are exactly what road cross drainage needs
- More rigorous alternative methods exist, but the sub-daily data required to apply them does not

Option 2 - The recipe did not hold

Annual maxima → Mononobe split to mm/hr → fit a curve (Ishiguro, Sherman or Talbot) → new IDFs.

What came out

- The resulting IDFs sat lower than the intensities already in use
- The outcomes did not sit right against observed storm behaviour
- Mononobe's limitation below six hours is the likely cause

So we looked regionally

- Indonesia — appears to have been developed with the same Mononobe approach
- Papua New Guinea — not using IDFs
- Malaysia — short-duration data uncertain
- Fiji — Nadi Airport holds 10-minute data from 1951 to 2006; distant, but monsoon-driven tropical

The test we set for any adopted IDF

A **Defensible at durations under one hour**

That is where these catchments actually respond, and where the failures happen.

B **From a rigorous, documented process**

Someone else must be able to audit how the numbers were produced, years from now.

C **From a climate that behaves like Timor-Leste's**

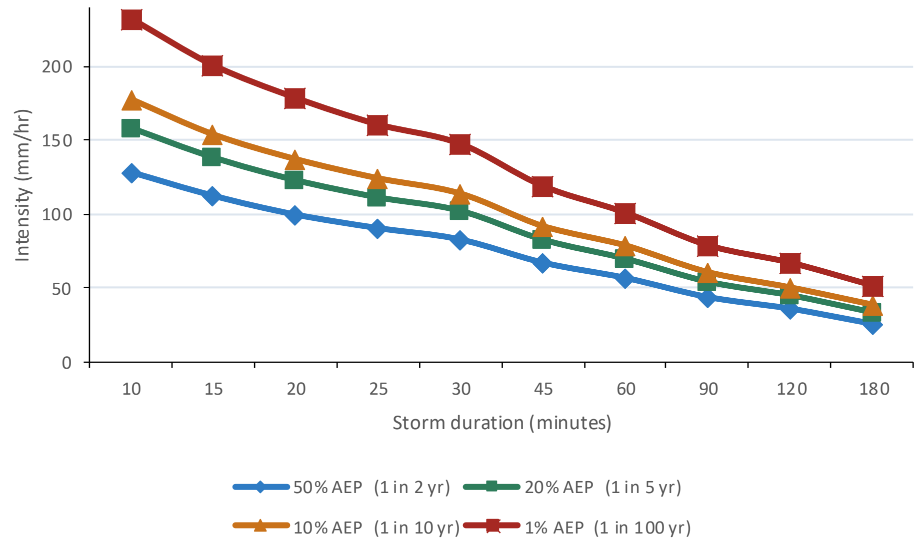
Monsoon-driven tropical, with convective storms of comparable structure.

Why Darwin

Australia has just completed an intensive 15-year project to rebuild its intensity–duration–frequency curves nationally.

- Led by the Bureau of Meteorology, with a rigorous documented process to eliminate erroneous data, and extensive industry testing
- Darwin is a few hundred kilometres away and has a genuinely similar monsoon-driven tropical climate
- Less than 5% variation in intensity across Australia's tropical north zone, so the choice of station within that zone is not critical
- It supplies real sub-hourly intensities from a pluviograph record, rather than a formula applied outside its valid range

Darwin design rainfall intensity — the parent dataset

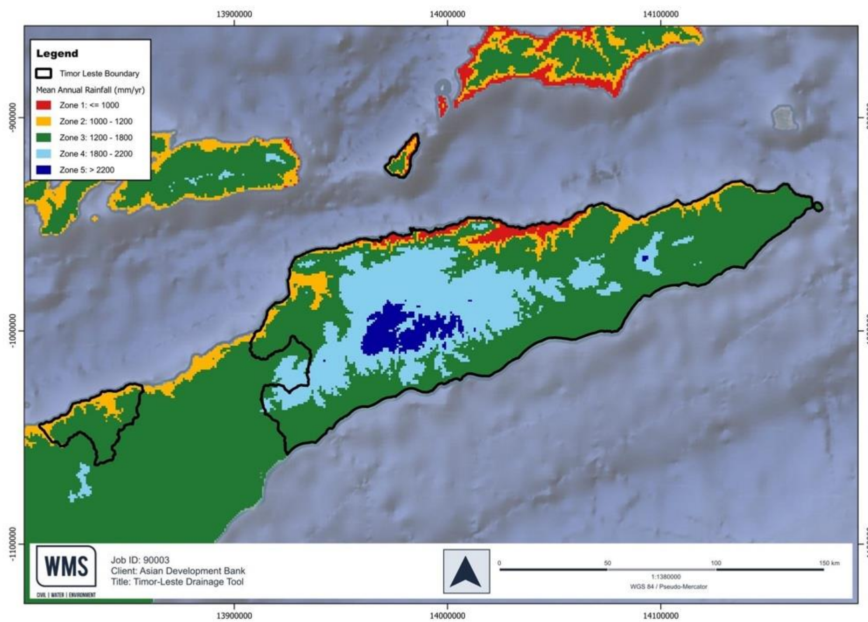


Darwin — a few hundred kilometres south, in the same monsoon system

Every value is multiplied by the rainfall-zone factor, and then by the climate multiplier. The shape of the curve comes from Darwin; the magnitude comes from Timor-Leste rainfall, and the future comes from a stated scenario.

Five rainfall zones, not one national number

The country is divided into five zones on mean annual rainfall, and the Darwin IDF is factored onto each.



Rainfall zone map

Zone	Mean annual rainfall	Scaling factor (as built)
Zone 1	< 1,000 mm/yr	0.60
Zone 2	1,000 – 1,200 mm/yr	0.70
Zone 3	1,200 – 1,800 mm/yr	1.10
Zone 4	1,800 – 2,200 mm/yr	1.30
Zone 5	> 2,200 mm/yr	1.50

Why five, and not twenty

Five zones capture the real variation and still let a user choose confidently from a map. Splitting the country into twenty would look more scientific and be less honest — the resolution of the zoning is matched to the resolution of the data.

Zones 3, 4 and 5 return higher intensities than current practice at durations up to one hour, and the resulting IDFs compare well with Nadi (Fiji) and with Malaysia.

Climate change as a setting, not an argument

The tool asks the user to choose a scenario and a horizon and shows what that choice does.

Design horizon	< 1 hr	2 hr	3 hr	6 hr	12 hr	> 24 hr
2030	1.18	1.16	1.14	1.12	1.11	1.10
2040	1.22	1.19	1.17	1.15	1.13	1.12
2050	1.27	1.23	1.21	1.18	1.16	1.14
2060	1.30	1.25	1.23	1.20	1.18	1.16
2070	1.33	1.28	1.26	1.22	1.19	1.17
2080	1.37	1.31	1.28	1.24	1.21	1.19
2100	1.41	1.35	1.32	1.27	1.24	1.21

Rainfall intensity multipliers, SSP2-4.5. $i_{design} = i_{IDF} \times multiplier$

One scenario only, and it is flagged as such

- Only SSP2-4.5 is populated; the workbook marks the scenario cell LIMITED so users know the range has not been explored
- SSP1-2.6 and SSP5-8.5 should be added so sensitivity can be tested rather than assumed

The gradient is the point

Short storms get the largest uplift — 41% by 2100 for sub-hourly events, against 21% for storms beyond a day.

Road cross drainage is sized on exactly the durations projected to intensify fastest.

Why exposing it as a dial matters

Because the setting is visible on the input sheet, a reviewer can see exactly what was assumed and re-run the design under a different assumption in seconds.

Design rainfall: what the approach delivers

What the adopted approach gives

- Uses well distributed Timor-Leste daily rainfall data with a good length of record
- Leverages a long, rigorous Australian programme rather than a formula used beyond its range
- Provides real sub-hourly intensities, spatially differentiated across five zones
- Can be factored for a range of climate projections

What it does not give

- A locally measured short-duration intensity for any Timor-Leste site
- Confidence that the shape of a Darwin storm matches a Timor-Leste storm
- A defensible treatment of the zone boundaries, which step discontinuously
- Sensitivity across emissions scenarios — only SSP2-4.5 is populated

Recommendations

- Install automated pluviographs recording at 5-minute intervals or finer, sited for road asset management rather than general meteorology
- Prioritise sites near main roads for accessibility, across the full range of elevations and rainfall zones
- Review the IDF regularly as sub-daily record accumulates; after roughly three to five wet seasons a local short-duration analysis becomes possible
- Consider partnering with local rainfall network operators — over 30 monitoring stations are already installed in-country
- Specify siting, calibration and data-management requirements up front, and name a single custodian for the dataset — a gauge suited to disaster warning is not automatically suited to IDF development
- Review international datasets regularly

Every year of local pluviograph record shortens the distance between what we assume and what we know.

The two tools

A cross drainage and swale sizing tool and a culvert blockage screening tool

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Two tools, one workflow

Each step is designed to be completed in well under an hour.

1

Describe the site

Slope, soil, vegetation, catchment size, opening size, access. Things you can see or measure without instruments.

2

Blockage tool

Answers seven questions about the site and returns a blockage band and percentage for this specific culvert.

3

Sizing tool

Takes the catchment, the rainfall zone, the climate horizon and the blockage factor, and returns a recommended pipe, box or swale size with alternatives.

4

Check and record

Capacity, velocity and cover are checked, warnings are raised, and a one-page sheet is printed for the drawing set.

Design brief: what a usable tool had to be

Five requirements agreed at the outset. These are constraints, not compromises.

1 Usable without specialist software

Excel. No hydraulic modelling licence, no scripting, no external dependencies, no internet connection.

2 Transparent, not a black box

Every coefficient, size catalogue and threshold sits in a single editable configuration sheet, visible to any user.

3 Documented assumptions

Methodology, adopted parameters and limitations stated on the face of the tool, not buried in a report nobody opens.

4 Defensible defaults

Where local data does not exist, a stated, conservative, replaceable placeholder - never a silent guess.

5 Built to be superseded

Structured so that local IDF data and local blockage records replace borrowed data without a rebuild.

The cross drainage and swale sizing tool

The question it answers: how big does this structure need to be, so that the design storm passes under the road instead of over it — allowing for debris and for a wetter future?

In

What you type in

Location and rainfall zone; road hierarchy; catchment area, slope and flowpath length; ground cover; culvert material, slope and length; available depth of cover; climate scenario and horizon; and the blockage risk from the other tool.

Out

What it gives back

A recommended standard pipe, box or swale configuration; two alternatives; the full-flow velocity; status checks on capacity, velocity and cover; and a print-ready one-page design record.

No

What it does not do

It is not a substitute for detailed hydraulic modelling on major structures, and it does not carry out structural, foundation or geotechnical design. It sizes flow capacity.

Modifiers		
SSP	SSP 2-4.5	LIMITED
Climate Scenario	2040	Year
Climate Change Multiplier	1.22	
Blockage Risk	Low	
Outlet Submerged	10%	
Modified Rainfall Intensisity	**294.5568**	mm/h

The modifiers block on the input sheet — the scenario, the horizon and the blockage risk are visible settings, not buried constants

Workbook architecture

Seven sheets. The user touches two. The other five are the engine and the parameter store.

`CrossDrainage`	Culvert sizing input and output sheet
`LongitudinalDrainage`	Swale and table drain sizing sheet
`Instructions`	Method, warnings and interpretation guidance
`_Config`	All editable lookup tables and size catalogues
`IFDandCC`	Darwin IDF, zone scaling, climate multipliers
`Calculations_Cross`	Manning capacity sweep across pipe and box sizes
`Calculations_Long`	Manning capacity sweep across swale sizes

The user touches two sheets

Everything else is the engine and the parameter store, kept separate so that a coefficient can be updated without anyone opening a formula.

Why the separation matters

Inputs, parameters and the calculation engine are kept apart, so that updating a coefficient never means editing a formula.

An authority that can edit the configuration sheet owns the tool. It no longer depends on the original consultants to reflect local practice.

From site inputs to a recommended size

1
Locate
Select rainfall zone and road hierarchy

2
Set standard
Hierarchy sets the AEP and the minimum cover

3
Catchment
Area, slope, flowpath length, surface type

4
Storm
Time of concentration sets the design duration

5
Rainfall
IDF lookup, then the climate change multiplier

6
Flow
Rational Method design discharge

7
Size
Smallest standard configuration that passes

Two checks run continuously

- Capacity — full-flow Manning discharge of the trial configuration against the design discharge
- Serviceability — full-flow velocity against 2.0 m/s, and available cover against the hierarchy minimum

The calculation - Rational Method

$$Q = 0.00278 \times C \times i \times A$$

- **A** the area of hillside draining to the culvert, in hectares — how much land is collecting the rain
- **i** the rainfall intensity in millimetres per hour, read from the IDF curve for the chosen storm severity and duration
- **C** the fraction of that rain which becomes runoff rather than soaking in — bare rock and road surfaces are high, dense forest is low
- **Q** multiply them and you have the flow the structure must carry, in cubic metres per second

This is the Rational Method. It is more than a century old, it is taught worldwide, and it is appropriate for the small, steep, short-response catchments that road cross drainage serves.

The calculations behind it

Storm duration

$$t = 0.67 \times (n \cdot L / \sqrt{S})^{0.467} \div 60$$

hours; n, L and S are catchment values, not culvert values

Design flow

$$Q\_design = 0.00278 \cdot C \cdot i \cdot A$$

A in hectares, i in mm/hr, i already modified for climate change

Capacity

$$Q\_full = (1/n) \cdot A \cdot R^{(2/3)} \cdot \sqrt{S}$$

full-flow Manning, per barrel, multiplied by the barrel count

The two modifiers

Applied to the rainfall i_design = i_IDF × CC multiplier

Applied to the structure A_eff = A × (1 − blockage factor)

Not modelled

- Inlet control
- Outlet control and headloss
- Tailwater and downstream effects
- Part-full and supercritical flow
- Hydrograph routing, storage and attenuation

This is a sizing tool. Confirm the selected structure with an inlet and outlet control check before design sign-off, and do not use it above roughly 50 hectares or where storage matters.

Runoff coefficients and design standards

Every value on this slide lives in the configuration sheet and can be edited without touching a formula.

Catchment type	C
Road surfaces and sloped surfaces	0.85
Steep mountainous land	0.83
Catchment areas of mountain streams	0.80
Gentle mountainous land	0.75
Rice paddy (fields)	0.75
Urban areas	0.75
Undulating land and woods	0.63
Small rivers on flat land	0.60
Flat farmlands	0.53
Forest zones	0.30

Road hierarchy	AEP	Min cover
National	1%	0.60 m
Major Town	20%	0.60 m
Local	50%	0.60 m
Private	50%	0.45 m

Culvert material	Manning n
Concrete	0.013
HDPE	0.012
Corrugated metal pipe	0.024

Material choice is a maintenance decision as much as a hydraulic one — corrugated metal is nearly twice as rough as concrete.

Size catalogue

- Circular: 15 sizes, 375–2,100 mm
- Box: 5 square sizes, 600–1,500 mm
- Swale: widths 1,000–5,000 mm
- Up to eight barrels permitted

These are the numbers most likely to be revised as local evidence accumulates — which is exactly why they sit in a table rather than inside a formula.

How a size is chosen

Every standard diameter is tested at full flow. Barrels are added until capacity meets the design discharge, and the smallest adequate configuration is returned.

Pipe Ø (mm)	Area (m²)	Q per barrel (m³/s)	Barrels needed	Total Q (m³/s)	Outcome
375	0.110	0.15	20	2.94	Too many barrels
450	0.159	0.24	13	3.11	Too many barrels
525	0.195	0.36	9	3.25	Too many barrels
600	0.254	0.52	6	3.09	Smallest adequate
675	**0.322**	**0.71**	**5**	**3.53**	**Returned as recommended**
825	0.481	1.20	3	3.61	Returned as alternative
1200	1.018	3.27	1	3.27	Single barrel

Worked for a design discharge of 2.92 m³/s. Concrete, n = 0.013, culvert slope 1.0%.

Alternatives offered

A larger pipe that achieves capacity with fewer barrels, and the smallest standard box culvert that meets the design discharge in a single cell. The engineer chooses between them on constructability and maintenance grounds.

Worked example - cross drainage

A Zone 2 catchment on a major town road, concrete culvert, 2030 design horizon.

Input	Value
Rainfall zone	Zone 2
Road hierarchy → AEP	Major Town → 20%
Catchment area	15 ha
Flowpath length / slope	2,400 m · 0.002 m/m
Catchment type → C	Steep mountainous → 0.83
Culvert material / slope	Concrete n=0.013 · 1.0%
Length / available cover	40 m · 1.20 m

Derived	Value
Time of concentration	0.616 hr (37 min)
IDF intensity	71.54 mm/hr
Climate SSP2-4.5, 2030	× 1.18
Design intensity	84.42 mm/hr
Blockage risk → factor	Low → 0.10
Minimum cover required	0.60 m
Full-flow velocity	1.81 m/s

DESIGN DISCHARGE

2.92 m^3/s

RECOMMENDED

5 × 675 mm concrete pipes

Alternatives: 3 × 825 mm · 1 × 1500 × 1500 box

Capacity
OK

Velocity 1.81 m/s
OK

Cover 1.20 m vs 0.60 m
OK

Scour protection
Not required

The same page prints as a one-page signed-off summary, reproducing every governing input and output, with prepared-by and checked-by fields.

Longitudinal drainage: the swale module

- Design discharge is derived exactly as for cross drainage — rainfall zone, climate multiplier, Rational Method
- Capacity is computed for a trapezoidal section from standard width, depth and side-slope
- The tool additionally tests whether the required section fits the width and depth actually available in the road reserve
- Returns required top width, bottom width, depth, bed slope, full-flow velocity and whether scour protection is needed

Standard width (mm)	Depth (mm)	Area (m^2)	Q_full (m^3/s)
1,000	1,000	0.75	0.91
2,000	1,000	1.75	4.64
3,000	1,000	2.75	9.90
4,000	1,500	5.44	33.20
5,000	1,500	6.94	49.01

Two constraints, not one

A section must both carry the design discharge and fit inside the width and depth available at the roadside. The first section satisfying both is returned — which is often the binding constraint in a narrow cutting.

The drainage blockage tool

The question it answers: how much of this particular culvert should we expect to be lost to debris and silt, given what the site looks like?

Why

Why it is important

Blockage is a variable. Blockage is important to consider to ensure adequate conveyance of runoff and minimise the risk of overtopping, roadway flooding and damage to road infrastructure.

How

How it works

Seven site characteristics are each scored on a simple scale, each score is weighted, the weighted scores are added, and a lookup converts the total into a blockage band and a percentage.

Use

What it is used for

Two things: setting the design blockage allowance in the sizing tool, and ranking culverts for maintenance so that limited cleaning effort goes where failure is most likely.

What it deliberately is not

- Not a prediction of blockage at a given storm — it is a relative screening score
- Not a substitute for inspection; its output is a decision about where to send an inspector first
- Not calibrated: every score and threshold is an expert-judgement starting point awaiting maintenance data

Seven questions you can answer on-site

1	**How steep is the ground upstream of the culvert?**	Steeper ground may deliver more debris
2	**What is the soil like?**	Erodible soils supply silt and gravel
3	**What is the land cover?**	Forest supplies branches and leaf litter that grass does not
4	**Which rainfall zone is it in?**	More intense storms mobilise more material
5	**How big is the opening?**	A small pipe has a higher risk of blockage than a large culvert
6	**What kind of debris is characteristic here?**	Sediment and timber behave differently
7	**How fast does water move through the structure?**	Faster flow tends to flush material through

A trained technician with a clipboard can complete the assessment.

Seven parameters, each scored

Higher scores mean a greater tendency for debris to reach, and remain at, the structure.

Parameter	Score 0	Score 1	Score 2	Max
Upstream slope	Flat (< 5%)	Moderate (5–20%)	Steep (> 20%)	2
Soil erodibility	Low	Moderate	High	2
Land use	Urban / industrial	Suburban / mixed	Rural / vegetated	2
Rainfall intensity zone	Zone 1	Zone 2 … Zone 4	Zone 5 (scores 4)	4
Culvert cross-section area	Large (≥ 4 m^2)	Medium (1–4 m^2)	Small (< 1 m^2)	2
Debris type	Non-floating	Floating	Mixed	2
Velocity through structure	Medium (0.5–1.5 m/s)	Low (< 0.5 m/s)	High (> 1.5 m/s)	2

Two scoring choices worth explaining

- Rural and vegetated land scores highest — vegetation is the debris source, so an undeveloped catchment is the higher blockage risk
- Velocity is non-monotonic — slow flow drops material, fast flow delivers it, so medium velocity scores best

Maximum possible score: 16

All weights are currently set to 1, so the score is a simple sum. The weight column exists so that calibration can change a parameter's influence without restructuring the tool — and so an authority with strong maintenance crews can lower them.

From score to design blockage allowance

Four bands, deliberately coarse, because the underlying evidence cannot yet support finer resolution.

None
score 0
0%

Low
score 1 – 5
10%

Medium
score 6 – 9
25%

High
score 10 – 16
50%

Band	Design blockage	Suggested inspection	Pre-wet-season action
None	0%	Routine network cycle	Visual check only
Low	10%	Annual	Clear inlet vegetation
Medium	25%	Six-monthly	Clear inlet and outlet, check apron
High	50%	Quarterly + after major events	Programmed clearing; consider retrofit

The inspection column is our recommendation, not a calibrated interval. It converts a score into an action, which is what makes the tool useful to an asset manager rather than only to a designer — and it improves the network that already exists, with no construction budget at all.

ADB

Three sites, three allowances

The same seven questions, answered for a benign site, a typical upland site and a worst case.

Parameter	Culvert A — benign	Culvert B — typical upland	Culvert C — worst case
Upstream slope	Flat (0)	Moderate (1)	Steep (2)
Soil erodibility	Low (0)	Moderate (1)	High (2)
Land use	Urban (0)	Suburban (1)	Rural / vegetated (2)
Rainfall zone	Zone 1 (0)	Zone 3 (2)	Zone 5 (4)
Cross-section	Large (0)	Medium (1)	Small (2)
Debris type	Non-floating (0)	Floating (1)	Mixed (2)
Velocity	Medium (0)	Low (1)	High (2)
Total score	**0**	**8**	**16**
Band → design blockage	**None → 0%**	**Medium → 25%**	**High → 50%**

Culvert B is the important one

Nothing about it looks alarming in isolation. Moderate on everything — and that is enough to reach a 25% design blockage allowance.

This is the realistic middle case for much of the network, and it is the case designers currently miss.

Same rainfall, same catchment

A blanket national blockage assumption gets both A and C wrong. It wastes money at A, and it builds a failure at C.

A and C are also the easy cases to spot on site. B is not.

How blockage reaches the design

Blockage tool

Score the site → band and percentage

Sizing tool

Blockage band selected → blockage factor

Design

Effective waterway reduced → larger configuration

`A_effective = A × (1 − blockage factor)`

A 25% allowance removes a quarter of every barrel's flow area before capacity is tested — which usually pushes the recommendation up a size, or adds a barrel.

Blockage band	Blockage factor
None	0.00
Low	0.10
Medium	0.25
High	0.50

The band on the blockage tool matches the Blockage Risk dropdown on the sizing sheet one for one.

The correct treatment, and why it matters

Blockage must be applied as a reduction in effective waterway area in the capacity check — not as an increase in design flow. Blocking a culvert does not create more runoff; it removes conveyance.

PART 4 OF 5

Why simple and open is the right answer here

Simplicity is not a limitation we accepted. It is a requirement we designed to — and the software choice is part of the engineering.

The complexity trap

You cannot build a precise tool on imprecise data. You can only build a tool that looks precise.

- A detailed hydraulic model needs inputs that do not exist here: sub-daily rainfall, surveyed cross-sections, measured roughness, gauged flows
- Faced with missing inputs, the user does not abandon the model — they guess, and the guesses are invisible inside the output
- The result is a number quoted to three decimal places resting on a series of undocumented assumptions
- A reviewer cannot audit it, a successor cannot reproduce it, and nobody can say which assumption drove the answer

A simple method with visible assumptions is not less rigorous than this. It is more rigorous, because its uncertainty is legible.

To be clear about what is not being argued

Complex models are not bad. They are the right answer for major structures, for bridges, and wherever storage, backwater or unsteady flow governs.

The argument is narrower and harder to dismiss: model sophistication must be matched to input quality. Here the inputs are the binding constraint, and the routine, high-volume culvert is where the network-wide risk actually sits.

Most experienced engineers have seen this failure mode themselves.

Four reasons simplicity is the right choice

1 It matches the data

The precision of the method should not exceed the precision of the inputs. With borrowed rainfall curves and estimated runoff coefficients, a robust approximate method is the honest choice.

2 It matches the workforce

Thousands of culverts must be assessed by district staff and technicians, not by a handful of specialists. A method that scales to the workforce is the only method that reaches the whole network.

3 It can be checked

Every step can be reproduced by hand with a calculator. A supervisor, a reviewer or a contractor can verify the result independently, which is what makes a design defensible.

4 It can be taught

The method can be taught in a two-day workshop and revised from a one-page sheet. Complexity that cannot be transferred to local institutions is complexity that leaves when the project does.

Black box or glass box

A black box

- The user sees inputs and an answer, and nothing between
- Wrong answers are indistinguishable from right ones
- Trust rests on the reputation of the software vendor
- Disagreement cannot be resolved, only asserted
- Users stop thinking, because the box appears to think for them

A glass box

- Every intermediate value is visible on the sheet
- An implausible answer can be traced to the input that caused it
- Trust rests on inspection, which anyone can perform
- Disagreement becomes a specific, resolvable question
- Users learn the method by watching it operate

The teaching effect is underrated. An engineer who uses the sizing tool for a season comes away understanding time of concentration and runoff coefficients, because they have watched those values move. A black box teaches nothing.

Why a spreadsheet was the right choice

1

It is already on the machine

Ministries, district offices, contractors, consultants and universities already run spreadsheets. Nothing to procure, nothing to install, no request to an IT department that may take a year.

2

The skill already exists

Staff do not need to learn new software, only a new sheet. Training can concentrate entirely on the engineering rather than on the interface.

3

It works offline

No server, no internet connection, no login. The tool runs on a laptop in a district office during a power cut, which is exactly where and when it is needed.

4

It survives the project

No licence to renew, no subscription to lapse, no vendor to depend on. A file that opens in ten years is worth more than a platform that is elegant today.

0

licences to buy, renew or transfer when staff move on

2

days of training for competent use

<5

files to copy, email or carry on a memory stick to any office in the country

What "open" actually means here

Auditable	Every formula can be inspected, so a reviewer can verify the engineering rather than trusting a claim about it
Teachable	A lecturer can project the sheet and walk a class through the method, cell by cell
Adaptable	A neighbouring country can take the file, replace the rainfall tables with their own, and have a working national tool
Correctable	A user who finds an error can locate it, prove it and report it precisely, instead of merely reporting that the answer looks wrong
Free to copy	Distribution costs nothing, so there is no reason to restrict who holds a copy, and no advantage in doing so

The method is not Timor-Leste specific

Any country facing thin sub-daily rainfall data, steep terrain and constrained maintenance can take this approach.

Openness is what makes that transfer possible at zero marginal cost — and it is why we are presenting the method, not selling a product.

The files, the assumptions register and the worked examples are available to anyone in the room who wants them.

ADB

Colour as the manual

A spreadsheet is dangerous precisely because everything looks equally editable. Colour converts an invisible risk into a visible convention.

Green — Type here

Your inputs. Site measurements and dropdown selections. A basic user can change any green cell freely and safely.

Yellow — Results

Calculated by the tool. Read them, do not type in them. Overwriting an amber cell breaks the chain that produced it.

Red — Warnings

The tool has found a problem: velocity too high, cover too shallow, capacity below the design flow. Never ignore a red cell.

Grey — The engine

Configuration tables and calculation sheets. Editable only by a nominated custodian who understands the consequences.

Guardrails behind the colours

- Dropdowns replace free typing wherever a defined option set exists
- Formula cells are protected, so a keystroke is refused not accepted
- Ranges are validated at entry

What we gave up by choosing a spreadsheet

Real costs of this choice	Why we accepted them
No detailed hydraulic routing, backwater or unsteady flow analysis	Major structures should go to specialist software anyway, and the tool says so on its face
Weaker version control than a proper software repository	Version discipline is handled by numbering, change logging and training
Files can be edited into an unsupported state by a determined user	Cell protection and the colour code sharply narrow the room for error
Macro security settings can block the tool in locked-down environments	Installation guidance covers the macro settings in one page
It will not impress anyone who evaluates tools by sophistication	Reach across the whole network beats sophistication on a few sites

Known limits and current status

Sizing tool — method limits, by design

- Full-flow Manning capacity only — no inlet control, outlet control, tailwater or headloss
- Rational Method peak flow; no hydrograph, storage or routing, and not above roughly 50 hectares
- Blockage applied as a flat reduction in flow area, not as a partial obstruction
- Time of concentration uses an overland-flow form over long flowpaths, which understates intensity

The three that matter most

- The rainfall basis is the weakest link. A borrowed IDF scaled by annual rainfall is the largest single uncertainty, and the zone factors step discontinuously at one boundary
- Blockage must actually reach the design. In the working file the factor is computed and not applied
- No inlet-control or headwater check, so barrel capacity can pass while headwater does not

Blockage tool — what it is, and is not

- An unweighted sum of seven ordinal scores — it ranks sites, it does not predict blockage
- Scores and thresholds are engineering judgement, not calibrated against observed blockage
- No account of maintenance regime, inlet configuration, debris screens or upstream storage
- Four output bands only, so many different sites return the same allowance

Why we are telling you this

These are findings from our own review of the working files, presented before issue rather than discovered after it. None requires a redesign; all are fixable inside the current structure, and every assumption is recorded on the Instructions sheet.

An assumption the user cannot see is an assumption the user will breach.

A path from provisional to grounded

Medium term

6 – 24 months · As gauge data accumulates

- Install the recommended 5-minute gauge network
- Begin a Timor-Leste short-duration IDF analysis
- Check zone scaling factors with measured intensities
- Calibrate blockage scores against inspection records
- Auto-populate slope, soil and land use from GIS
- Add a debris-load index from photographic survey
- Validate design blockage percentages against maintenance data

Long term

2+ years · Mature dataset

- A local IDF dataset replacing the donor parent
- Regional flood frequency relationships for ungauged catchments
- Probabilistic blockage rather than a deterministic percentage
- Whole-of-life cost optimisation of size against maintenance
- Integration with the road asset management system
- 2D hydraulic verification of priority sites
- The method enters national standards and curricula

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ADB

Simple, open, colour-coded, and built to be outgrown.

That is not a lesser tool. It is the tool that fits.

Thank you

Cross Drainage & Swale Sizing Tool · Drainage Blockage Tool

Climate-Resilient Road Infrastructure Standards Study, Timor-Leste

Asian Development Bank · WMS Engineering · August 2026