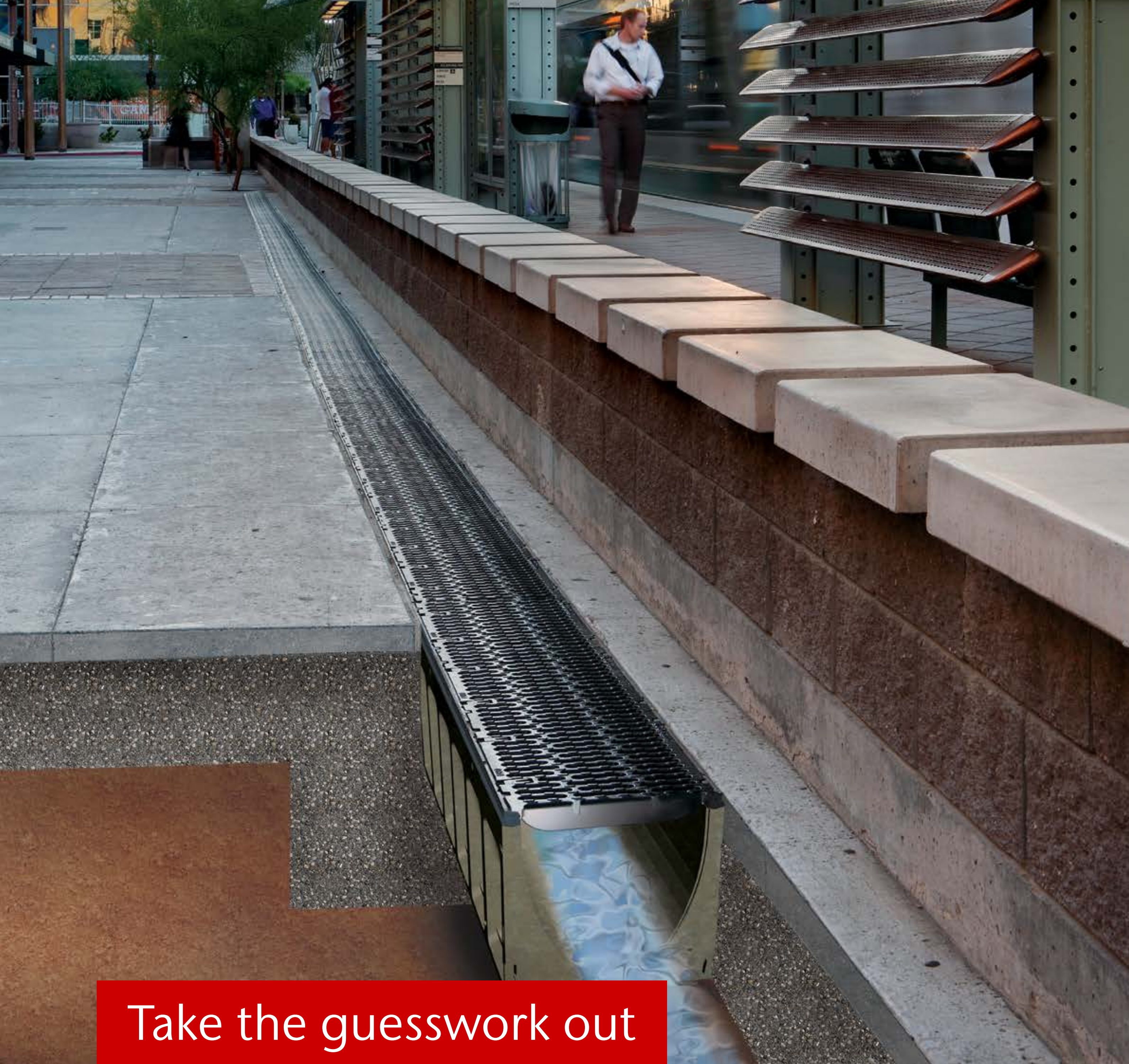


Take the guesswork out of trench drainage selection

An accurate approach based on real-world hydraulic behaviour

Protecting properties and reputations

When trench drains fall short of their hydraulic design performance, they can cause water ingress that damages property and contents. In extreme cases, flooding can also undermine infrastructure, not to mention the reputation of the specifying engineer!

More commonly however, poor-performing drainage creates safety hazards such as slipping on pedestrian pavements and aquaplaning on roads, as well as adding to maintenance and repair costs. To avoid these serious consequences, engineers must understand how to select the right channel size and configuration, and a grate that prevents surface water from bypassing it.

The science behind the hydraulics of a trench drain only is complex. There are no off-the-shelf mathematical formulae, and engineers must adapt each drainage system to the unique catchment design of the site. The good news is that there are workable solutions to avoid both undersized channels, which will cause flooding, or expensive, oversized channels that end up flowing close to empty for most of the time. To navigate the range of products on the market, engineers need a good understanding of how drains perform in the real world.

Theory vs. practice

When selecting a grated trench drain, it is important to use the equations, models and tools that most closely reflect how it behaves in practice. This begins with an acknowledgement of a grated trench drain's real-world hydraulic behaviour. Engineers must still apply theoretical formulae to practical situations, but these equations must be grounded in empirical data from full-scale laboratory testing.

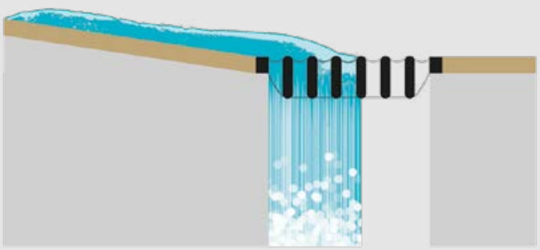
Inlet grate performance

The hydraulic behaviour of inlet grates cannot be captured by simple models. Australian Rainfall and Runoff offers rudimentary guidelines, but does not take into account the attributes of each grate or the pavement geometry of the intended installation. In practice, subtle variations in either of these can have a significant influence on a grate's hydraulic performance, as can temporary blockages to inlets.

Under certain conditions (for example, concentrated runoff down a steep slope), grates may not be able to capture all the flow, even if the underlying channel is correctly sized. When surface flow from the catchment runoff exceeds the hydraulic capacity of all the inlets combined, runoff bypasses the drain.

Grates can have one or more inlets with varying orientation, size, shape and pattern. Specific experimental testing is the only sure way to predict how effectively a grate will intercept surface runoff for varying catchment types and geometries. When liquid moves over a grate, one or both of these scenarios may occur. A "weir", when liquid depths are minimal or a "drowned orifice" where there is an accumulation of liquid above the grate.

No bypass



100% Capture
All the liquid flows through the grate opening

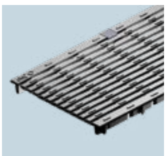
Bypass

Less than 100% Capture
Bypass occurs when not all the liquid flows through the grate openings.
Reasons for this include:

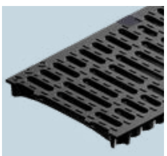
- Not enough inlet open area
- Too much run off
- Too much slope perpendicular to the grate

Testing at Water Research Laboratory, UNSW

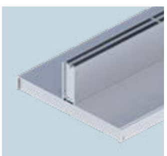
In general, there are three types of grates. Assuming equal intake area and width:



Grates with longitudinal inlets have the highest liquid intake and maximum 'flow through'



Grates with transverse inlets have a moderate liquid intake. The bars can create a bridge for liquid to move across the grate and cause early bypass



Discreet grates with (generally only one or two) longitudinal slot inlets have the lowest liquid intake.

Another consideration is the direction of flow. To directly intercept the path of runoff in one direction, a barrier drain is an appropriate solution. In contrast, multidirectional flow would require a sag or valley drain. The latter allows liquid to accumulate over the inlets, thereby creating a pressure head above it. This would further increase the inlet capacity of the grate but would produce localised ponding.

ACO commissioned the Water Research Laboratory, UNSW to test grate hydraulics. Three studies were carried out in 1998, 2004 and 2016 to investigate the water intake performance of ACO grates. The tests were carried out under varying flow rates and catchment approach slopes. Each grate was tested until bypass occurred, the point where liquids pass across the grate.

! Engineers should also discuss with clients the trade-off between selecting grates with small inlets for heel safety and large inlets for peak hydraulic performance.

Channel Performance

The flow rate of a channel or pipe is obtained by multiplying its cross-sectional area by the velocity of the liquid flowing through it. While the cross-sectional area is a straightforward calculation, accurately calculating hydraulic velocity has challenged engineers for more than a century.

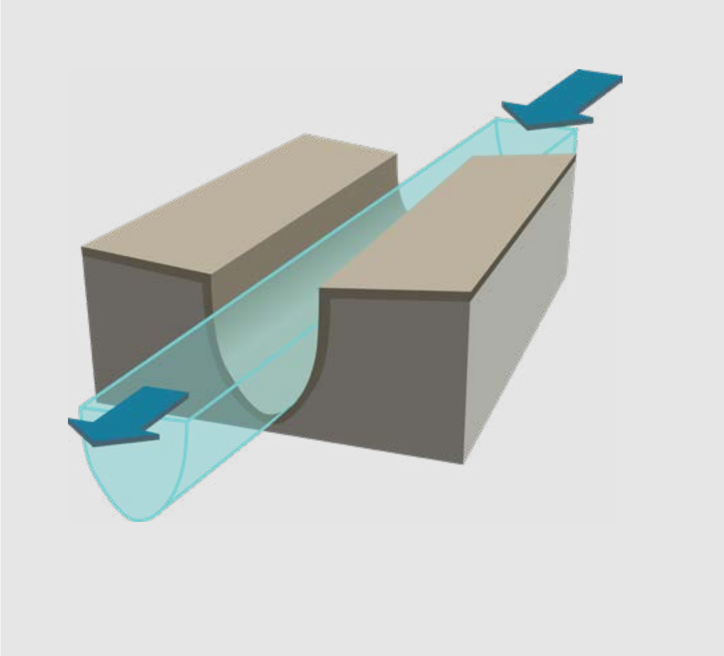
$$Q=VA$$

Engineering formulae (such as Manning's equation) calculate hydraulic velocity based on the roughness of the channel's inside surface, gradient, and hydraulic radius. These equations are simple to use and produce results that transpose easily into design charts. Nevertheless, because they are based on assumptions that are not always reflected in practice, they can lead to disastrously inaccurate results.

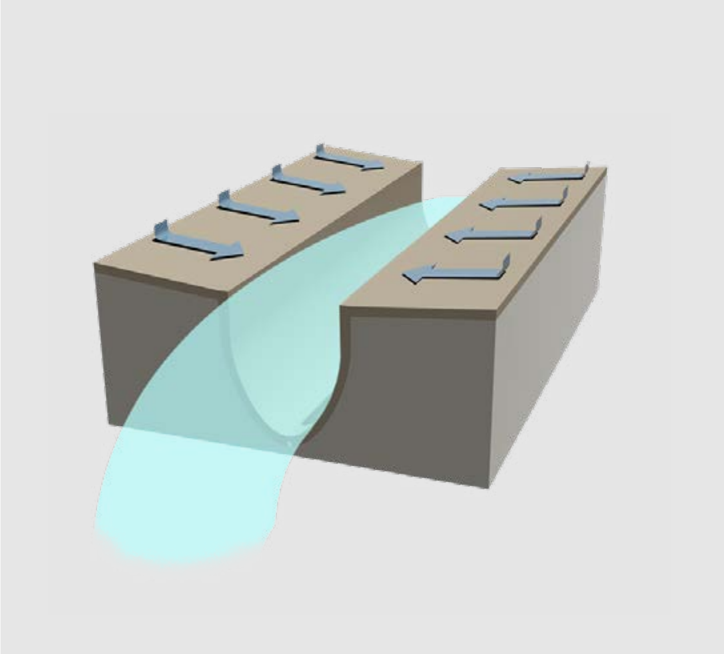
It is common for engineers to use simple pipe or open channel formulae to calculate drainage capacity. However, this technique assumes that the flow in the channel is uniform. If the flow is uniform, the cross-sectional area and velocity of the liquid remain constant at each successive cross-section. This approach might apply to a culvert or a pipe where liquid is simply transported from one end to the other, but not to open channel linear drains.

In consultation with researchers, ACO has shown that the flow in a trench drain is in fact non-uniform. In practice, liquid is carried along the channel length with the constant addition of more liquid spilling laterally into it from the catchment runoff. As the accumulated liquid travels to the downstream end, its flow and velocity vary at successive cross-sections along the trench. Liquid heights are no longer constant producing a signature hydraulic profile unique to a site's catchment hydraulics and the trench run's configuration.

Steady uniform flow



Non-uniform flow



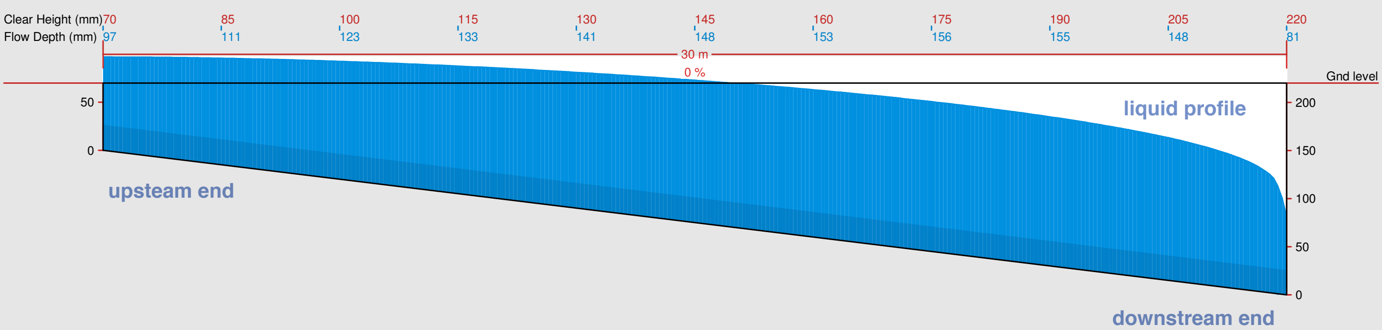
Eckernförde University, Germany

Described as steady non-uniform (or spatially varied) flow, a characteristic of this is that a trench run's length to a downstream outlet has a profound effect on the channel run's hydraulic capacity. With all other factors equal, an increasing run length gives a corresponding decrease in channel capacity.

$$\frac{dy}{dx} = \frac{S_0 - S_1 - 2aQq / gA^2}{1 - aQ / gA^2 D}$$

For this reason, ACO engineers use a differential equation to determine the signature hydraulic profile for each trench drain for individual catchments. To suit real-life scenarios, the equation has been calibrated by full-scale independent tests. A comparison of the results to those from conventional theoretical calculations using simple pipe and open channel (steady uniform) formulae has revealed that the latter can overestimate the practical channel capacity by up to 100 per cent.

Signature hydraulic profile

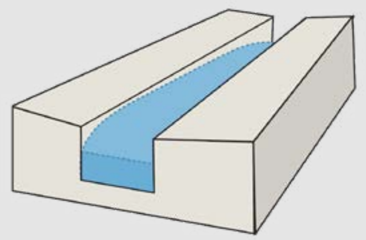


The consequences of applying the wrong formula to trench drain sizing

Non-uniform flow

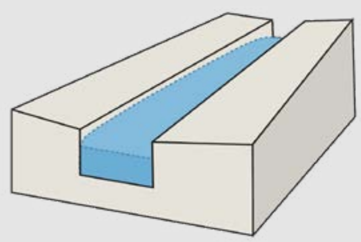
Accurately accounts for effect of slope and run length. Models accurate hydraulic performance and allows correct size of trench drain to be used.

Zero slope



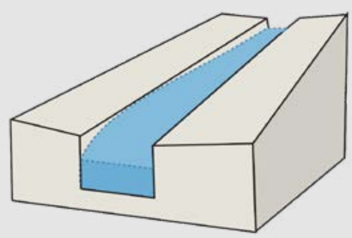
Slope is part of the differential equation - but not as a multiplier. **Trench size is accurately calculated.**

Small slope



Slope is part of the differential equation - but not as a multiplier. **Trench size is accurately calculated.**

Large slope

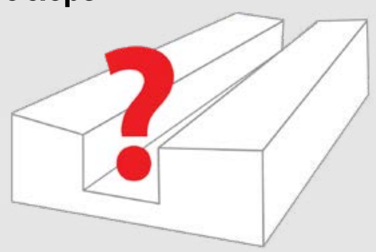


Slope is part of the differential equation - but not as a multiplier. **Trench size is accurately calculated.**

Steady uniform flow

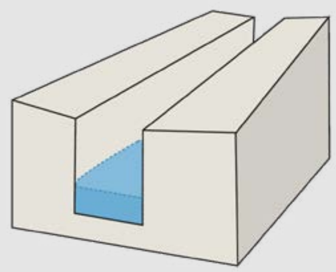
When there is little or minimal slope, velocity trends towards zero, and water depths are over-estimated. When there is significant slope, steady uniform flow under-estimates the water depths in the trench drain.

Zero slope



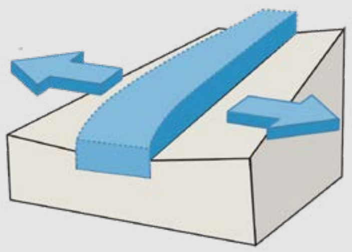
Slope 'S' is the multiplier in Manning's equation ($Q=(1/n)AR^{2/3}xS^{1/2}$). For flat gradients slope is zero and water depth cannot be calculated, therefore **trench cannot be sized.**

Small slope

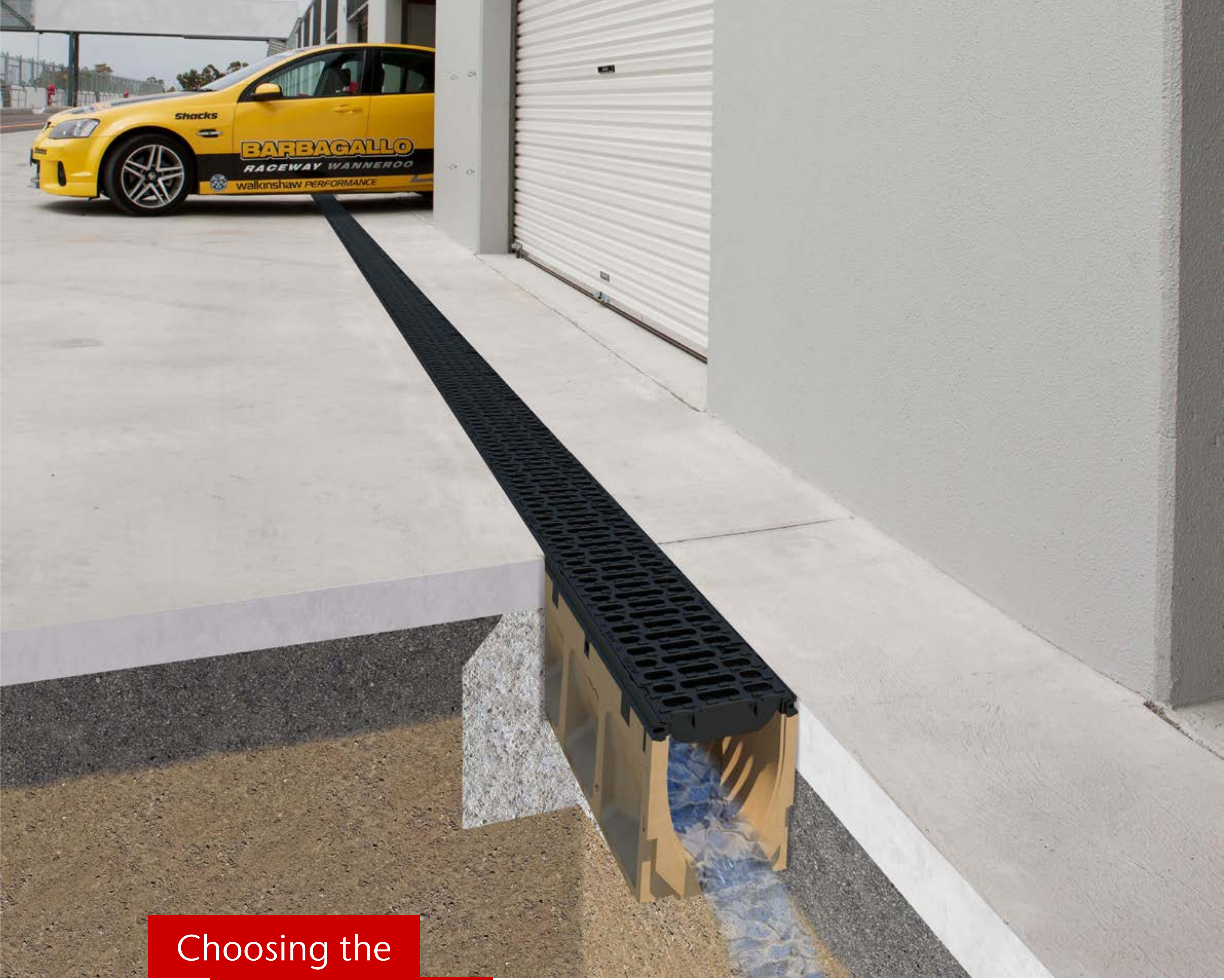


When slope is small, water depths are over-estimated - **resulting in a larger, more costly trench.**

Large slope



When slope is large, water depths are under-estimated - **resulting in flooding.**



Choosing the right solution

There are two main problems engineers need to solve before specifying a trench drain (after determining the catchment hydraulics for a site):

1. The correct size (width and depth) of channels. This is influenced by the fall along the invert and the number of stormwater outlets along its length
2. The correct style of grate to intercept surface water runoff

Additionally, the drain's placement, configuration, inner shape and construction material can also affect its hydraulic performance. This is discussed further below.

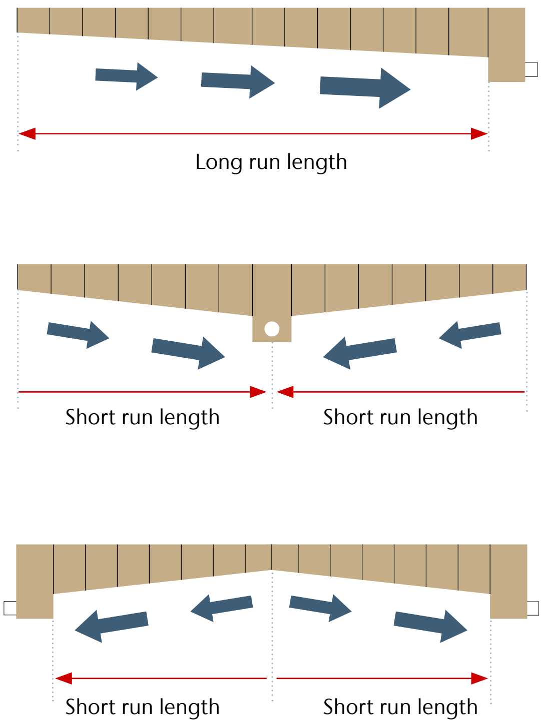
Placement

Engineers need to consider a number of factors when deciding where to position trench runs for a site. These include runoff direction(s) and the location of buildings, plant and equipment. The relative positions of pedestrian and vehicle thoroughfares are also important, as are the client's requirements and site characteristics. For instance, some drains may also act as barriers to prevent runoff transgressing into building entranceways. In such cases, the presence of leaves and litter will reduce the performance of the trench drain and to account for this behaviour, engineers must use a blockage factor when making their design calculations.

Size and slope

Slope is an important consideration when draining flat areas or sites. As the slope of the drain increases, so does its hydraulic capacity and as previously stated, short runs have higher hydraulic capacities than long runs. Engineers can use the natural slope of a site in their design to influence trench drain performance and where possible, choose the position of the outlet location.

For flat sites, engineers can use stepped constant invert channels to simulate a slope, or channel products with a built-in internal fall (sloping invert). Stepped runs are less effective in increasing liquid velocity than continuously sloped drainage channels. For level pavements, which are difficult to drain, a trench run with a sloping invert may be the only hope engineers have to direct water to a pit.



Choice of slope configurations for flat pavements

ACO's smooth (nonstick) V-shaped drainage channels

Shape and materials

The inner shape of the channel also affects drain performance. Common profiles are rectangular and U-shaped. ACO based the design of its V-shaped drainage channels on the 'egg-shaped' oval designs that were first used for sewers in 19th century London. The narrow end of the V-profile is located at the bottom of the channel, and the wider end at the top.

During low rainfall events, the narrow bottom of the channel allows a greater depth (head) of water, compared with wider rectangular or U-shaped channels. This allows the liquid to flow at a higher velocity for greater drainage efficiency. Combined with a channel's smooth surface, V-profile channels may also contribute to a self-cleaning effect that removes debris and keeps the channel clear in preparation for peak flows during storm events.

The inside surface material of the channel is another performance factor. The smooth surfaces from Polycrete® *Channels* reduce the chance of blockages typically from silt, plant and microbial growth. If buildup does occur, it won't stick to the smooth channel surface. This facilitates cleaning to ensure drains flow efficiently throughout their design life.

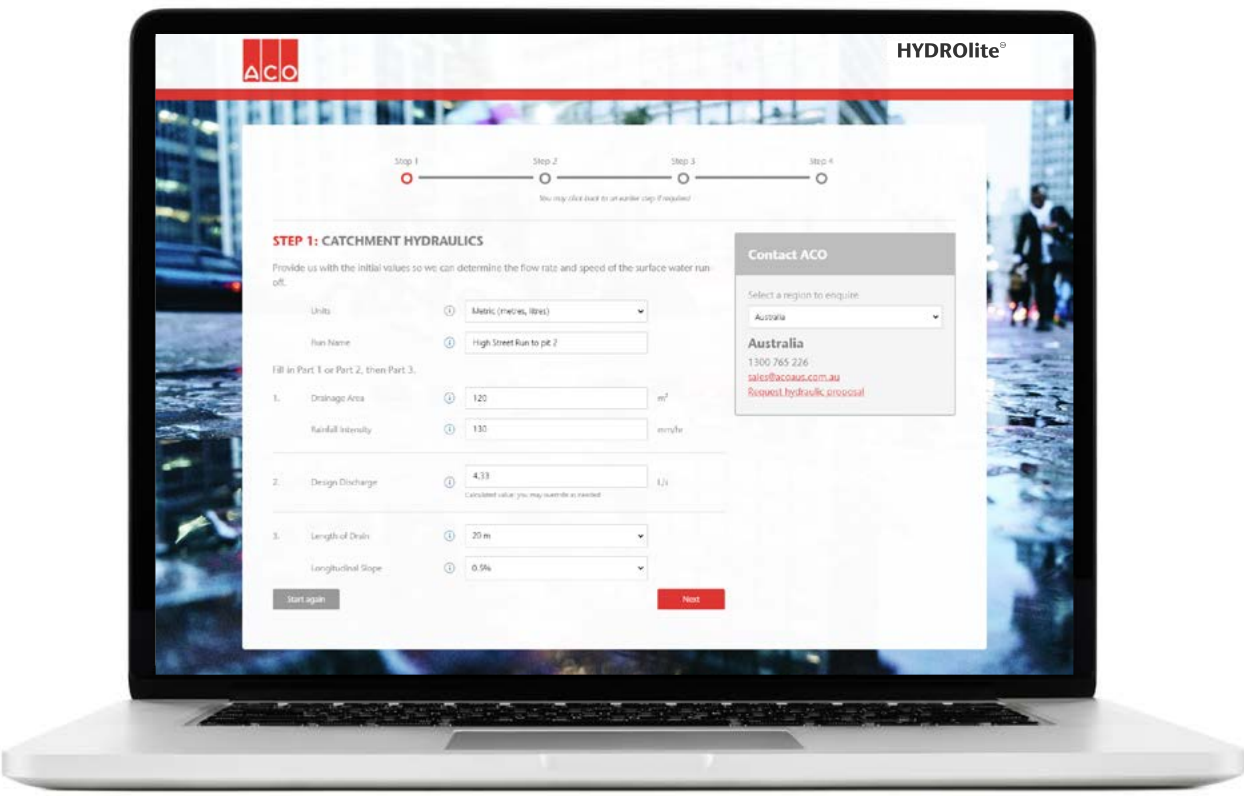
How ACO can help

Further to the research and findings mentioned above, ACO is launching an additional free service to assist engineers and other designers with the correct selection of trench drainage products based on channel and grate hydraulics.

Users can enter into the web-based program, site-specific information such as the area to be drained, finished floor gradients, and design rainfall intensity. The program will then make recommendations on effective drainage using an ACO solution. This software will be available 24 hours a day without restriction and users will have the option to engage with ACO's technical engineers and technical sales staff if required.

In addition, ACO can offer underground stormwater systems for retention, detention or infiltration. To learn more about ACO's geocellular storage tanks visit ACO Stormbrixx.

In partnership with Engineers Australia, ACO is also sharing a wealth of experience in surface water management through a series of webinars and CPD courses.



Input screen of ACO's new hydraulic public software.
To access the program visit: www.acodrain.com.au/hydrolite

The ACO advantage

ACO assists engineers to design and specify accurate, integrated drainage solutions within budget and time constraints, while keeping risks to engineers and clients to a minimum.

This is achieved with advice and experience based on more than two decades of local manufacturing, design and comprehensive support from the company's technical services team in Sydney. ACO's solutions are based on extensive research and development, both independently and in conjunction with leading academic institutions and research bodies.

ACO produces the world's most hydraulically efficient range of adaptive drainage solutions. These products are locally sourced and manufactured, and the company takes pride in also investing in local technologies and engineering talent.

AUSTRALIAN MADE

ACO products support the ACO System Chain

About ACO

ACO Australia has over 25 years of local experience in analysing customer requirements and developing and specifying reliable, integrated project tailored trench drainage solutions.

This is supported by the company's strong in-house design resources and technical support from engineers and specialist sales professionals. ACO's partnerships with universities in Australia and overseas mean that its trench drainage solutions are backed up by rigorous empirical testing.

askACO

askACO is a corporate initiative designed around advice and industry education. Services are offered free of charge and obligation and are designed to compliment (not substitute) professional engineering advice. For more information, or an obligation-free design service to meet your individual project requirements, **contact ACO today** or visit **www.askACO.com.au**

ACO can guide, recommend, source, manufacture and deliver a complete, cost-effective drainage solution. To visit the website, visit **www.acodrain.com.au**

ACO Pty Ltd

Head office:
134-140 Old Bathurst Road
Emu Plains
NSW 2750

Branches in:
New South Wales
Australian Capital Territory
Victoria
Tasmania
South Australia
Northern Territory
Queensland
Western Australia
Pacific Islands
South East Asia
Indo China

1300 765 226
+61 2 4747 4000

sales@acoaus.com.au

www.acoaus.com.au

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